CHAPTER 2 - REVIEW OF LITERATURE

The tropical forests, harbouring more than half of the world’s flora and fauna, are a labyrinth of ecological interactions. They occupy about 7% of the earth’s area (Myers, 1986) and in India; they occupy ca. 84% of the total forest cover (637293 km²), which is 19.39% of the total geographical area. They are a source of wonderment, scientific curiosity, enormous complexity as well as a basic foundation for human welfare (Tilman, 2000). The dense leafy canopies of tropical forests make them highly productive plant communities storing almost 30% of the global soil carbon (Sayer et al., 2007). However, the past and present rates of tropical land conversions indicate that most mature tropical forests will disappear in the coming time leaving behind a complex landscape consisting of a matrix of agricultural fields and forest patches of under different levels of succession (Quesada et al., 2009). Hence, it has become imperative to document the astonishing diversity of life forms and species inhabiting these landscapes which have been shaped by the natural selection processes and the local biotic and abiotic factors. During the last decade, a need to address conservation questions with a wider social, political and cultural framework was recognized (Hodgkin & Rao, 2002). In the recent past, approaches such as the ex situ conservation, in situ conservation, creating biosphere reserves, protected areas, etc. have been extended to address the conservation and restoration of tropical forest resources (Shands, 1991; Uma Shanker et al., 2001; Nageswara Rao et al., 2007, 2011).

The Western Ghats, featuring in 34 global biodiversity hotspots (Conservation International, 2005) and among the 200 globally most important ecoregions of the world (Olson & Dinerstein, 1998) has been the epicenter of numerous floristic and vegetation studies, which have seen a
marked increase in the last few decades. The majority of the area under moist forest types falls within the southern states of Kerala and Karnataka which together account for about 80% of evergreen forest and 66% of moist deciduous forests in the entire Western Ghats (IIRS 2002). The central Western Ghats in Karnataka stretches from 12°N to 14°N, ranging from Uttara Kannada district in the north to Coorg district in the South. The elevation in this region ranges from 400 m to 800 m and is covered with evergreen to semi-evergreen climax forests and their various stages of degradation, especially around human habitations, whereas the higher altitudes, rising up to 1700 m, are covered with evergreen forests especially along stream courses and rich grasslands in between (Ramachandra et al., 2012). The spectrum of angiosperms in the flora has been widely documented through the monumental works of Buchanan (1870), Lavery (1888), Cooke (1901-1908), Gamble (1915-1936), Saldanah (1976), Yoganarasimhan (1981) and so on. However, the cryptogams have been largely understudied and hence, the lacunae in their diversity and distribution in the central Western Ghats is still prevalent. This study deals with two groups of cryptogams – pteridophytes (including ferns and fern-allies) and lichens.

PTERIDOPHYTES

The world flora comprises of approximately 12,000 species of pteridophytes of which around 1000 species distributed in 70 families and 192 genera are likely to occur in India. A lot of researchers from other countries have put forward some earliest records of pteridophytes in their works. Chief among them is the vast work of Beddome (1863-1864; 1865; 1865-1870; 1883) spanning over almost two decades incorporating the details of ferns collected during the British era. Beddome’s “Handbook of the ferns of British India, Ceylon and Malay Peninsula” published in 1883 was a very authentic work and is even useful in today’s works on pteridophytes. A little
later, its supplement in 1892 dealt with the ferns only, excluding the fern-allies. Later on Clarke (1880) provided information on the ferns of northern India and after long gap, Holttum (1974) published ‘Taxonomy of Indian Ferns’. Hope (1899 - 1904) through his works, contributed towards fern flora of North-Western India. Later on, Chandra & Kaur (1987, 1994) also updated the nomenclatures of all the fern taxa as listed in Beddome’s various works.

Among the Indian researchers, S. S. Bir was one of the pioneering researchers in pteridology, who not only worked on the cytology of ferns (Bir, 1960; 1962; 1973) but also contributed significantly towards the taxonomy and regional fern floras (Bir, 1963; 1964; 1985; 1987). In his detailed account on ‘Taxonomy of Indian Pteridophytes’, Among other significant contributions, Dixit (1984) published ‘Census of the Indian Pteridophytes’ wherein he listed more than 1000 species of pteridophytes distributed in 191 genera from India. Dixit (1959, 1974, 1975a, 1975b) and Dixit & Singh (2004) contributed significantly towards the knowledge about medicinally important ferns from India. Dixit (1989) also brought out the importance of tree ferns and emphasized upon the urgent need for their conservation.

According to Dixit (2000), the different studies carried out on the diversity of pteridophytes throughout the country reveal that on all India basis, maximum number of 150 species occur in the family Polypodiaceae. Other major families of pteridophytes in India include Dryopteridaceae (109 species), Athyriaceae (101 species), Thelypteridaceae (88 species), Aspleniaceae (70 species), Aspeliaceae (50 species), Hymenophyllaceae (35 species), Cheilanthaceae (30 species), Adiantaceae (30 species), Lindasaeeaceae (26 species), Bolbitidaceae (22 species) and Vittariaceae (20 species). On the genus level, the maximum
diversity of about 70 species was observed in genus *Asplenium*, followed by *Selaginella* (62 species), *Pteris* (60 species), *Dryopteris* (57 species), *Polystichum* (40 species), *Athyrium* (35 species), *Adiantum, Cheilanthes, Lepisorus, Pyrossia* each with 30 species, *Christella* (25 species) and *Lindsaea* (23 species).


Jenkins (2008a) gave a detailed taxonomic revision of three hundred Indian sub-continental pteridophytes with a revised census list. Based on the field observations, data from herbarium
collections and literature references, the assessment of rare and threatened pteridophytes of India was carried out by Chandra et al., (2008). This study yielded the results that a total of 219 species were ‘At Risk’ out of which 160 were ‘Critically Endangered’. 82 species were considered to be ‘Near Threatened’ while 113 species were considered under the category ‘Rare’. Jenkins (2008b) also assessed the endemic and pseudo-endemic species of India. Based on this study, he stated that out of about 530 pteridophytic species reported to be as endemics by the recent studies, only 47 were true endemics. The remaining 483 were ‘pseudo-endemics’ and were mistaken as endemics mainly due to insufficient investigative taxonomic research.

With respect to South India, some early studies on ferns and fern-allies continue to form a baseline for present studies in the region. The earliest among them was the work of Van Rheede (1703) who gave the illustrations of few ferns and fern allies. However, the only comprehensive work on the ferns of South India was by Beddome (1863-1864, 1865) wherein he included 271 species recorded by him from South India and Sri Lanka. After long gap, Abraham et al., (1962) worked on the cytology of 100 species of pteridophytes of South India. Bir and Vasudeva (1971) recorded 118 species of ferns from the Palni hills and Bir (1965) also studied the cytology of some ferns of the Palni hills. Manickam (1984 and 1986) published the “Ecological studies on the Fern Flora of Palni hills” and “Fern Flora of Palni Hills, South India” respectively. Manickam and Irudayaraj (1988) provided the cytological information of about 200 ferns of South India in “Cytology of the ferns of Western Ghats, South India”. Manickam & Irudayaraj (1992) also published the “Pteridophyte flora of Western Ghats, South India” in which they described and gave illustrations for 256 ferns and fern allies collected from the Western Ghats region lying south of Palghat Gap. Manickam & Rajkumar (1999) explained the polymorphism in 100 south Indian ferns. The phytochemistry of South Indian ferns was also explored by


Some noticeable studies which have been carried out in the central Western Ghats include the collection and listing of 75 species of ferns from North Canara (Uttara Kannada) district by Matchperson (1986). Later, in 1992, Blatter & Almeida included 90 species of ferns from Uttara Kannada district, then a part of Bombay Presidency, in their “Ferns of Bombay”. Alston (1945) recorded 58 species of Selaginella from India of which 4 species have been recorded from
Karnataka. Kammathy et al., (1967) listed 25 species of ferns and fern-allies in their “Contribution towards a Flora of Biligirirangana Hills”. Razi & Rao (1971) published an artificial key to the Pteridophytes of Mysore city and its neighbouring areas in which they included 70 species of ferns and fern-allies spread over 41 genera. Bhaskar & Razi (1973) recorded 7 species of ferns and one species of Selaginella from aquatic and semi-aquatic habitats of Mysore district. Holttum (1976) included 10 members of Thelypteridaceae in the “Flora of Hassan District”. Yoganarsimhan et al., (1981) recorded 12 species of ferns in their “Flora of Chikmagalur District”. However, the only in depth and comprehensive work on the pteridophytes of Karnataka has been done by Rajagopal & Bhat (1998). They gathered the data on Pteridophyte diversity of Karnataka state from 1988-1995 and hence as a result, published the “Pteridophytic Flora of Karnataka state, India”. After a significant time gap, there has been a surge in various research aspects of pteridophytes of central Western Ghats. Some of the recent studies on ferns and fern-allies include the record of 23 species of pteridophytes in Madhuguni state forest of central Western Ghats by Deepa et al., (2011); enumeration of 22 species of pteridophytes from Agumbe forest of central Western Ghats (Nataraja et al, 2011) and record of 38 taxa of pteridophytes from Kemmangundi forest of Karnataka by Deepa et al., (2013). However, there has been no in-depth studies on the diversity and ecology of pteridophytes especially with respect to Uttara Kannada district and hence, special focus is laid on that district in this study.

**LICHENS**

The lichens form perfect example of a stable and symbiotic organism comprising of fungal partner (the mycobiont, responsible for providing the shape, structure and colour to the thallus)
and algae/cyanobacteria (photobiont, responsible for producing the food through photosynthesis). They form easily distinguishable coloured patches on the substrates (tree barks, rocks and soil) they grow upon and are distributed widely in varied climatic conditions ranging from the poles to the tropics (Kumar, 2010). The word ‘Lichen’ (lie ken) was introduced into the Greek literature in about 300 BC by Theophrastus, to describe outgrowths from the bark of olive trees (Hawksworth & Hill, 1984). In spite of its important roles in the ecosystem, the study of lichens remains quite neglected throughout the world, though they together with mosses form dominant organism in ecosystem covering over 10% of the earth terrestrial habitats, particularly at higher elevations (Nash & Egan 1988). They also have a very useful role as indicators of air pollution, ecosystem health and changing climatic conditions.

The earliest record of lichen studies dates back to 1753 A.D. when Linnaeus mentioned about Lichen fuciformis (L.) DC. (Rocella montagnei Bél) from India, in his monumental masterpiece work ‘Species Plantarum’. Later on, the father of Lichenology, Erik Acharius (1810, 1814) produced his classical works ‘Lichenographia Universalis’ and ‘Synopsis Methodica Lichenum’ in which he gave the descriptions of lichens. In the later years, the studies on Indian lichens picked up drastically and were explored upon by many researchers. However, after a most vigorous and vast exploration of the different phytogeographical regions of India, Awasthi (1965) a comprehensive catalogue of lichens from India, Nepal, Pakistan and Ceylon. In the later years he also produced the key for macro and microlichens of India, Nepal and Sri Lanka (1988, 1991, 2007). After examining all the works done so far, it is now known that the different biological hotspots of India harbor 2305 species of lichens (Singh & Sinha, 2010). Based on the 10 dominant families, 10 largest genera and other interesting features of lichen communities
Singh & Sinha (1997) divided India into eight lichenogeographic regions. Amongst all these regions, the Western Ghats harbor the highest number of lichen taxa (1096 spp.) followed by Eastern Himalayas (850 spp., Bujarbarua et al., 2002) and Western Himalayas (~800 spp. unpublished).

The earliest records of lichenological explorations in Western Ghats can be found in the work of Belanger (1834-1838) who, in his enumeration of the lichens of Western Ghats, also described 40 taxa from the Pondicherry and Coromandel Coast. This was followed by a number of lichen studies by some important European lichenologists which included - Montagne (1842), Stirton (1876, 1879), Hue (1898, 1899, 1900a,b and 1901), Jatta (1902, 1905, 1911), Smith (1921), Choisy (1931), Moreau and Moreau (1952). These explorations also contributed to the understanding of lichen flora of Western Ghats. With regard to Indian researchers, Singh & Sinha (1997) and Patwardhan (1983) estimated the presence of about 800 species of lichens in Western Ghats whereas Kumar & Stephen (1999) listed about 771 species of lichens from Western Ghats in their work. Few years later, after a thorough compilation and enumeration, around 1096 species of lichens belonging to 188 genera and 50 families were found to be occurring in the various habitats of Western Ghats, which formed about 47% of the total lichen flora of India, making it the richest lichen-geographic region in the country. It was also noteworthy that out of these total species, 257 species were endemic to the Western Ghats. Among the Western Ghats state, Tamil Nadu was found to be richest with 736 species followed by Karnataka (455 species), Kerala (391 species) and Maharashtra (184 species). The lichen flora of Western Ghats is mainly dominated by the microlichens (crustose and leprose growth forms) with 719 taxa followed by foliose forms with 324 taxa and fruticose forms with 71 taxa (Nayaka, 2006).
The central Western Ghats of Karnataka state comprise a major portion of Western Ghats and have been extensively explored for its angiosperm flora and by some researchers for lichens too. Among the lichen diversity studies, a significant study was carried out by Nayaka & Upreti (2002) wherein they enumerated 143 lichen species belonging to 50 genera and 26 families from the Sharavathi river basin which also included six species as new records for lichen flora of India. Kanivebagilu et al., (2011) recorded presence of 67 macrolichens and 85 microlichens from the different vegetation types of Bhadra Wildlife Sanctuary. Vinayaka et al., (2012) reported six macrolichens as new record for the lichen flora of central Western Ghats (mainly from Shimoga, Hassan, Coorg and Chickmagalur districts). Rashmi (2012) enumerated 30 species of lichens belonging to 25 genera and 18 families from the Mysore district. Joshi et al., (2010) described a new species *Phlyctis karnatakana* during their survey near Jog falls in Shimoga district.

The ecological factors such as vegetation, climate, substrate and altitude produce several microclimatic niches for the lichens as well as govern their distribution. The Western Ghats biodiversity hotspot provides a vast array of substratums for lichen colonization and the high diversity of corticolous lichens in the region can be attributed to the high diversity of trees and shrubs in the region. The lichen diversity is often found variously influenced by the age of phorophytes, ambient air quality and changes in the neighborhood land-cover (Saipunkaew et al., 2007; Pinho et al., 2008; Thomas et al., 2008). Because of these characteristics lichens are often regarded as the potential indicators of forest health, anthropogenic disturbances and micro-site (Lucking, 1997). The usefulness of epiphytic lichens as indicators can be attributed to general structural peculiarities of lichen thallus (i.e. absence of waxy cuticle, absence of root and
absorption of water and nutrients passively from the environment) and microhabitat sensitivity (Will-Wolf et al., 2002 a, b). However, the large scale degradation and loss of natural habitat has emerged as the most serious threat to biodiversity in general (Groom et al., 2006) and to lichens in particular (Wirth, 1976, 1999).

The use of epiphytic lichens as bioindicators of atmospheric pollutants and environmental conditions has been widely studied especially with respect to the temperate regions (Nimis et al., 2002). However, in compared to that there have been fewer studies especially focusing on their ecological linkages in tropical forests of regions like India. Pinokiyo et al., (2008) carried out a diversity and ecological study on the lichens of Mehao Wildlife Sanctuary in Arunachal Pradesh and found out that altitude and humidity were the two key factors controlling the diversity and distribution of the lichens within the sanctuary. They also found that the core region of the sanctuary which was relatively undisturbed harbored more lichens as compared to the disturbed peripheral region. One of the significant studies done in Western Ghats was on the epiphyte-host relationship of lichens in Silent Valley National Park by Sequiera & Kumar (2008). They found out that some macrolichens showed specificity to a particular host while some had a broad niche of host plants, which was principally attributed to the various ecological conditions within the sanctuary. Their results were in concurrence with many other similar studies which have provided observational and experimental evidences to show that the microclimatic factors are of utmost importance in determining the distribution and performance of macrolichens (Hoffman & Kazmierski 1969; Kershaw & Rose 1971; Yarranton & Green 1966; Yarranton 1975). Nag et al., (2011) in their study on lichen diversity and distribution in a community reserve forest in Nepal, also found that the lichen diversity increased from the fringes towards the core. They also
recorded that the lichen diversity was constrained phorophyte determinants (stand age, aspect, and bark properties) and community harvesting of the forest.

Uttara Kannada district, the focal study region in this study, has been bestowed with very rich floristic diversity and yet has not been properly explored upon for the cryptogams, especially pteridophytes and lichens. Though there have been sporadic collections and mentions of some species of lichens and pteridophytes in earlier works, there is a lack of systematic sampling as well as ecological insights into these plants. Hence, this study was carried out with an aim to document lichen diversity and pteridophyte diversity from different habitats of this district as well as some other parts of central Western Ghats and understand their ecological linkages along with their responses in disturbance gradients.