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DIVERSITY OF PTERIDOPHYTES IN THE SURROUNDINGS AND DAM SUBMERGENCE AREAS OF HYDROELECTRIC PROJECTS IN KULLU DISTRICT OF HIMACHAL PRADESH, INDIAN HIMALAYA

Pankaj Sharma[1*] and Sher Singh Samant[2]

[1]Himachal Pradesh State Biodiversity Board, H. P. State Council for Science, Technology & Environment, 34, SDA Complex, Kasumpti, Shimla-171009, Himachal Pradesh, India.
*E-mail: spankaj80@gmail.com
[2]G.B. Pant Institute of Himalayan Environment and Development, Himachal Unit, Mohal-Kullu-175126, Himachal Pradesh, India

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Abstract

The Himalayan Region in India is very unique and globally known for its unique topography, large altitudinal range, climate and diverse habitats. The pteridophytes are important from evolutionary point of view, as they show the evolution of vascular system and reflect the emergence of seed habitat in the plants. Due to rich biodiversity of Himachal Pradesh, the pteridophytic flora is also interesting in its diversity and distribution, however, little is worked out on the economic aspects of these plants. Therefore, present communication pertains to the diversity of ferns in the surroundings and dam submergence areas of three hydroelectric projects of Himachal Pradesh. Overall, 63 species of pteridophytes, belonging to 15 families and 29 genera, were recorded. Maximum species (56 spp.) were found in forest habitat, followed by riverine/watercourse (48 spp.), shadymoist (42 spp.), bouldary (21 spp.), dry (17 spp.), degraded (12 spp.), submergence area (12 spp.), landslide and near crop field/orchards (4 spp. each), waste place/road side (1 sp.). Large scale deforestation and increasing anthropogenic activities have caused elimination of the habitats, which is posing a serious threat to the pteridophytes of the Himalayan region. Several conservation measures and management programmes have been taken up in various regions for the angiosperms, but very little attention has been given to the conservation of pteridophytes. Therefore, it is important to formulate and implement a detailed scientific study with aim of conservation of pteridophytes to ensure their long term conservation.

Key words: distribution, diversity, ferns, habitat, Himachal Pradesh, hydroelectric project.

Introduction

The Himalayan Region, one among the 34 global biodiversity hotspots, is the richest source of biological diversity and very well known for its unique topography, valleys and hills, climate, large altitudinal range, diverse habitats and network of rivers and streams (Sharma 2013). These unique features of the Himalaya support diverse species, communities and ecosystems (Samant et al. 1998, Singh 2006). The Indian Himalayan Region (IHR) includes about 8,000 species of angiosperms

(40 % endemic), 44 species of gymnosperms (16 % endemic), 600 species of pteridophytes (25 % endemics), 1737 species of bryophytes (33 % endemic), 1,159 species of lichens (11 % endemic) and 6,900 species of fungi (27 % endemic) (Singh and Hajra 1996, Samant et al. 1998, Sharma et al. 2014). In addition to these, it is also a rich repository of pteridophytic plant wealth. The pteridophytes form a conspicuous element of the Earth's vegetation and are important from evolutionary point of view as they show the evolution of vascular system and reflect the emergence of seed habitat in the plants (Das and Nath 2012). About 250 million years ago, they formed the dominant part of Earth's vegetation, but in the current scenario, flora has been largely replaced by the seed bearing plants. About 12,000 species of pteridophytes occur in the world flora of which more than 1000 species are distributed in different biogeographical regions of India with the main centers of the Himalayas. They are widely distributed to the wetter parts of the country, but are much less common, or even absent from very dry or severely cold regions (Benniamin 2012). They occur in abundance in tropical, subtropical, temperate and moist-deciduous forests of India and their life cycle is based on the existence of the forests. However, large scale deforestation and increasing anthropogenic factors have caused the elimination of the habitats, which is posing a serious threat to the pteridophytes of the Himalayan region. In the recent years, though the pteridological studies have picked up in various parts of the country, many questions regarding the pteridophytic wealth of the North Western remain unanswered and hence, more studies are required for developing *in situ* and *ex situ* conservation strategies for this wonderful and important group of plants.

Himachal Pradesh (30°22′40" to 33°12′40" N latitudes and 75°45′55" to 79°04′20" E longitudes, area 55,673 km^2), one of the states of IHR, covers parts of Trans and North West Himalaya (10.54 % of the Himalayan landmass). Of the total geographical area, 66.45 % is under forests and of the total forest, 20.45 % area is under protected area network and 3.41 % area under reserve forests. The state is represented by tropical, temperate, sub-alpine and alpine vegetation (Samant et al. 2007). It supports 32 wildlife sanctuaries; 02 national parks and 01 recently notified cold desert biosphere reserve (CDBR) (Samant et al. 2012). The vegetation comprises of sub-tropical, temperate, sub-alpine and alpine types and supports a representative, natural, unique and ecologically and economically important biodiversity. Like other states, the peteridophytic diversity of the Himachal Pradesh is facing tremendous pressure due to anthropogenic activities, such as construction of roads, hydroelectric projects, industrialization, urbanization, etc. The constructions of hydroelectric projects have caused a great loss of peteridophytic diversity, inspite of the environmental management plans (EMP) and catchment treatment plans (CAT). Therefore, the present attempt has been made to assess the pteridophytic diversity of three hydroelectric projects i.e., Sainj, Parbati Stage II and Malana II, so that information on pteridophytic diversity of hydro-electric projects areas in Kullu district of Himachal Pradesh could be obtained.

Material and Methods

Study area

The present study has been conducted in Sainj (100 MW), Parbati Stage II (800 MW)

and Malana II (100 MW) hydro-electric projects in Kullu district of Himachal Pradesh. The study areas fall in Kullu district (31°25' to 32°35' N Latitudes and 76°09' to 77°09' E Longitudes) of Himachal Pradesh. The Kullu district is bounded by Lahaul-Spiti and Kangra districts on north and north-east, Kinnaur and Shimla districts on its east and south-east. It is one of the richest districts in terms of biodiversity and supports one national park (i.e., Great Himalayan National Park) and six wildlife sanctuaries (i.e., Manali, Kanawar, Khokhan, Kais, Sainj and Tirthan) (Singh et al. 1990). The study areas are approximately 25–75 km from the district headquarters, Kullu. The areas fall under the Seraj Forest Division and Parbati Forest Division. These areas are very well known for their diverse habitats, microclimatic conditions and rich biodiversity including flora and fauna. These project areas are mainly inhabited by Raila, Suind, Niharni, Neuli, Sangad, Sainj, Barsaini, Garsha, Manhiar, Majhan, Barsaini, Tosh, Pulga, Tulga, Kalga, Rasol and Malana villages. The inhabitants of the area largely depend on the forests for wild edibles, medicinal plants, fuel, fodder, timber, making agricultural tools, fiber, religious, livestock grazing and various other purposes.

Geology and pedology

The study areas fall within the Lesser Himalayan ranges characterized by rugged topography of the northwest Himalaya. The different hydroelectric project areas are in the geological domain of the Larji Rampur tectonic window zone. This window zone exposes two granitoid complex bodies, the Bandal granitoid gneiss in the northwest and the Jeori-Wangtu granitoid gneiss in the southwest. The Bandal granitoid gneiss is considered equivalent to the Jeori-Wangtu gneiss complex in tectonic position, lithology, and chronology of rocks. The Bandal gneiss complex, spread over 500 km^2, is exposed in Garsha valley in the northwest to the Sainj valley in southeast, where it has reportedly been enveloped by the Manikaran quartzite. The Bandal granitoid gneiss with litho trend along the north-northwest-south-southeast comprises porphyroclastic, as well as medium-to coarse-grained gneiss, and mylonitic gneiss. The Rampur group presents an association of metabasalts and metasediments (Sharma 2008). The major part of the study areas is constituted by Khokhan Formation of the Kullu Group. The Khokhan Formation comprises of mainly quartzites, quartz schists, quartz chlorite and quartz biotite schists, slates, phyllites and garnetiferous schists. Locally, amphibolites appear associated with the metasediments. The other formations of the Kullu group exposed in the study area are Gahr and Khamrada Formations. Gahr Formation is characterized in the area by streaky and banded gneisses, while Khamrada Formation is characterized by carbonaceous slates, phyllite, quartzite and lenticular limestone (Srikantia and Bhargava 1998).

Climate

With increase or decrease in altitude the climate of the region varies to a greater extent. The climate of the study areas is typically sub-tropical, temperate, sub-alpine and alpine types, and consists of mainly four distinct seasons; summer (April–July), rainy (August–September), autumn (Oct–Nov) and winter season (Dec–March). The higher reaches of Malana, Tosh, Sainsar, Sangad, Majhan and Manhihar villages are snow covered during the winter season. From climatic point of view the area

is unique. Temperature ranged between -2 °C to 39 °C in the study area during the study period. Average annual rainfall was about 878, 836, 805 and 783 mm/year in 2008, 2009, 2010 and 2011, respectively. Average maximum temperature was recorded in monsoon (23 °C) and summer (23 °C), minimum in winter (11 °C), whereas relative humidity was maximal in monsoon (77 %) and minimal in winter (58 %). Frequent snowfall during winter occurs from December to March (Sharma 2013, Sharma and Samant 2016).

Survey, sampling and identification of the species

Frequent surveys were conducted seasonwise during 2008 to 2012 in and around three hydroelectric project areas, i.e. Sainj, altitude ranges from 1400 to 2600 m a.s.l., Parbati Stage II, altitude ranges from 1300 to 2600 m a.s.l. and Malana II, altitude ranges from 1800 to 3400 m a.s.l.. Sainj, Barsaini, Gadsa and Malana areas were thoroughly explored. The rapid sampling was done for the pteridophytic diversity inventory. The habitats were identified based on the physical characters and dominance of the vegetation. The sites facing high anthropogenic pressure were considered degraded habitats and sites having closed canopy with high percent of humus and moisture were considered moist habitat, whereas low percent of the same as dry habitat. The sites having >50 % boulders of the ground cover were considered bouldery habitat. Samples of each species were collected, information on altitudinal range, habitat/s, occurrence, distribution, etc. was gathered. Species were identified with the help of flora (Chowdhery and Wadhwa 1984; Dhaliwal and Sharma 1999; Khullar 1994, 2000; Singh and Rawat 2000; Pande and Pande 2002, 2003).

Results

A total of 63 species (Sainj: 47; Parbati Satge II: 52; and Malana II: 45) of pteridophytes belonging to 15 families and 29 genera were recorded from different hydro-electric projects areas (Table 1). Dryopteridaceae (12 spp.); Athyriaceae (10 spp.); Polypodiaceae (9 spp.); Pteridaceae and Thelypteridaceae (5 spp., each); Adiantaceae and Aspleniaceae (4 spp., each); Hemionitidaceae and Sinopteridaceae (3 spp., each); Cryptogrammaceae and Equisetaceae (2 spp., each) were the dominant families; 4 families (Davalliaceae, Ophioglossaceae, Osmundaceae and Selaginaceae were monotypic (Fig. 1).

Table 1. Diversity, altitudinal range, habitat/s, occurrence and distribution of pteridophytes in three Hydroelectric Projects (HEPs) areas in Kullu district, Himachal Pradesh, India.

Taxa	Altitudinal Range, m	Habitats	Occurrence in HEPs	Distribution
Adiantaceae				
Adiantum capillus-veneris L.	2000–3400	1, 2, 3, 4, 6, 8	A, B, C	Europ Occ et Austr Afr As Temp Himal
A. edgeworthii Hk.	1300–2600	1, 4, 8	A, B, C	China Ind
A. lunulatum Burm.	1700–2500	1, 4, 8	A, B	Afr As Austr Polyn Trop Amer Centr

A. venustum D. Don	1700–3000	1, 2, 3, 4	A, B, C	Afghan Ind Bor
Aspleniaceae				
Asplenium dalhousiae Hk.	1300–2700	1, 2, 3, 5	A, B, C	Afghan Ind Kash Nepal Pakistan Afr
A. ensiforme Wall. ex Hk.	2000–2600	1, 2, 3	A, B, C	Ind Yun
A. varians Wall. ex Hk.	1600–3000	1, 3, 6	A, B, C	Japon China Ceyl Afr Austr Ins Hawaii
A. yoshinagae Mak.	2200–2600	1, 3, 5, 6	A	Japon As
Athyriaceae				
Athyrium anisopterum Christ.	1700–2600	1, 2, 3, 4, 5	A, B, C	As Merid
A. atkinsonii Bedd.	2200–2500	2, 3, 4, 5	B, C	Himal
A. attenuatum (Wall. ex Cl.) Tagawa	2000–3000	1, 2, 3, 5	A, B, C	Kash China
A. fimbriatum Moore	2100–3300	3, 4, 6	B, C	Himal Yun
A. rubricaule (Bl.) Moore	2000–3300	1, 2, 6	C	Kash China
A. rupicola (Edgew. ex Hope) C. Chr.	2300–2500	2, 3	B	Ind Bor
A. schimperi Moug. ex Fee	2000–2700	2, 3, 5	B, C	Abys Ind Bor
Diplazium esculentum (Retz.) Sw.	1300–2700	1, 2, 3, 5	A, B, C	As Temp As Trop
D. spectabile (Wall. ex Mett.) Ching	1600–2500	2, 3, 5, 8	B	Yunn Ind Nepal
Lunathyrium allantodioides (Bedd.) Ching	1700–3400	1, 6, 9	A, B, C	As
Cryptogrammaceae				
Onychium contiguum Wall. ex Hope	1500–2700	1, 2, 3, 4, 5, 8, 9	A, B, C	As
O. fragile Verma et Khullar	1600–2500	1, 3, 7	A, B	Himal
Davalliaceae				
Araiostegia beddomei Hope	2200–3400	1, 4, 6	A, B, C	Ind Bor
Dryopteridaceae				
Cyrtomium caryotideum (Wall. ex Hk. & Grev.) Presl.	1700–2500	1, 2, 10	A, B, C	Ind As
Dryopteris cochleata (D.Don) C.Chr.	1700–2500	1, 2, 3, 4, 5	A, B, C	Ind Bor et Austr
D. juxtaposita Christ.	1700–3300	1, 2, 4, 5, 8	A, B, C	Yunn
D. panda (Cl.) Christ.	2000–2700	1, 2, 3, 4	A, C	Ind Bor As Austr et Occ
Polystichum nepalense (Spreng.) C.Chr.	1700–2600	1, 2, 3	A, B	Ind Bor As
P. piceopaleaceum Tag.	1500–2600	1, 2, 4	A, B	Yun Afghan Ind Japon Kash
P. lonchitis (L.) Roth	1700–2400	1, 2, 5, 6	A, B	Europ As et Amer Arct et Temp Himal
P. longipaleatum Christ	1700–2500	1, 2, 3	A, B, C	Yun
P. lachenense (Hk.) Bedd.	2700–3400	1, 2, 5	C	Himal As
P. setosum Schott.	1500–3200	1, 2, 10	A, B, C	Japon South Kor
P. squarrosum (D. Don) Fee	1300–3000	1, 2, 4	A, B, C	Ind As
P. stimulans (Kunze ex Mett.) Bedd.	2000–2500	1, 2, 3	B	Ind Bor As Merid

Equisetaceae				
Equisetum arvense L.	2000–2600	1, 2, 10	B, C	Arct Temp Europ North Amer As
E. diffusum L.	1700–2500	1, 2, 3	A	Yunn Ind Japon Kash As
Hemionitidaceae				
Coniogramme fraxinea (Don) Diels	1700–2500	1, 2, 3, 5	A, B	Ind Bor Malaysia Ins Philipp
C. intermedia Hieron. var. *glabra* Ching	1700–3000	1, 2, 5	A, B, C	Ind Bor As Japon
Gymnopteris vestita (Wall. ex Moore) Underw.	2000–2600	1, 5	C	China Ind Bor
Ophioglossaceae				
Ophioglossum petiolatum Hk.	2100–2600	1, 2, 10	A, C	As Amer
Osmundaceae				
Osmunda claytoniana L.	2000–3000	1, 2, 6	A, C	Amer Bor Atlant Himal As
Polypodiaceae				
Drynaria mollis Beddome	2000–2600	1, 2, 6, 8	A, C	Himal As Merid
Lepisorus nudus (Hk.) Ching	2000–3300	1, 4, 5	A, B, C	As Yun
Phymatopteris malacodon (Hk.) P. Serm.	2100–2600	1, 3	A, B	Himal As Merid
P. stracheyi (Ching) P. Serm.	2200–3200	1, 3, 6	A, B, C	As China
Polypodium polypodioides L. Watt.	1700–2700	1, 5, 2	A, B, C	Mex
Polypodiastrum argutum (Wall. ex Hk.)	1700–2600	2, 3, 5, 8	B	Yun As
Polypodiodes amoena (Wall. ex Mett.)	2000–2500	1, 2, 3	A, B, C	Ind Bor As
P. microrhizoma (Cl. ex Baker) Ching	2000–2700	1, 3	A, B, C	Himal Yun
P. subamoena (Cl.) Ching	2200–3300	2, 3, 5	B, C	As Merid Himal
Pteridaceae				
Pteris cretica L.	1300–3300	1, 2, 3, 8, 9	A, B, C	Trop Subtrop
P. biaurita L.	1300–2000	1, 3, 4, 5, 9	A, B, C	As Ind Subcont As Trop
P. vittata L.	1700–2400	1, 2, 3	A, B, C	Afr As Europ Trop et Subtrop Austr Polynes Trop
P. wallichiana Ag.	1700–2500	1, 2, 3	A, B, C	Ind Bor Java Celebes Ins Philipp
Pteridium aquilinum (L.) Kuhn.	1700–2700	1, 2, 3, 4	A, B, C	Afr As Trop As Temp Europ N Amer
Selaginaceae				
Selaginella chrysoleuca Spring	2000–2700	1, 2, 3, 8	A, C	Peru
Sinopteridaceae				
Cheilanthes albomarginata Cl.	1500–2700	1, 2, 3,	A, B, C	Himal Ind Austr
C. dalhousiae Hk.	2000–2500	1, 2, 3	B, C	As Ind
C. subvillosa Hk.	2100–2600	1, 2, 3, 6	A, B	Himal
Thelypteridaceae				
Phegopteris punctata (Thunb.) Bedd.	1700–2200	1, 3, 8	B	Hawaii

Pseudophegopteris distans (D. Don) Mett.	1500–2600	1, 2	A, B	As Ind China
P. levingei (Cl.) Ching	2500–3300	1, 2, 3	C	Ind As
Stegnogramma mollissima (Kunze) Fras.-Jenk.	1700–2600	1, 2, 3, 8	A, B	Ind Ceyl Jappon Kor
Thelypteris palustris (Salisb.) Schott.	1700–2600	1, 2, 3	B	Canada

Abbreviations used: HEPs – Hydroelectric projects; A – Sainj HEP; B – Parbati Satge II HEP; C – Malana II HEP; 1 – Forest; 2 – Riverine/Watercourse; 3 – Shadymoist; 4 – Dry; 5 – Bouldary; 6 – Degraded; 7 – Waste place/Road side; 8 – Dam submergence area; 9 – Land slide; 10 – Near crop field/orchards; Europ – Europe; Occ – Occidetalis; Austr – Australia; As – Asia; Afr – Africa; et – And; Temp – Temperate; Abys – Abyssinia; Arct – Arctica; Amer – America; Afghan – Afganistan; Atlant – Atlantica; Bor – Boreal; Centr – Central; Ceyl – Ceylon; Himal – Himalayan; Ins – Insular; Ind – Indian; Japon – Japan; Kash – Kashmir; Kor – Korea; Mex – Mexico; Merid – Meridian; Philipp – Philippines; Polyn – Polynesia; Subcont – Subcontinental; Subtrop – Subtropical; Trop – Tropical; and Yun – Yunnan.

Among the genera, *Polystichum* (8 spp.); *Athyrium* (7 spp.); *Adiantum*, *Asplenium* and *Pteris* (4 spp., each); *Dryopteris*, *Polypodiodes* and *Cheilanthes* (3 spp., each); *Diplazium*, *Equisetum*, *Coniogramme*, *Phymatopteris* and *Pseudophegopteris* (2 spp., each) were dominant genera (Table 1). 63 species were reported in the altitudinal zone 1800 to 2800 m, followed by 36 species in the altitudinal zone 1300 to1800 m and 19 species were present in the altitudinal zone >1800 m. Maximum species (56 spp.) were found in forest habitat followed by riverine/watercourse (48 spp.), shadymoist (42 spp.), bouldary (21 spp.), dry (17 spp.), degraded (12 spp.), submergence area (12 spp.), landslide and near crop field/orchards (4 spp. each), waste place/road side (1 sp.) (Fig. 2).

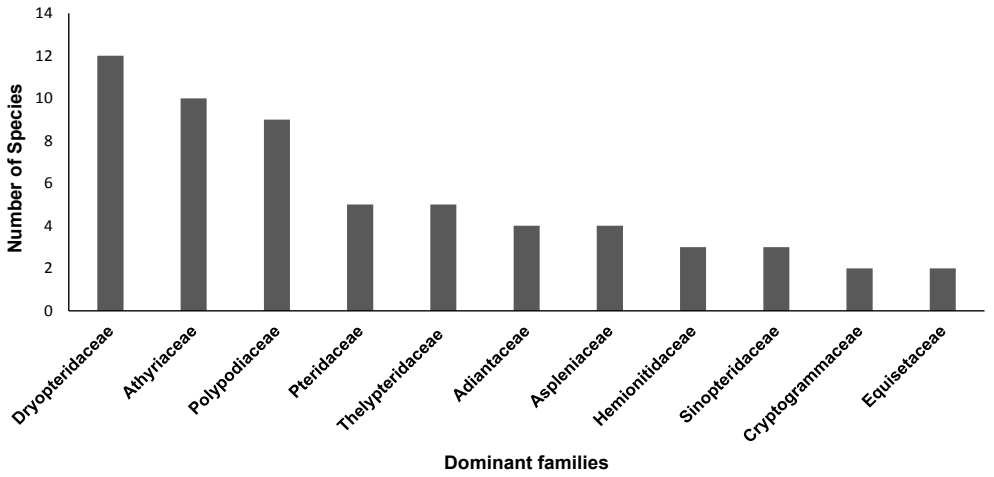

Fig. 1. Dominant families for peteridophytes in three Hydroelectric Projects areas in Kullu district, Himachal Pradesh, India.

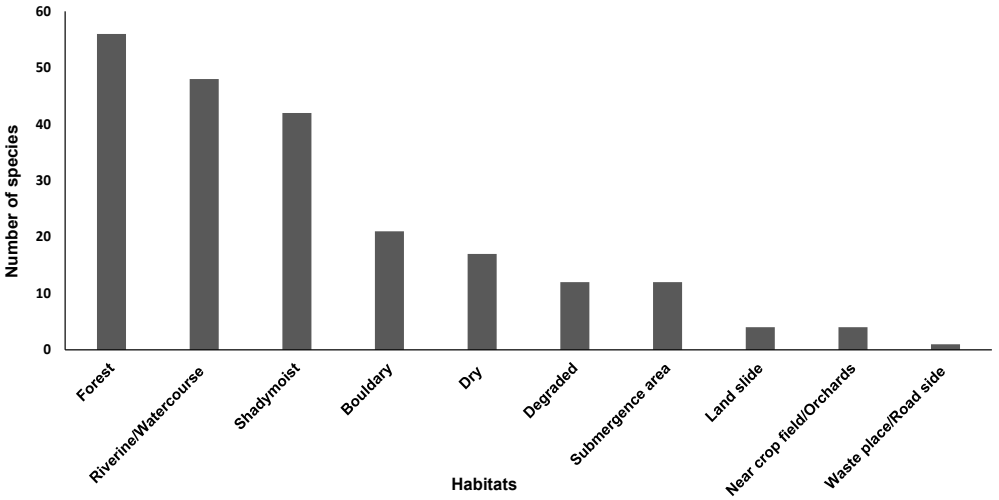

Fig. 2. Habitat wise distribution of peteridophytes in three Hydroelectric Projects areas in Kullu district, Himachal Pradesh, India.

Discussion and Conclusions

The pteridophtes are very well known and used in various ways by mankind from ancient times. They are seedless vascular plants and had a very flourishing past in dominating the vegetation on the Earth about 280–230 million years ago (Mehra and Bir 1964; Bir 1987, 1993). Although they are now largely replaced by the seed bearing vacular plants in the extant flora today, yet they constitute a fairly prominent part of the present day vegetation of the world. India, with a highly variable climate, has a rich diversity of its flora and Pteridophytic flora greatly contributes to its diversity (Bir 1987). According to a recent census, the Pteridophytic flora of India comprises of 67 families, 191 genera and more than 1,000 species (Dixit 1984, Dixit and Kumar 2002) including 47 endemic Indian ferns, less than 10 % of those reported previously and 414 species of Pteridophytes (219 at risk, of which 160 critically endangered, 82 near-threatened and 113 rare), constituting 41–43 % of the total number of 950–1000 Pteridophytes of political India. Chandra (2000) recorded 34 families, 144 genera and more than 1100 species of ferns with about 235 endemic species from Indian region. Analysis of the fern flora (Western Himalaya), Dhir (1980) recorded 264 species, Khullar (2000) recorded 360 species, Khullar (1988) documented 246 species from Uttrakhand, Khullar (1988) recorded 258 species from Garhwal Himalaya, 341 species reported from Kumaon Himalaya by Pande and Pande (2003). In the present scenario many different ecological niches are under tremendous threat due to various anthropogenic activities, creating severe problems for the persistence of ferns in the area. Increase in human population, expansion of agricultural land, harvesting of fuel wood and timber, exploitation of non-timber forest products (NTFPs), selective removal of species and other developmental activities are continuing at the verge of natural flora/fauna. In addition to these, construction of hydroelectric projects, roads, urbaniza-

tion, construction of buildings, etc. in the areas are all examples of direct assaults on nature resulting in the loss of the pteridophytic diversity of the areas. The huge decrease in forest cover indicates a danger for many epiphytic ferns, climbing ferns and many other shade loving ferns, which cannot survive in the absence of forest cover.

The state Himachal Pradesh represents one of the richest zones of vegetation wealth in India. Pteridophytic flora is also interesting for its diversity and distribution, however, little is worked out on the economic aspects of these plants. The occurrence of 63 species of pteridophytes species in the area indicates that its environmental conditions, particularly, shady moist and forest habitats, are suitable for growth and development of such species. Therefore, present communication pertains to the diversity of ferns in the surroundings and dam submergence areas of different hydroelectric projects in Kullu district of Himachal Pradesh, India and based on frequent field trips to various remote localities and collecting the information from the local inhabitants. Several conservation measures and management programmes have been taken up in various regions for the angiosperms, but very little attention has been given to the conservation of pteridophytes even though they have ecological value and a good potential for academic, medicinal, ritualistic, food and ornamental uses. In view of this it is important to formulate and implement a detailed scientific study with aim of in situ, as well as ex situ conservation of pteridophytes in target localities with a high value at district and state level has been sugested. In a nutshell, to ensure the long term conservation of pteridophytes in Himachal Pradesh proper strategy and policy dealing with conservation management for this important group of plants should be formulated, so that effective management of forests could be achieved in posterity.

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