Chapter 6. The status and distribution of aquatic plants of the Western Ghats

R. Brawin Kumar[1], K. Anitha[2,3], Aparna Watve[4], S. Mani[5], Shiny Rehel[6] and W. Arisdason[7]

6.1 Overview of the Western Ghats aquatic flora....73
6.1.1 Phytogeography of the Western Ghats assessment region....73
6.1.2 Aquatic flora of the Western Ghats....75
6.2 Conservation status....75
6.3 Patterns of species richness....79
6.3.1 Aquatic plant species richness....79
6.3.2 Species richness for threatened aquatic plant species....79
6.3.3 Species richness for endemic aquatic plant species....81
6.4 Major threats to the Western Ghats freshwater plants....81
6.4.1 Habitat degradation....81
6.4.2 Habitat loss....83
6.5 Conservation recommendations....83
6.6 References....84

6.1 Overview of the Western Ghats aquatic flora

6.1.1 Phytogeography of the Western Ghats assessment region

The Western Ghats, a major tropical evergreen forested regions in India, also known as the Sahyadri Mountains, is one of the 34 global biodiversity 'hotspots' (Mittermeier *et al.* 2005). It is one of the best representatives of non-equatorial tropical evergreen forests in the world (Bawa *et al.* 2007). Floristically, the Western Ghats is one of the richest areas in the country. Nayar (1996) reports that about 27% of the total plant species in India (about 4,000 species) are recorded from the Western Ghats, of which 51 genera and 1,600 species are endemic to the region. Out of the 51 endemic genera of flowering plants in the Western Ghats, 43 are monotypic (Pushpangadan 1997). Most of the species of flowering plants endemic to peninsular India are confined to the Western Ghats (Nayar 1996). Approximately, 63% of India's woody evergreen taxa are endemic to the Western Ghats (Johnsingh 2001) and of the nearly 650 tree species found in the Western Ghats, 352 (54%) are endemic (Daniels 2001). According to Nair (1991) the grass family Gramineae (Poaceae) has the highest number of endemic genera, with its genus *Nilgirianthus* having the highest number of endemic species (20). Owing to differences in the seasonal rainfall patterns over the Western Ghats, plant species richness and endemism are not uniform, with the southern Western Ghats containing higher levels of plant richness and greater numbers of endemic species (Pascal 1988, Ramesh *et al.* 1991).

No specific study has been undertaken to understand species richness and diversity of aquatic plants across the Western Ghats barring a few studies in certain restricted regions. These studies document plant communities from rocky plateaus on the northern Western Ghats hilltops (Keystone 2006, Watve 2007) and ongoing studies on Myristica swamps in Karnataka. When compared to terrestrial flora of Western Ghats, the knowledge of aquatic flora is limited.

The Western Ghats assessment region (Figure 2.1, Chapter 2) falls in one of the 10 biogeographical zones in India defined by Rodgers and Pawar (1988). Administratively, it is part of six states of India; the southern tip of Gujarat, Maharashtra, Goa, Karnataka, Kerala and Tamil Nadu. The climatic condition in the region varies considerably and is one of the reasons for the species richness. The western slopes receive high levels of rainfall, with 5,000 mm per annum. This contrasts with about 600 mm in the rain shadow areas of the eastern slopes. These variations have resulted in a variety of forest types, the southern part of Western Ghats with higher diversity of flowering plants compared to the rest of the Western Ghats. Almost 87% of the Western Ghats flowering plants are found south of the Palghat Gap in which 37% are endemic to this sub-region. In the case of the Nilgiri Hills although the region contains 60% of the flowering plants, only 5% are endemic

[1] Zoo Outreach Organisation, 9A Lal Bahadur Colony, Peelamedu, Coimbatore, Tamil Nadu 641004, India. brawinkumar@rocketmail.com
[2] Conservation Research Group (CRG), Department of Aquaculture, St. Albert's College, Kochi, Kerala 682018, India. anithasacon@gmail.com
[3] Advanced Centre of Environmental Studies and Sustainable Development, Mahatma Gandhi University, Kottayam, India.
[4] 34/6 Gulawani Maharaj Road, Pune, Maharashtra 411004, India. aparnawatve1@gmail.com
[5] DST Young Scientist Fellow, Centre for Ecological Sciences, Indian Institute of Science, Bengaluru, Karnataka 460012, India. manitrees@yahoo.com
[6] Consultant, Keystone Foundation, Keystone Centre PB 35, Groves Hill Road, Kotagiri, Nilgiris District, Tamil Nadu 643217, India. shinyrehel@gmail.com
[7] Lecturer, Department of Botany, Madras Christian College (Autonomous), Tambaram, Chennai, Tamil Nadu 600059, India. dasonaris@yahoo.co.in

Bhavani River in the Nilgiris. © Keystone Foundation

The evergreen Wyanad forests of Kerala mark the transition zone between the dry northern and wet southern ecoregions of the Western Ghats.

Singh *et al.* (2002) classify the Western Ghats into four regions based on floristic composition: (i) Tapi River to Goa, (ii) River Kalinadi to Kodagu, (iii) The Nilgiris, and (iv) The Anamalai, Palni and Cardamom hills. The mountain range has the following forest types: dry shrub vegetation, dry deciduous forests, moist deciduous forests, semi-evergreen forests, evergreen forests, the sholas and grasslands.

The dry shrub vegetation forests occur at the foothills of the eastern side. The vegetation is dominated by thorny species, tree and climbers are very few; herbaceous flora is seasonal and composed of grasses. The dry deciduous forests also occur on the eastern side. In the moist deciduous forests the herbaceous flora is very profuse during rainy season and not dominated by any species in particular although large bamboo patches can be seen. The semi-evergreen forests are seen at an elevation ranging from 500–1500 m mostly on the western slopes. The evergreen forests receive heavy rainfall ranging from 3500-7500 mm and elevations ranging from 500-2600 m. Shola forests are found along the folds of rolling downs at a height of 1600 m and above where moisture content is very high. These are evergreen patches with stunted trees and bushes with high species diversity. Grasslands occur in southern parts of Western Ghats. Poaceae, Leguminosae, Orchidaceae, Acanthaceae, Cyperaceae and Euphorbiaceae are some of the dominant families of the Western Ghats flora.

6.1.2 Aquatic flora of the Western Ghats

Aquatic macrophytes play an essential role in the ecology and biogeochemistry of wetlands in the Western Ghats region. However, there is little published information specifically on these aquatic species. Monocots, dicots, ferns and fern allies and algae are all present displaying varying life histories and growth forms including floating, submerged and emergent habits.

6.2 Conservation status (IUCN Red List Category)

A checklist of Western Ghats aquatic plant species from 42 pre-selected families, representing 32 orders (Table 6.1) was drawn together. This list was composed of Hydrophytes – plants physiologically bound to water, at least part of the generative cycle takes place in or on the surface of water and Helophytes – essentially terrestrial plants whose photosynthetically active parts tolerate long periods submerged or floating (Cook 1996). A total of 608 species of aquatic plants were identified from these families and all were assessed against the IUCN Red List Categories and Criteria (IUCN 2001), the results are shown in Table 6.2, Figure 6.1. Among the families of aquatic flora, the most speciose were the Cyperaceae (146 species), Gramineae (82 species), Eriocaulaceae (61 species) and Scrophulariaceae (42 species).

Of the extant species for which sufficient data are available to assess the risk of extinction, 54 species (9.3%) of the aquatic plants of the Western Ghats are threatened, whereas the vast majority, 517 species (89.3%) are assessed as Least Concern. The 54 threatened species are listed in Table 6.3. All the threatened species are flowering plants apart from one fern species *Isoetes panchganiensis* (Isoetaceae), and all are endemic to the Western Ghats region, apart from one species *Farmeria metzgerioides*, which is also found in Sri Lanka.

Some of the Critically Endangered species such as *Eriocaulon bolei*, *E. santapaui*, *E. sharmae* are known only from a single location where tourism is considered the biggest threat to these species and their habitats. Species such as *Aponogeton satarensis* and *Lindernia manilaliana* are highly restricted in their distribution and declining quality of their habitat is a major threat. *Eriocaulon karnatakense* (Vulnerable) is known only from the type locality, Kemmangundi Hills in Karnataka, a popular tourist location, however it may be benefiting from the conservation and management of adjacent Bhadra Wildlife Sanctuary.

In the past 100 years, many plants have been described for which often only the type locality or a few surrounding localities are documented. Newly described species such as *Eriocaulon bolei* and *E. ratnagiricum*, both Critically Endangered, urgently require further range studies to establish their distribution.

Aponogeton satarensis in ephemeral pool. © Sanjay Thakur

Aquatic plants in a hill stream in Nadugani. © Keystone Foundation

Restoration ex-situ has been undertaken for one grass species *Hubbardia heptaneuron* (Vulnerable) that was confined to one small patch in one locality (A. Watve pers. obs. 2010). In 2009, the species was introduced in 16 ghat regions at 108 locations, covering a stretch of 677 km (air distance) from Jog Falls in the south to Malshej Ghat in the north, and over 5,000 individuals have been established so far in the Western Ghats. However, recent surveys in its reintroduced habitats are not available, and it is difficult to confirm if it has established population outside its original locality until further surveys are carried out.

There are 29 species that have been assessed as Data Deficient. One DD species, *Bonnayodes limnophiloides* may be Extinct, it is thought to be endemic to Bhushi lake, Lonavla, Pune where it was discovered in 1918 and last collected in 1921. Extensive botanical surveys (including in 1996 and 1998) in the area of the type locality failed to find the species; however, the occurrence of the species in other similar suitable areas is possible but has not been studied, these areas urgently need to be surveyed and if it is not found the species can be reassessed as Extinct. Most of the DD species are categorized due to one or more of the following reasons: (i) recently recorded new species with little information on distribution, threats or population trends, (ii) species recorded only from the type locality often many years ago with no subsequent surveys, (iii) little information on their distribution, biology and population, (iv) taxonomic disputes/ uncertainties of species status. The family *Cyperaceae* had the highest number of DD species (8) followed by *Scrophulariaceae, Eriocaulaceae* and *Characeae* (each with 3 species).

Of the 42 selected plant families (Table 6.1), 14 families contain threatened species (Figure 6.2). The family with greatest number of threatened species (15 species; 25% threatened) is the pipewort family Eriocaulaceae, it is a relatively speciose group with 61 species in the region. All the species from this family are from the genus *Eriocaulon*, and are found in wet soils and marshes in shallow water. The family with the greatest proportion of threatened species is Aponogetonaceae, with 33%, however the family contains only six species in the region. The Aponogetonaceae family is fully aquatic (i.e. all species within it are true aquatic species) and its species are found in still water (ponds and pools) with leaves floating on the surface and emergent flowers. Other families containing high numbers or proportions of threatened species are Gramineae (grasses) with nine threatened species (11%); Lythraceae five threatened species (21%); Umbelliferae (umbellifers) with one threatened species (25%) and the Podostemaceae (river weed family), another fully aquatic family that survive attached to rocks in fast flowing water such as rapids or waterfalls, that has five threatened species (28% threatened).

Table 6.1 List of the 42 families of freshwater plants species assessed in Western Ghats Hotspot region. (* Fully aquatic plant families)

Family	Number of species
Green algae	**16**
Characeae*	16
Ferns and allies	**18**
Azollaceae*	1
Isoetaceae*	5
Lomariopsidaceae	9
Marsileaceae*	2
Pteridaceae	1
Flowering plants	**574**
Acanthaceae	12
Alismataceae*	8
Amaranthaceae	1
Amaryllidaceae	2
Aponogetonaceae*	6
Araceae	12
Campanulaceae	4
Ceratophyllaceae*	2
Commelinaceae	21
Compositae	20
Convolvulaceae	4
Cruciferae	2
Cyperaceae	146
Droseraceae	3
Eriocaulaceae	61
Euphorbiaceae	2
Gramineae	82
Hydrocharitaceae*	13
Hydrophyllaceae	1
Juncaceae*	4
Labiatae	5
Leguminosae	14
Lemnaceae*	8
Lentibulariaceae	22
Lythraceae	24
Nymphaeaceae*	3
Onagraceae	5
Podostemaceae*	18
Polygonaceae	10
Pontederiaceae*	2
Potamogetonaceae*	6
Ranunculaceae	1
Scrophulariaceae	42
Trapaceae*	1
Typhaceae*	3
Umbelliferae	4

Table 6.2 The number and percentage of aquatic plant species in each IUCN Red List category in the Western Ghats assessment region.

Global Red List Category	No.	%
Extinct	0	0.0
Extinct in the Wild	0	0.0
Critically Endangered	12	2.1
Endangered	21	3.6
Vulnerable	21	3.6
Near Threatened	8	1.4
Least Concern	517	89.3
Data Deficient	29	N/A
Total	**608**	

The highlighted rows (CR, EN and VU) are the 'threatened' categories.

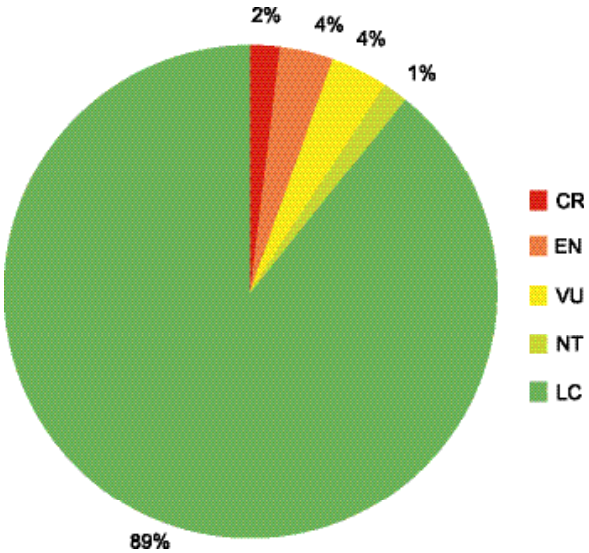

Figure 6.1 Percentage of aquatic plant species in each Red List category in the Western Ghats assessment. region. (IUCN Red List Category: CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, LC – Least Concern)

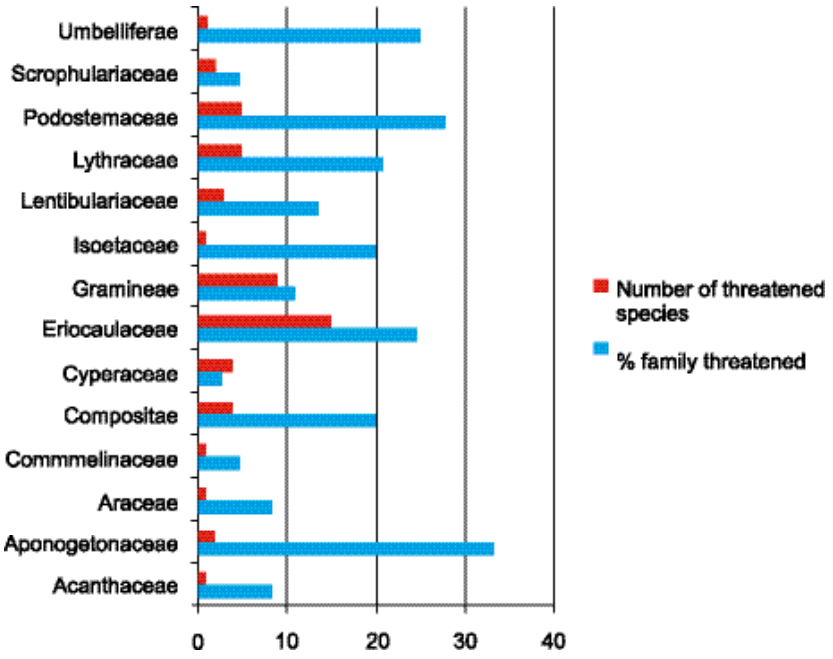

Figure 6.2 Number and proportion of threatened species in the selected aquatic plant families.

Table 6.3 Threatened aquatic plant species of the Western Ghats Hotspot assessment region.

Family	Binomial	Status
Isoetaceae	*Isoetes panchganiensis*	EN
Araceae	*Cryptocoryne cognata*	EN
Commelinaceae	*Murdannia lanceolata*	VU
Cyperaceae	*Fimbristylis crystallina*	EN
Cyperaceae	*Fimbristylis dauciformis*	EN
Cyperaceae	*Fimbristylis hirsutifolia*	CR
Cyperaceae	*Fuirena swamyi*	VU
Gramineae	*Dimeria hohenackeri*	EN
Gramineae	*Hubbardia heptaneuron*	VU
Gramineae	*Isachne bicolor*	VU
Gramineae	*Isachne meeboldii*	CR
Gramineae	*Isachne swaminathanii*	EN
Gramineae	*Isachne veldkampii*	CR
Gramineae	*Ischaemum jayachandranii*	CR
Gramineae	*Ischaemum vembanadense*	EN
Gramineae	*Limnopoa meeboldii*	EN
Eriocaulaceae	*Eriocaulon anshiense*	EN
Eriocaulaceae	*Eriocaulon bolei*	CR
Eriocaulaceae	*Eriocaulon dalzellii*	EN
Eriocaulaceae	*Eriocaulon karnatakense*	VU
Eriocaulaceae	*Eriocaulon kolhapurense*	VU
Eriocaulaceae	*Eriocaulon konkanense*	VU
Eriocaulaceae	*Eriocaulon maharashtrense*	VU
Eriocaulaceae	*Eriocaulon pectinatum*	VU
Eriocaulaceae	*Eriocaulon ratnagiricum*	CR
Eriocaulaceae	*Eriocaulon richardianum*	EN
Eriocaulaceae	*Eriocaulon rouxianum*	CR
Eriocaulaceae	*Eriocaulon santapaui*	CR
Eriocaulaceae	*Eriocaulon sharmae*	CR
Eriocaulaceae	*Eriocaulon sivarajanii*	CR
Eriocaulaceae	*Eriocaulon tuberiferum*	VU
Aponogetonaceae	*Aponogeton bruggenii*	VU
Aponogetonaceae	*Aponogeton satarensis*	EN
Umbelliferae	*Hydrocotyle conferta*	EN
Compositae	*Anaphalis beddomei*	VU
Compositae	*Anaphalis leptophylla*	VU
Compositae	*Anaphalis wightiana*	VU
Compositae	*Notonia shevaroyensis*	VU
Lythraceae	*Ammannia nagpurensis*	EN
Lythraceae	*Rotala cookii*	EN
Lythraceae	*Rotala floribunda*	VU
Lythraceae	*Rotala malabarica*	CR
Lythraceae	*Rotala ritchiei*	EN
Podostemaceae	*Farmeria indica*	EN
Podostemaceae	*Farmeria metzgerioides*[*]	VU
Podostemaceae	*Podostemum munnarense*	EN
Podostemaceae	*Polypleurum filifolium*	VU
Podostemaceae	*Willisia selaginoides*	VU
Acanthaceae	*Hygrophila madurensis*	CR
Lentibulariaceae	*Utricularia albocaerulea*	VU
Lentibulariaceae	*Utricularia cecilii*	EN
Lentibulariaceae	*Utricularia wightiana*	VU
Scrophulariaceae	*Lindernia manilaliana*	EN
Scrophulariaceae	*Lindernia minima*	EN

[*] Non-endemic

6.3 Patterns of species richness

Due to lack of precise location information for some species of aquatic plants, not all could be mapped to sub-basin as is the standard mapping methodology described in Chapter 2 (section 2.4) and have instead been mapped to sub-country units (Indian states) or even for globally widespread species to countries (i.e. to the whole of India).

6.3.1 Aquatic plant species richness

The geographic distribution of aquatic plant species in the Western Ghats assessment region is presented in Figure 6.3. Species richness is highest (186–199) in the southern Western Ghats Hotspot of Kerala and Tamil Nadu, for example in the Chaliyar, Bhavani, Kabini, Periyar and Pambayar river systems. There is also an area of high species richness (186–232) in the hotspot in southern Maharashtra, Goa and northern Karnataka from the Shastri River in the north to the Kalinadi River in the south. These regions have a range of aquatic habitats ranging from coastal wetlands to ephemeral wetlands on hilltops, rivers and mountain streams, well above 1000 m altitude. Diversity is much lower (125–185 species) in the northern and eastern region and central areas, which has considerably less rainfall although large natural and manmade water bodies, rivers and canals are abundant in the region. Species richness is lowest (108–124) in the Satpura region to southern Madhya Pradesh.

Wiesneria triandra in a lateritic pool. © Ashok Captain

However, this could be a result of poor floristic data from the region, as it also has diverse freshwater systems, ranging from large water bodies to rivers.

6.3.2 Species richness for threatened aquatic plant species

The distribution of the 54 threatened aquatic plant species (Figure 6.4) shows that the areas containing the most threatened species (11–14) are the west flowing coastal rivers and the upper Krishna of southern Maharashtra, the coastal rivers of Kerala, such as Chaliyar, Kadalundi and the upper

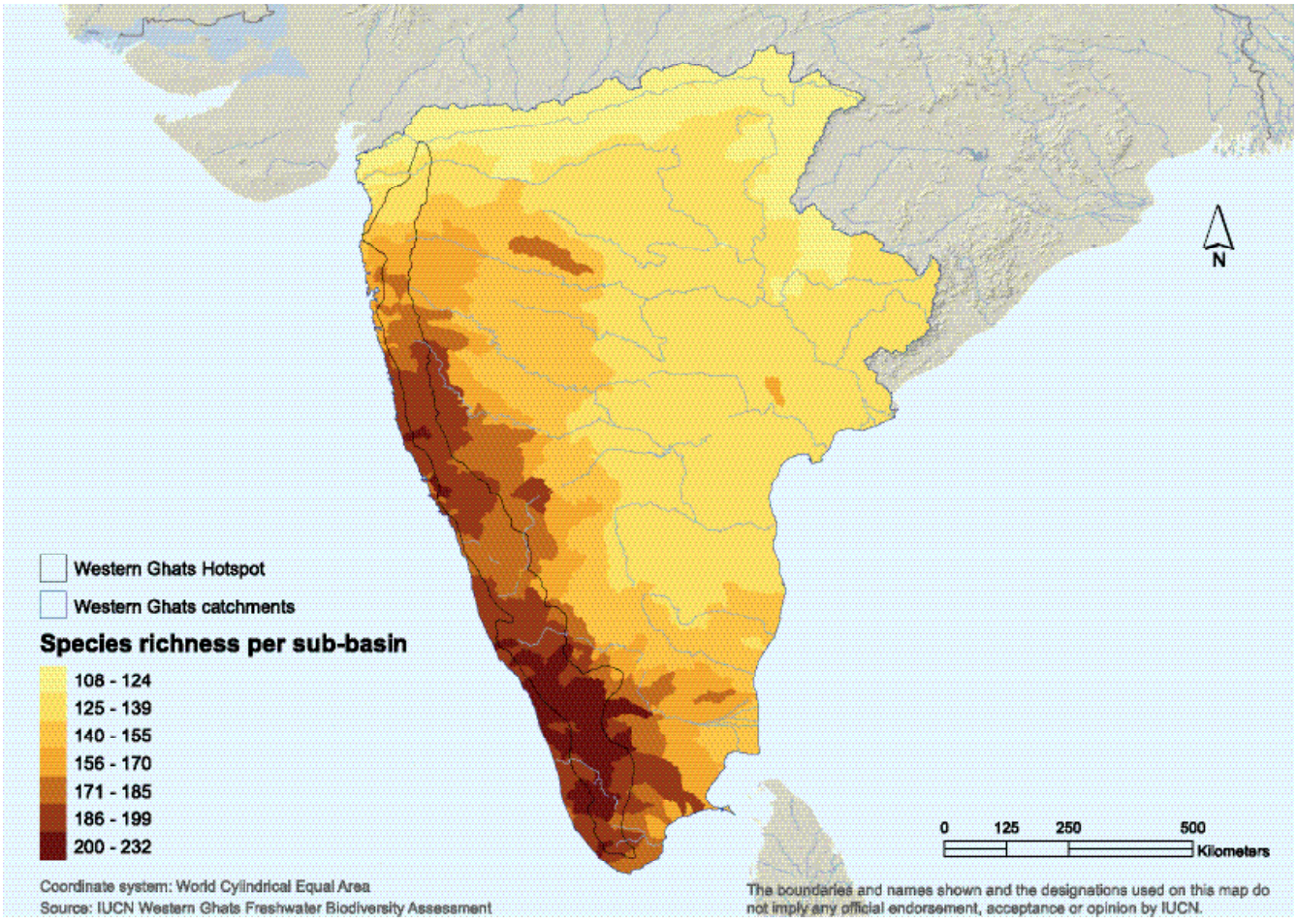

Figure 6.3 Species richness of aquatic plants species in the Western Ghats assessment region.

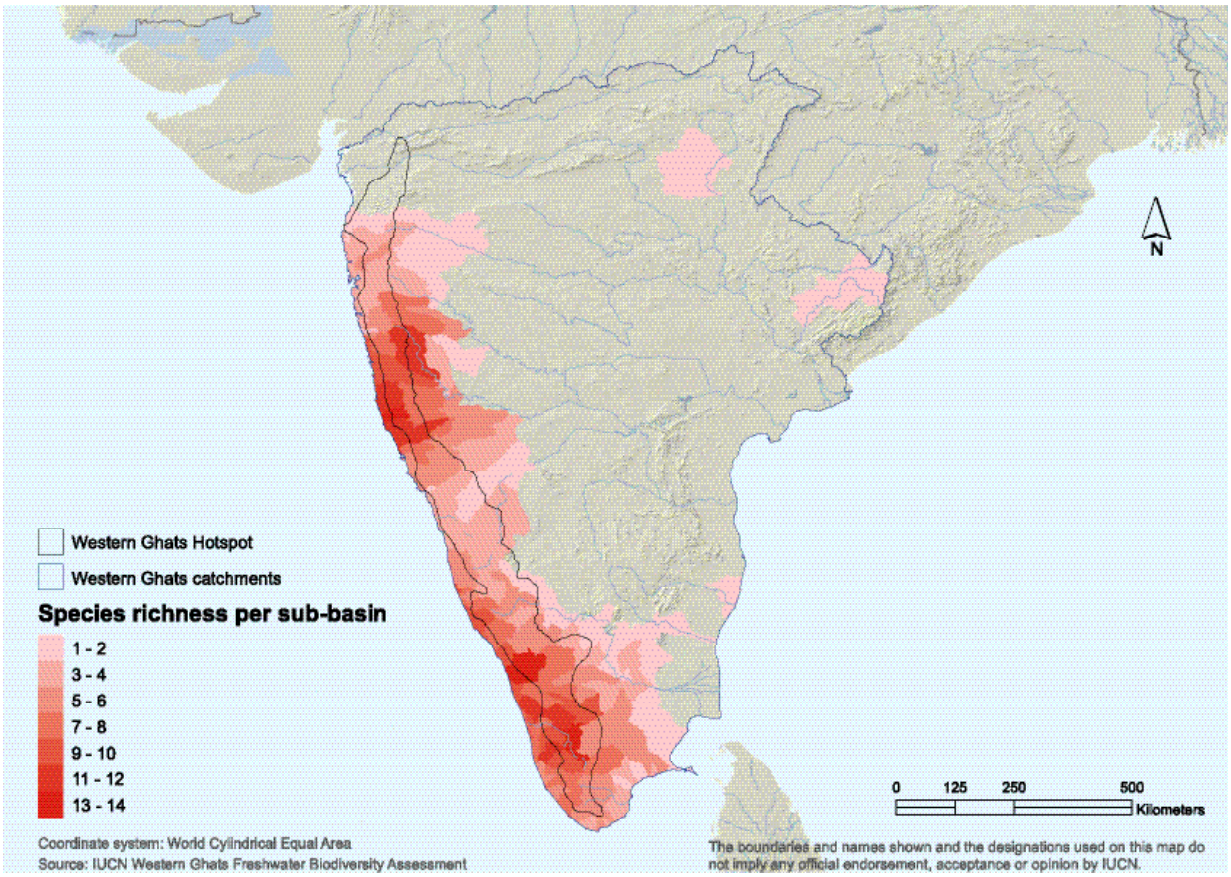

Figure 6.4 Species richness of threatened aquatic plants species in the Western Ghats assessment region.

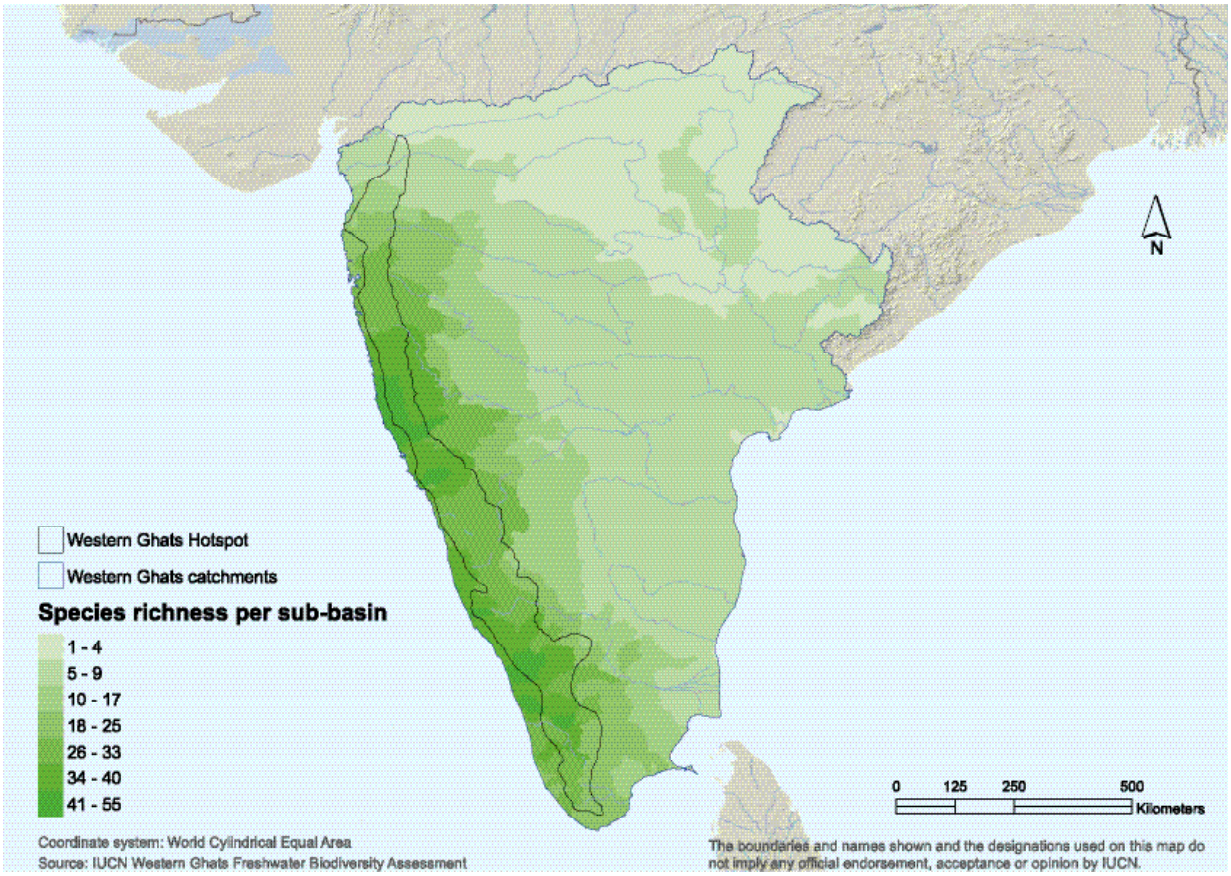

Figure 6.5 Species richness of aquatic plants species endemic to the Western Ghats assessment region.

Periyar. Areas of high numbers of threatened species are all within the Western Ghats Hotspot itself, with the majority of the remaining threatened species also distributed within the Hotspot; only a few threatened species occur outside the Hotspot.

6.3.3 Species richness for endemic aquatic plant species

The Western Ghats Hotspot is widely valued as one of the richest centres of endemism in India. Several studies conducted in the last few years identified the area as a global priority (Rodrigues and Gaston 2001, Das *et al.* 2006). Of the total 608 species assessed 148 (24%) are endemic to the Western Ghats assessment region. Figure 6.5 shows that the highest areas of aquatic plant endemism (34–55 species) are found in the higher altitudes regions of Kerala, and Konkan (southern Maharashtra). Altitudinal zones and different climatic conditions prevailing in these regions help to harbour endemic species in these landscapes (Nayar 1996).

6.4 Major threats to the Western Ghats freshwater plants

Through this assessment the major threats to aquatic plants of the Western Ghats have been identified and are discussed below (see Chapter 7 for a quantitative analysis of the threats).

6.4.1 Habitat degradation

Urban, agricultural and industrial pollution and development

Many of the watercourses originating from the Western Ghats are now polluted with untreated waste from expanding urban areas, agricultural pesticides and fertilisers, and toxic and organic pollutants from growing industries. The impacts can be severe, causing mass loss of aquatic biodiversity, eutrophication of wetlands, long term pollution of sediments and river beds with heavy metals, increased transmission of human diseases and loss of drinking water for local communities. Many Western Ghats aquatic plant species are being severely impacted by habitat degradation due to pollution such as industrial effluents, and large-scale use of pesticides and insecticides, which threaten aquatic plants. For example, *Isachne meeboldii* (CR) and *I. swaminathanii* (EN) are endemic grass species found in marshy grasslands of Karnataka (in Shimoga) and Maharashtra (in Aurangabad) with highly restricted ranges and face serious risk due to urban pollution. *Lindernia minima* (EN) is endemic to Chengalpattu and Tirunelveli on the eastern coast of Tamil Nadu where it is threatened by habitat conversion due to urbanization and the development of Special Economic Zones (SEZ) where the widening of roads, and construction of information technology parks are causing a loss of marshy areas and temporary pools that is the species, habitat. *Podostemum munnarense* (EN) is endemic to the Periyar River and is currently

Tea plantation in the Nilgiris. © Keystone Foundation

Habitat degredation from effluents. © P. Mohana

only known from one location at Munnar, Idukki District, Kerala. The lower reaches of the Periyar River are heavily polluted, and the stretch where the species occurs is polluted by pesticide runoff from tea plantations. *Rotala malabarica* (CR / Possibly Extinct) was described in 1990 and has not been re-found in the type locality (in Kannur District in Kerala). It occupies a very restricted area, on lateritic rocks, of less than 10 km^2 and is threatened by lateritic mining and extensive use of herbicides in the adjoining cashew plantations.

Tourism and recreational activities

There is an increasing trend in tourism in the Western Ghats. A recent study (Anon. 2011) shows that in Kodaikanal the number of tourists increased from two million in 1999 to 3.2 million a decade later. According to this study there are 23 tourist spots in the Western Ghats of Tamil Nadu, 41 in Kerala, 37 in Karnataka, 22 in Maharashtra and 25 in Goa. Many areas that have undergone tourism development have suffered negative environmental impacts as deforestation for development, increased pressure on resources such as water and an increase of untreated waste have all impacted natural habitats including freshwater systems. The physical flow of high numbers of tourists in sensitive areas has also led to the trampling and disturbance of rare and threatened species and their habitats. Many aquatic plant populations are under severe threat in the Western Ghats, particularly in Kerala and Maharashtra. For example, *Isoetes panchganiensis* (EN) is reported from temporary ponds and pools on the high altitude plateaus of Panchgani tablelands in Maharashtra and Kemmangundi Hills in Karnataka. It is threatened by tourism particularly on the Panchgani tableland which is a scenic rocky plateau attracting tourists all year. The tourists trample and drop litter, ride racehorses and drive cars, this disturbs the entire ecosystem impacting the temporary ponds (A. Watve *pers. comm.* 2010). *Ischaemum vembanadense* (EN) is known from the Alleppey backwaters, in Kerala, which is highly polluted due to tourism actives such as houseboats and domestic sewage. *Eriocaulon bolei* (CR/ Possibly Extinct) is known from only one site, near Mahabaleshwar, Satara in Maharashtra. The species habitat is severely impacted by tourism and it has not been recorded since 1955. *Eriocaulon sharmae* (CR) is endemic to Maharashtra (in Amboli, Sindhudurg), which is an important pilgrimage and tourism destination with many temples, the species habitat of ephemeral ponds along the margins of streams is declining in quality due to increasing levels of garbage and tourist pollution.

Mining

Mining in and around freshwater systems leads to the loss of primary habitat of species. Mining has become a widespread threat in the Western Ghats, especially in central and southern Western Ghats. For example, *Fimbristylis hirsutifolia* (CR) is known only from a single location in the Malappuram District of Kerala where it is threatened by laterite mining in marshy areas. *Eriocaulon anshiense* (EN), a recently described species, is known from a few locations in Goa and Karnataka. In one of these locations, Suctoli (near Molem National Park, Goa) ongoing mining activities pose a potential threat to the population (S.A. Punekar. *pers. comm.* 2011). Similarly *Rotala cookii* (EN), which is known only from its type locality in Ernakulam and Malappuram districts of Kerala, is restricted to less than 25 km^2 and to isolated ponds in two severely fragmented locations. The cause of isolation, which is also degrading and reducing the area of suitable habitat, is land conversion for non-agricultural purposes and sand mining.


Unregulated tourism on the fragile habitat of Kas. © Aparna Watve

Grazing

Cattle grazing is a principal source of income generation for many people. However, it is becoming a threat for some aquatic plant species of the Western Ghats. Grazing affects natural forest ecosystems through the clearance of vegetation, the annual burning to encourage new grass growth, and overgrazing in general. For example *Eriocaulon tuberiferum* (VU) is endemic to a few locations in Maharashtra where it grows on the edges of seasonal pools on ferricretes at altitudes of 600-1,200 m. Cattle grazing are slowly impacting the species by causing soil compaction, increased nutrient loads in water, and trampling. *Isachne bicolor* (VU) endemic to Maharashtra, is found in less than eight fragmented locations, some of which are impacted by grazing.

6.4.2 Habitat loss

Plantations

The forests of the Western Ghats experience large-scale conversion into various plantations such as coffee, tea, rubber, teak, and black wattle. High altitude grasslands, face severe threat from black wattle plantations, which have also become invasive species in Kerala and Tamil Nadu (FAO 2003). *Anthoxanthum borii* (NT) found in marshy meadows and high altitude grasslands in Kerala and Tamil Nadu faces such a threat from black wattle and eucalyptus plantations. Many pteridophytes in the Kanyakumari region (southern Tamil Nadu) are under severe threat from plantations; for example, *Bolbitis appendiculata* (LC) is under severe threat in the southern Western Ghats due to conversion of forests to plantations (rubber in Kanyakumari District; tea in Upper Kodayar, Tirunelveli District). Since it is patchily distributed here, and is very sensitive to changes in habitat, requiring running water and shade at high altitudes, such activities may impact the species in the near future (V. Irudayaraj and S. Jeeva *pers. comm. 2010*). *Fimbristylis crystallinae* (EN) is currently known only from three isolated locations; one in Assam and two in Tamil Nadu. The Tamil Nadu population is threatened because of tea plantations (S. Karuppusamy *pers. comm.* 2010).

Construction and development including dams

Development of urban, industrial and agricultural areas lead to the direct loss of habitat, in addition to degradation (see above). Where wetlands are drained for urban development or dams replace riverine environments with reservoirs, species often lose large tracts of their habitat. For example *Isachne veldkampii* (CR) is endemic to one location, Manipal in Udupi District, Karnataka where it has been under severe threat from urbanization since its description in 1983. Unless immediate site protection is undertaken, the species could become extinct in the near future. Construction of dams in northern Kerala, namely Anakkayam and Sholayar, is threatening two locations of *Fimbristylis dauciformis* (EN). *Ischaemum jayachandrani* (CR), which has not been recorded for the past three decades is known from an area planned for high levels of development, in Kannur District of Kerala. It is at serious risk due to habitat conversion, urbanization and economic development. *Eriocaulon ratnagiricum* (CR) is a small annual growing on the edges of temporary pools on lateritic plateaus in Ratnagiri District, Maharashtra, which is under serious threat due to conversion of land for housing and industrialisation. Further surveys are urgently needed to determine its full distribution as this species might be present in other similar locations (A. Watve *pers. observ.* 2010).

6.5 Conservation recommendations

The assessment shows that 29 of the 608 species are Data Deficient. Some of these species, e.g. *Bonnayodes limnophiloides* a potentially extinct species requires urgent surveys to determine the current distribution and conservation status. There is no specific study undertaken to record or discuss the ecology of aquatic plants of the assessed region, compared to terrestrial flora. Habitat loss and degradation are considered to be the major threats to aquatic plants in the region. A check on this could be achieved only by fully applying existing legislation or by way of proper regulations in the tourism industry and by strengthening existing protection measures. Aquatic plants are highly valued for their nutritious and medicinal values, and are key species in the provision of wetland ecosystem services, such as water filtration and nutrient recycling. Greater awareness of

Eriocaulon tuberiferum in seasonal pools on ferricretes.
© Aparna Watve

High altitude pool in Nadugani. © Keystone Foundation

the importance of wetlands, their ecosystem services and their biodiversity needs to be built at all levels of the community who live in the region, and among visiting tourists, decision makers and other stakeholders. Existing scientific, policy and educational networks in different states involved in Western Ghats conservation should be strengthened by inviting new institutions and individuals and through capacity building.

Ex-situ conservation can be a valuable, if costly, conservation tool and should be considered for some threatened species, for example this method has been applied with relative success for *Hubbardia heptaneuron*.

Conservation actions needs to focus on the species identified here as threatened, particularly as only one of the threatened species is found outside of the Western Ghats assessment region. The level of knowledge about Western Ghats freshwater biodiversity, particularly aquatic plants is limited. The prevailing information gaps on species distribution, biology, population status, habitat status, threats, and impact of climate change on the freshwater plant species need to be filled and thoroughly understood. Priority should be given for further research on Data Deficient and threatened species.

6.6 References

Anon. 2011. *Tourism in forest areas of Western Ghats*. Equations, January 2001, Bangalore.

Bawa, K.S., Joseph, G., and Setty, S. 2007. Poverty, biodiversity and institutions in forest-agriculture ecotones in the Western Ghats and Eastern Himalaya ranges of India. *Agriculture, Ecosystems & Environment* 121(3): 287-295.

Cook, C.D.K. 1996. *Aquatic and Wetland Plants of India*. Oxyford University Press. New York.

Daniels, R.J.R. 2001. *National Biodiversity Strategy and Action Plan - Western Ghats Ecoregion*, submitted to the Ministry of Environment and Forests, Government of India, in 2001.

Das, A., Krishnaswamy, J., Bawa, K.S., Kiran, M.C., Srinivas, V., Kumar, N.S., and Karanth, K.U. 2006. Prioritisation of conservation areas in the Western Ghats, India. *Biological Conservation* 133(1): 16-31.

FAO. 2003. The unwelcome guests. *Proceedings of the Asia-Pacific forest invasive species conference*. Kunming, Yunnan Province, China, 17-23 August 2003.

Johnsingh, A.J.T. 2001. The Kalakad-Mundanthurai Tiger Reserve: A global heritage of biological diversity. *Current Science* 80(3): 378-388.

Keystone Foundation. 2006. *Wetlands Conservation and Sustainalble Management in the Nilgiris*-Keystone Foundation Kotagiri.

Mittermeier, R.A., Robles-Gil, P., Hoffmann, M., Pilgrim, J.D., Brooks, T.M., Mittermeier, C.G., Lamoreux, J.L., and Fonseca, G. 2005. *Hotspots Revisited: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions*. CEMEX, Mexico City.

Nair, S.C. 1991. *The Southern Western Ghats: A Biodiversity Conservation Plan*. INTACH, New Delhi.

Nayar, M.P. 1996. *Hotspots of Endemic Plants of India, Nepal and Bhutan*. Tropical Botanic Garden Research Institute, Palode, Trivandrum, India.

Ninan, K.N., Jyothis, S., Babu, P and Ramakrishnappa, V. 2007. The economics of Biodiversity Conservation, 11-12.

Pascal, J.P. 1988. *Wet Evergreen Forests of the Western Ghats of India*. Inst. fr. Pondichéry, trav. sec. sci. tech. Tome 20.

Pushpangadan, P. and Nair. K.N. 1997. Biodiversity and Panchayat level planning and development. *Proceedings of the 9th Kerala Science Congress*, Trivandrum.

Ramesh, B.R., Pascal, J.P. and De Franceschi, D. 1991. Distribution of endemic arborescent evergreen species in the Western Ghats, pp. 20-29. In: Kerala Forest Department (ed). *Proceeding of the Rare, Endangered and Endemic Plants of the Western Ghats*.

Rodgers, W.A. and Panwar, H.S. 1988. Planning a wildlife protected areas network in India. Vol 1 and 2. *Dept of Environment, Forests, and Wildlife/Wildlife Institute of India report*. Wildlife Institute of India.

Rodrigues, A.S.L. and Gaston, K.J. 2001. How large do reserve networks need to be? *Ecology Letters* 4: 602-609.

Singh, M.P., Singh, B.S and Dey, S. 2002. *Plant diversity and Taxonomy*. Daya Publishing House, New Delhi, pp. 108-121.

Watve, A. 2007. *Plant community studies on rock outcrops in Northern Western Ghats*. Report of the DST-Young Scientist fellowship, conducted and available at Agharkar Research Institute, Pune (Unpublished)

Cauvery River at Ranganathittu Bird Sanctuary. © Sanjay Molur

Stream vegetation on Chaliyar River. © Sanjay Molur