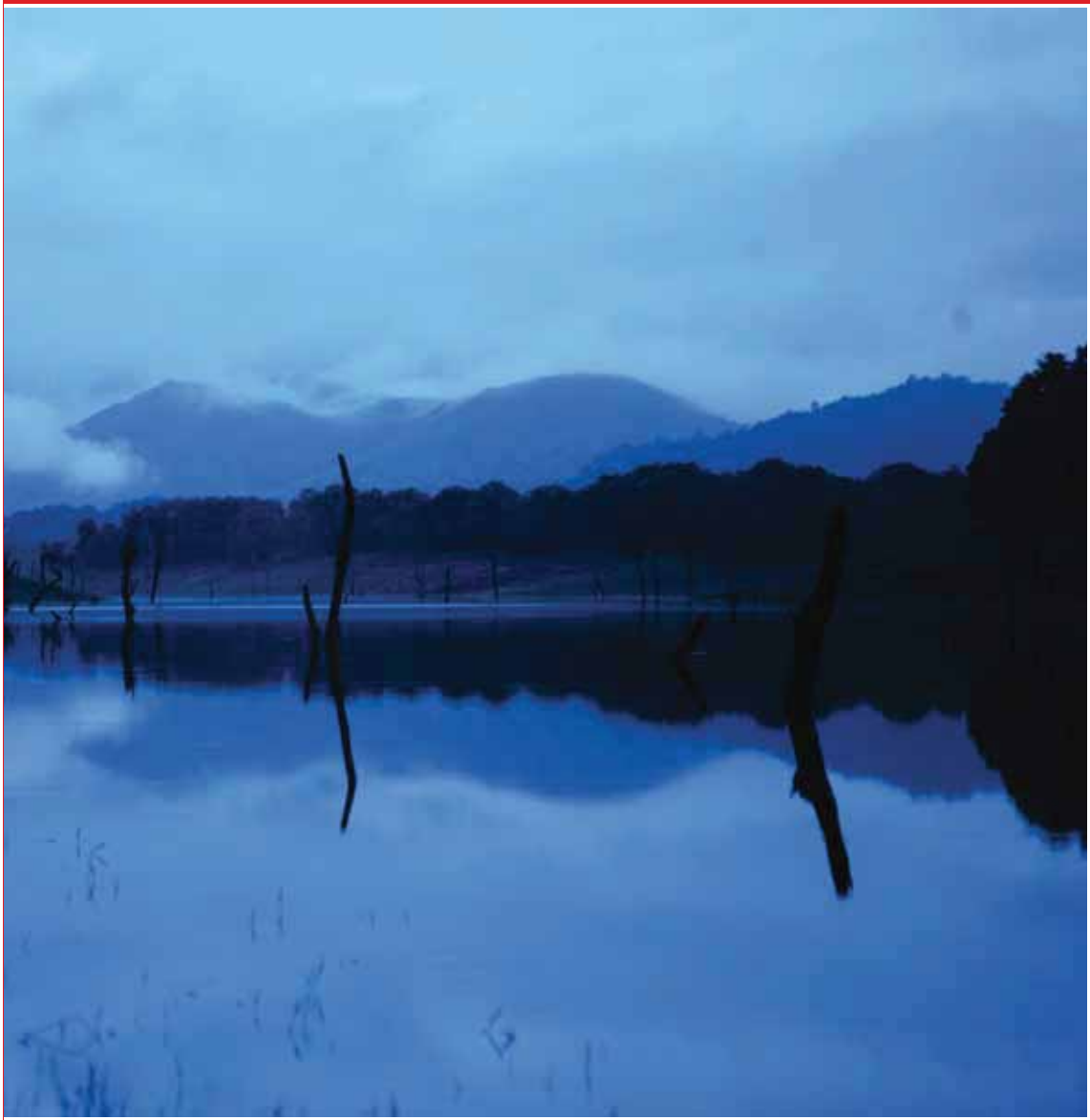
THE STATUS AND DISTRIBUTION OF FRESHWATER BIODIVERSITY IN THE WESTERN GHATS, INDIA

S. Molur, K.G. Smith, B.A. Daniel and W.R.T. Darwall (Compilers)



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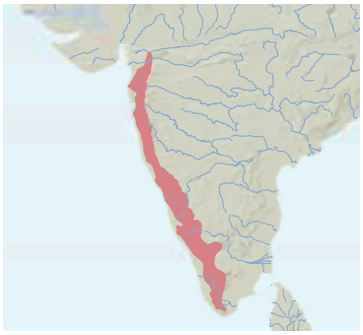

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Published by:	IUCN, Cambridge, UK and Gland, Switzerland.
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Red List logo:	© 2008
Citation:	Molur, S., Smith, K.G., Daniel, B.A. and Darwall, W.R.T. (Compilers). 2011. *The Status and Distribution of Freshwater Biodiversity in the Western Ghats, India*. Cambridge, UK and Gland, Switzerland: IUCN, and Coimbatore, India: Zoo Outreach Organisation.
ISBN:	978-2-8317-1381-6
Cover design:	Zoo Outreach Organization
Cover photo:	© Rateesh/CRG. A tranquil setting of Periyar Lake in the Periyar Tiger Reserve, Kerala
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Layout by:	Zoo Outreach Organization
Produced by:	Zoo Outreach Organization
Available from:	IUCN (International Union for Conservation of Nature), Publications Services, 28 Rue Mauverney, 1196 Gland, Switzerland
	Tel: + 41 22 999 0000, Fax: + 44 22 999 0020, Email: books@iucn.org, www.iucn.org/publications
	A catalogue of IUCN publications is also available.

The text of this book is printed on 130 gsm matt art paper

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Acknowledgements

All of IUCN's Red Listing projects rely on the willingness of scientists to contribute and pool their collective knowledge to make the most reliable estimates of species status. Without their enthusiastic commitment to species conservation, this kind of assessment project would not be possible. Those scientists are the authors of the various chapters in this report, and the assessors for the IUCN Red List species assessments completed through this project. They are: Dr. K. Anitha, Anvar Ali, Dr. Aparna Watve, Dr. N.A. Aravind, W. Arisdason, Brawin Kumar, Dr. Francy Kakkassery, Dr. Neelesh Dahanukar, Rajeev Raghavan, Robin Abraham, Dr. Shanmugam Mani, Shiny Rehel, C.P. Shaji, and Dr. K.A. Subramanian.

There are also a number of assessors and reviewers who assessed species through other related projects (e.g. Eastern Himalaya Freshwater Biodiversity Assessment), these people are acknowledged specifically within the reports for those projects and within the relevant Red List species assessments on the IUCN Red List website. Species distribution maps were digitized by some of the above assessors, the IUCN Freshwater Biodiversity Unit (FBU), Jemma Able, Andrew Ladle, Mita Drius and Felicity Watts.

We would like to offer our sincere thanks to the directors of the Zoological Survey of India and the Botanical Survey of India for making a number of staff available for the compilation and provision of data and for participation in the assessment workshops.

We would like to thank the members of the IUCN Species Survival Commission Specialist Groups who have provided advice and expertise throughout this project, in particular the Dragonfly Specialist Group, Mollusc Specialist Group and the Freshwater Fish Specialist Group.

The training workshop was kindly hosted in January 2010 by Zoo Outreach Organisation, with the invaluable assistance of all the staff at the Karunya University campus in Coimbatore. Red List, GIS and database training was provided by Rebecca Miller, Dr. Sanjay Molur (from ZOO), Emma Brooks, David Allen, Vineet Katariya, and Kevin Smith from the IUCN Global Species Programme. We would also like to thank the scientists, in addition to those who undertook assessment work, who attended this workshop: Dr. B.A. Daniel, G. Perera, Dr. N.M. Ishwar, Dr. Devika Weerakoon, Dr. A. Manimekalan, R. Marimuthu, Dr. Manju Siliwal, Dr. Prem Budha, Dr. Raghavendra Shivalingaiah, R. Wathsala, Dr. C. Srinivasulu and W. Rananjali.

The review workshop, was coordinated by project partners (Zoo Outreach Organisation) and held at Karunya University guest house, Coimbatore. It was facilitated by Dr. Sanjay Molur and Dr. B.A. Daniel from ZOO and by Emma Brooks, Diego Juffe and Neil Cox from the IUCN Global Species Programme. We thank all the participants of the first review workshop: Robin Kurian Abraham, Dr. Aniruddha Dey, Dr. K. Anitha, Dr. T.V. Anna Mercy, Anvar Ali, Dr. Aparna Watve, Dr. N.A. Aravind, W. Arisdason, Dr. M. Arunachalam, Chiranjibi Pattanaik, Dr. Francy K. Kakkassery, Dr. A. Gopalakrishnan, Dr. J.A. Johnson, K. Krishna Kumar, Dr. B. Madhusoodana Kurup, Dr. N.A. Madhyastha, Manoj Vasudevan Nair, Dr. D. Narasimhan, Dr. Neelesh Naresh Dahanukar, Rahul Kumar, Rajeev Raghavan, Rajendra G. Mavinkurve, Dr. K. Ravikumar, Dr. K. Rema Devi, Dr. V. Sampath Kumar, C.P. Shaji, Dr. Shanmugam Mani, Shiny Mariam Rehel, Dr. Shrikant Jadhav, Shrikanth Gunaga, Dr. K.A. Subramanian, Dr. M.K. Vasudeva Rao, Dr. R. Vasudeva and Vidyadhar Atkore. A second review workshop for the remaining plant species was held at the same venue. Dr. Neelesh Dahanukar, Rajeev Raghavan, Dr. B.A. Daniel and Dr. Sanjay Molur facilitated the workshop. We thank all the participants of the second review workshop: Dr. K. Anitha, Dr. A.E.D. Daniels, Dr. V. Balasubramaniam, Brawin Kumar, Dr. Gopala Krishna Bhat, Dr. V. Irudayaraj, Dr. Jomy Augustine, Dr. S. Karuppasamy, Dr. P. Lakshminarasimhan, Dr. C.N. Manju, Dr. K.P. Rajesh, Dr. L. Rasingam, Dr. B. Sadasivaiah, Dr. Shanmugam Mani, Shrikanth Gunaga, Dr. Soloman Jeeva and Dr. M.K. Vasudeva Rao.

We would like to thank the publishers for the excellent typesetting and proof reading that they provided. We are grateful to all the administrative staff of ZOO (Latha G. Ravikumar, B. Ravichandran, K. Geetha, S. Radhika, R. Pravin Kumar, G. Arul Jegadish, R. Marimuthu, K. Ravindran and S. Sarojamma) and IUCN (Maureen Martindell and Amy Burden) who worked tirelessly with all project reporting and financial issues. We thank Sally Walker, the Founder and Honourary Director of ZOO and Convenor of CBSG South Asia for introducing CBSG's assessment tools to India in 1993 and continuing to support.

Last, but not least, we would like to thank the Critical Ecosystem Partnership Fund (CEPF), who have provided the financial support for this project, and also the Ashoka Trust for Research in Ecology and the Environment (ATREE) who are the regional implementation team for CEPF in the Western Ghats. We would like to thank Jack Tordoff, Deborah Rainey, Malick Keita and Russell Frandsen at CEPF for all their advice and guidance; also Dr. Bhaskar Acharya and his colleagues at the CEPF regional implementation team for their support and guidance to the project. The Critical Ecosystem Partnership Fund is a joint initiative of l'Agence Française de Développement, Conservation International, the Global Environment Facility, the Government of Japan, the MacArthur Foundation and the World Bank. A fundamental goal is to ensure civil society is engaged in biodiversity conservation.

Executive Summary

The Western Ghats is one of the world's most heavily populated Biodiversity Hotspots providing for and supporting 400 million people through water for drinking, transport, irrigation, and hydroelectric power, together with food and resources to sustain livelihoods. However, the pace of growth of the Indian economy and rates of industrial and urban development are not in tune with the conservation needs of it's diverse freshwater ecosystems and the remarkably high diversity of species they contain. In most instances the development planning process does not consider the requirements of these freshwater ecosystems, mainly due to a lack of adequate information on the distribution and status of freshwater species and the threats they face. There is also little appreciation for the value of freshwater ecosystems to the livelihoods of many highly dependent people, often the poorest in society. In response to this need for information and for raised awareness, the IUCN Global Species Programme's Freshwater Biodiversity Unit, in collaboration with the Zoo Outreach Organisation (ZOO), conducted the *Western Ghats Freshwater Biodiversity Assessment* to review the global conservation status and distributions of 1,146 freshwater species belonging to four taxonomic groups: fishes (290 taxa), molluscs (77 taxa), odonates (171 taxa) and aquatic plants (608 taxa).

The methodology for this assessment is based on the collation and analysis of existing information, requiring experts to be trained in biodiversity assessment methods including application of the IUCN Red List Categories and Criteria, and species mapping using GIS software. Distribution ranges have been mapped to river sub-basin (the logical unit for management) for the majority of species. This provides an important tool for input to the conservation and development planning processes. The full dataset, including all species distribution files (GIS shapefiles), is freely available on the DVD accompanying this report and through the IUCN Red List of Threatened Species™ (www.iucnredlist.org). Additional freshwater groups that have, through other projects, also been comprehensively assessed in the region are amphibians, birds, mammals and crabs and results from these assessments are also available through the IUCN Red List.

Conservation measures are proposed to reduce the risk of future declines in species diversity and the associated ecosystem services that contribute to the livelihoods of millions of people across the Western Ghats region. The geographic scope of this assessment is determined by the extended hydrological boundaries of the Western Ghats region and includes all major river catchments with their origins within the Western Ghats Biodiversity Hotspot. The major river systems of the Tapi, Krishna, Cauvery and Godavari are included within this assessment. Freshwater species native to the Western Ghats states of Gujarat, Maharashtra, Goa, Karnataka, Kerala and Tamil Nadu are assessed, and the states of Andhra Pradesh and western and southern portions of Madhya Pradesh, Odisha and Chattisgarh are included as the drainages of the rivers originating in the Western Ghats flow through these states. Species introduced to the region prior to 1500 AD are assessed, whilst species introduced after that date are considered non-native to the region and are not assessed. IUCN Red List Criteria (IUCN 2001), the world's most widely accepted system for measuring relative extinction risk, were employed to assess the status of all species. Information on each species was compiled by a core team of experts, in collaboration with Specialist Groups of the IUCN Species Survival Commission and other relevant experts, who then conducted the assessment and its review. More than 40 experts from the Western Ghats region and beyond were involved in the process, either through direct participation in the two review workshops or through correspondence.

Key Outcomes

- The Western Ghats hotspot, originally designated for its high diversity and endemicity of plant species, is confirmed as a globally significant centre of diversity and endemism for freshwater species.
- The southern Western Ghats region with catchments including the Pamba, Meenachil, Muvattupuzha, Periyar, Karuvannur, Bharatapuzha, Chaliyar, Kuttyadi, and Valappattanam (Kerala), Netravati, upper Kabini and Cauvery (Karnataka), upper Vaipar, Amaravati, Bhavani and Moyar (Tamil Nadu) has the highest richness (260–312 species) and endemism (103–129 species) of freshwater species.
- Although many protected areas are located within or near areas of the richest freshwater diversity, the southern Western Ghats region also experiences the highest level of threat to freshwater species.
- The highest numbers of threatened species (40 and 48 species within each sub-catchment) occur within the southern Western Ghats Hotspot in Kerala, Tamil Nadu and southern Karnataka.
- Overall species richness and numbers of threatened species decrease along a northerly gradient through the Western Ghats Hotspot and eastwards towards Andhra Pradesh.
- Close to 16% of the 1,146 freshwater taxa assessed are threatened with extinction, with a further 1.9% assessed as Near Threatened. No taxa were assessed as Extinct or Extinct in the Wild. Approximately one-tenth of species were assessed as Data Deficient (10.5%), with the two invertebrate groups contributing more to data deficiency (25.8% on average).
- The main threats impacting freshwater biodiversity in the Western Ghats include: a) **pollution**, with approximately 50% of fish, 20% of molluscs, and 21% of odonates threatened, and with urban and domestic pollution ranking as the worst threats followed by agricultural and industrial sources of pollution; b) **biological resource use** with 38% of fishes, 17% of molluscs, and 7% of odonates threatened by commercial fisheries and the aquarium trade;

c) **residential and commercial development** with 14% of fishes, 11% odonates and aquatic plants, and 8% of molluscs threatened; d) **dams and other natural system modifications**, with 13% of fishes, 8% of molluscs, 4% of odonates and 3% of plants impacted; e) **alien invasive species** which, as understood currently, impact 22% of fishes; f) **agriculture and aquaculture** which impact 7% of odonates and 4% of plants; and g) **energy production and mining** which impact 6% of fishes, 5% of molluscs and 4% of plants overall.

- The northern Western Ghats region within Maharashtra has a lower documented freshwater diversity than the southern region. Although this trend supports the expected relationship between species richness and rainfall, the lower diversity is probably due to inadequate surveys in the freshwater ecosystems of the west flowing rivers of the northern Western Ghats.
- Catchments that qualify as potential **Key Biodiversity Areas** (KBAs) lie primarily in the southern Western Ghats. KBAs triggered by the highest numbers of fish, odonate and mollusc species include the Pamba, Manimala, Periyar, Bharatapuzha and Chaliyar rivers in the southern Western Ghats.
- Aquatic plants and fishes are the most heavily utilized freshwater groups in the Western Ghats. Twenty-eight percent of aquatic plants are harvested for medicinal purposes, and 14% and 13%, as food for people and animals, respectively. More than half (56%) of fish species are harvested for human consumption, and a growing percentage (37%) of species are captured for the aquarium trade. Eighteen percent of mollusc species are used as food for humans.

Recommendations / Conclusions

- **Taxonomic studies, survey and monitoring**: Freshwater fauna and flora of the Western Ghats are, in general, poorly studied. Population ecology, life history traits and monitoring of most freshwater species lack proper study and documentation. Of the 1,146 species assessed in this project 120 are Data Deficient. Many of these species are likely to be threatened as they are only known from historical records. A thorough taxonomic review and monitoring of all freshwater groups in the Western Ghats is recommended. Particular attention is needed to improve our knowledge of subterranean species.
- **Habitat restoration**: Many endemic species of odonates, molluscs and fishes are narrowly distributed within the Western Ghats. For these species, destruction or alteration of a small catchment may lead to their extinction. Actions required include: a) protection of key habitats such as fast flowing streams and rivers; b) where possible, prevention of flow modifications; c) conservation of specialized ecosystems such as Myristica swamps, high altitude peat bogs, and lateritic plateaus; d) prevention of pesticide and other agrochemical use in upper catchments, and; e) regulation of tourism in critical habitats.
- **Pollution control**: A combination of strategies to combat pollution must be implemented immediately, including: improved enforcement of pollution laws; best management practices for crop and livestock production; effective effluent treatment for the industries located within river basins; promotion of organic cultivation, and better solid waste disposal protocols.
- **Invasive alien species management**: Research into the spread and impact of invasive fish and plant species in the Western Ghats is a priority. Collaboration with industry is essential for educating buyers, sellers, and the public, certifying stock, and preventing the releases into the wild of aquarium and aquaculture species. There is a need to develop and implement a national policy on the introduction and management of exotic species.
- **Environmental impact assessment of development activities**: Dam and road construction, urban and industrial expansion and other development activities should be independently evaluated for impacts, and in case of adverse impacts, mitigation measures must be implemented.
- **Awareness and education outreach**: Awareness programmes promoting better understanding of the values, sustainable use, and management of wetlands and rivers are crucial to eliminating public perception of wetlands as wastelands. Local communities must participate in the conservation of freshwater species and their habitats. Effective educational programmes, with special focus on children, should be implemented. Given the rapid rate of development across the region, politicians, legislators and other relevant stakeholders must be given access to key biodiversity information for freshwater ecosystems and this should be integrated within decision-making and planning processes.
- **Legislation and enforcement**: Legislation to protect species and habitats exists across the region, but implementation and enforcement need to be more effective. Strict laws must be developed and implemented to curb tree felling and deforestation, supported by social forestry and afforestation programmes. Construction of large dams should be avoided where unacceptable impacts to freshwater species and the services provided are predicted. Mining and quarrying should be regulated with strict laws. Threatened and endemic species of freshwater fish of biological and socio-economic importance should be included within the Indian Wildlife (Protection) Act. Policies should also be developed for conservation of lesser-known invertebrate groups such as molluscs, dragonflies, damselflies and crustaceans.
- **Key Biodiversity Areas:** Workshops involving local and regional stakeholders should be carried out to identify and prioritise a set of Freshwater Key Biodiversity Areas based on the potential KBAs identified in the current study. Management plans for these areas can then be implemented to benefit both the many dependant people and the rich biodiversity that these areas support.

Chapter 1. Background

Sanjay Molur[1], David Allen[2] and Kevin Smith[2]

The Western Ghats biogeographic region in southern India runs along the west coast extending from $08^0$19'08"–$21^0$16'24"N to $72^0$56'24"–$78^0$19'40"E with a north to south distance of 1,490 km, a minimum width of 48 km and maximum width of 210 km, covering a total area of 136,800 km^2 (CEPF 2007). The Western Ghats mountain range traverses the states of Gujarat, Maharashtra, Goa, Karnataka, Kerala and Tamil Nadu interrupted only once by a 30-km break called the Palghat Gap in northern Kerala (Figure 1.1).

Broadly, the freshwater rivers and streams in the Western Ghats fall under five main categories or ecoregions, viz., Narmada-Tapi, the Northern Deccan Plateau (Godavari River system), the Southern Deccan Plateau (Krishna River system), the Southern Eastern Ghats (Cauvery River system) and the Western Ghats (west flowing rivers) (Abell *et al.* 2008) (Figure 1.2). The freshwater ecosystem and all its denizens together constitute the rich biodiversity of one the world's 34 hotspots (Myers *et al.* 2000).

The Western Ghats is home to some of the world's most unique fauna, flora and fungi. Compared to the other hotspots, it has the highest human population per unit area (more than 300 humans/km^2), making it that much more challenging to conserve (Molur 2009). The Western Ghats have also lost nearly 50% of forest cover since the early 1900s and the trend is continuing with increased fragmentation and encroachments. Additional threats include hunting in many parts, which has extirpated local populations of several species and groups of terrestrial and freshwater fauna.

The freshwater ecosystem biodiversity within the Western Ghats region is highly diverse, unique and of immense importance to livelihoods and economies. However, in a rapidly increasing economy such as India, development activities are not always compatible with the conservation of this unique diversity with the ecosystem requirements of biodiversity frequently ignored. A major drawback is the absence of a baseline data set on the distribution of biodiversity and its conservation status for planners. The aim of this report is to present the outcomes of the *Western Ghats Freshwater Biodiversity Assessment* project that was developed with the intention of compiling and making freely available information on the conservation status and distribution of key groups of freshwater biodiversity to inform conservation and development policy and decision making across the region.

Freshwater ecosystems are among the mostly heavily used, depended upon and exploited by humans for sustainability and well-being. The dependence on water and other resources in this environment has placed enormous pressures on the ecosystem worldwide resulting in direct impacts to species diversity and populations. While ecosystem assessments are broad based, the actual impacts of change can be best understood from the status of species in those ecosystems. The relationship between biodiversity and human well-being is being promoted increasingly through the concept of ecosystem services provided by species (MEA 2005, McNeely and Mainka 2009). Using species assessments as a tool is one way of understanding the threats to biodiversity, ecosystems and specifically the impacts of changing ecosystems on human well being. In doing so, compiling information on available knowledge on the role of individual species in the heavily exploited freshwater ecosystem will provide tangible benefits in protecting biodiversity and habitats.

Although the 2010 targets of the CBD were not fully met, the premise of the targets remains fundamentally solid. At the 2010 Nagoya 10th Conference of Parties, the targets were reiterated with more emphasis on achieving them over the next ten years. The expansion of freshwater species assessments across the globe will contribute to a foundation of scientific understanding of the current status as well as the priority areas for action.

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Pool riffle with riparian cover in Bhavani River. © Rajeev Raghavan

Figure 1.1 Map showing the location of the Western Ghats and its key features.

1.1 Value of freshwater biodiversity

While covering less than 1% of the Earth's surface freshwater ecosystems provide humans with a wealth of goods and services, and provide a home for around 10% of the world's described species, including a quarter of all vertebrates (Strayer and Dudgeon 2010). Their value to human society is easily seen through the direct services they provide, such as fish for food or water purification for drinking, but they also provide many indirect services—universal benefits—nutrient cycling, flood control and water filtration. Putting a dollar value on these services is extremely difficult, as many have no market value. However, attempts have been made to estimate the annual value of the direct and indirect services of the world's wetlands, with differing results. For example, the Millennium Ecosystem Assessment (MEA 2005) values the total goods and services derived from inland waters globally at up to USD 15 trillion, whilst another study estimates a value of USD 70 billion (Schuyt and Brander 2004). Tropical inland fisheries alone have been valued at USD 5.58 billion per year (Neiland and Bene 2008).

Asia has the largest fisheries production of all the worlds' continents and many livelihoods are dependant upon freshwater biodiversity, which provides food security to the poorest of communities. In India 5.5 million people are employed in inland fisheries, 72% of them women (Dugan *et al.* 2010).

1.2 Global status of freshwater biodiversity

1.2.1 Species diversity

Freshwater biodiversity constitutes a vitally important component of the planet, with a species richness that is relatively higher than that in terrestrial and marine ecosystems (Gleick 1996). Freshwater ecosystems support various orders of animals, plants and fungi, contributing a quarter of vertebrate diversity and almost as much of the invertebrate diversity that has been described to date. The order Odonata, a group largely dependent upon freshwater ecosystems, includes 6,500 described species (Trueman and Rowe 2009), and the phylum Mollusca with eight extant classes is composed of nearly 93,000 species, 70,000 of which are gastropods (Haszprunar 2001). Although comparatively better studied than the marine ecosystem, the rapidly increasing number of described species of freshwater fishes contributes nearly 50% of all the fish presently described (Froese and Pauly 2010). Aquatic macrophytes defined as including aquatic angiosperms (flowering plants), pteridophytes (ferns) and bryophytes (mosses, hornworts, and liverworts) are found growing in or very near surface waters. The number of species of aquatic plants globally varies depending upon the definition of 'aquatic', with estimates ranging from 2,000 to 6,000 (Cook 1996, Chambers *et al.* 2008).

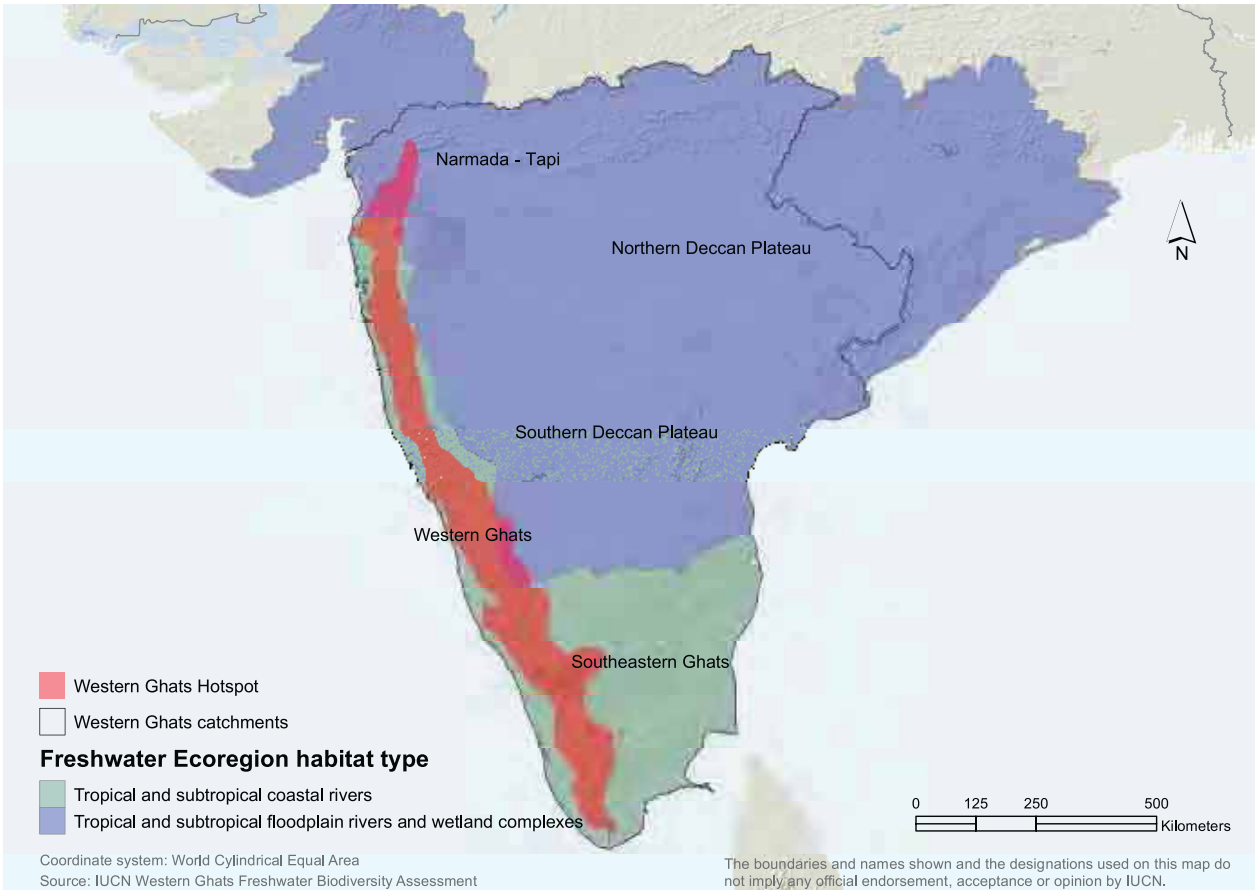

Figure 1.2 Freshwater ecoregions of the peninsular India (taken from Abell *et al.* 2008).

The Western Ghats is part of the Western Ghats–Sri Lanka Biodiversity Hotspot (Figure 1.2). To qualify as a hotspot, a region must meet two criteria: the area needs to contain at least 1,500 species of endemic vascular plants and to have lost at least 70% of its original habitat (Myers *et al.* 2000). Although the hotspot definition is focused on terrestrial features, it still highlights the importance of the area for freshwater species conservation due to the massive levels of habitat loss which will severely impact freshwater systems and the likely congruence between plant and vertebrate endemism within hotspots (Myers *et al.* 2000). Although the Western Ghats covers only 6% of the total land area of India, it contains more than 30% of the species of all major plant and animal groups found in India (CEPF 2007). The Western Ghats is very rich in faunal, floral and fungal diversity, with more than 5,000 species of angiosperms, 140 species of mammals, 508 species of birds, 140 species of amphibians (and increasing rapidly), 240 species of reptiles, and 290 species of freshwater fishes (Nameer *et al.* 2001, Kumar *et al.* 2002, CEPF 2007). In the Western Ghats, endemicity is the highest in amphibians (78%), followed by reptiles (62%), fish (53%), plants (34%), mammals (12%) and birds (4%) (Nameer *et al.* 2001, Kumar *et al.* 2002, CEPF 2007, Molur 2008).

The Critical Ecosystem Partnership Fund (CEPF) has developed a set of conservation outcomes for the Western Ghats region. Conservation outcomes are the full set of quantitative and justifiable conservation targets in a hotspot that should be achieved to prevent biodiversity loss: (i) species (extinctions avoided); (ii) sites (areas protected); and (iii) landscapes (corridors created) (see CEPF 2007). The principal resource for defining species outcomes was the *2005 IUCN Red List of Threatened Species*, which is based on quantitative, globally applicable criteria under which the probability of extinction is estimated for each species. To date, the conservation outcomes (in terms of (ii) and (iii) above) are primarily focused on terrestrial species, since the 2005 IUCN Red List contained few assessments of freshwater species from within the region. This assessment will contribute to the process of addressing priority species and sites for the conservation of freshwater species within the Western Ghats region.

1.2.2 Major threats to freshwater biodiversity

Major threats to freshwater biodiversity can be grouped under five interacting categories: over-exploitation; water pollution; flow modification; destruction or degradation of habitat; and invasion by exotic species, with global scale environmental changes superimposed upon them all (Dudgeon *et al.* 2006). These globally escalating threats have led to freshwater biodiversity falling into a state of crisis (Vorosmarty *et al.* 2010) and becoming more imperilled than its marine or terrestrial counterparts (Strayer and Dudgeon 2010).

In South Asia, population growth and its related development has led to heavily degraded water quality (Babel and Wahid 2008)

with threats such as deforestation leading to sedimentation, poor waste water treatment, agricultural and industrial expansion and pollution, huge levels of water abstraction, and construction of dams leading to altered flow regimes and saltwater intrusion. Overharvesting, of both target species and as by-catch, has also led to population declines of many freshwater species.

1.2.3 Species threatened status

In keeping with the principles of the Convention on Biological Diversity, assessing the status of species, which is one of the widely used indicators for the status of biodiversity, provides the means to monitor biodiversity trends and losses, and helps in setting priorities for species conservation. There are several methods of determining species status and the most commonly used tool is the IUCN Red List Categories and Criteria (IUCN 2001), which allows consistency in approach across different taxonomic groups. It helps in determining the relative risk of extinction and provides the basis for understanding if a species is Extinct, threatened (Critically Endangered, Endangered or Vulnerable), Near Threatened, Least Concern, or lacking sufficient basic data for assessment (Data Deficient). The IUCN Red List of Threatened Species™ publishes the results of the global assessments for each species (www.iucnredlist.org). The IUCN Red List also provides basic information on species taxonomy, distributions, habitat and ecology, threats, population trends, use and trade, livelihood values, ecosystem services provided, and research and conservation priorities.

The representation of freshwater species assessed and published in the IUCN Red List remains low relative to other ecosystems although efforts, such as this one, are improving the knowledge base. Globally, of the freshwater species groups only crabs, crayfish, waterbirds, amphibians, and freshwater mammals (e.g. otters, river dolphins) have been fully assessed; nearly one-third of amphibians have been assessed as threatened with extinction. In addition, freshwater species from some regions (e.g. Eastern Himalaya, Mediterranean, Africa) have been assessed (Darwall *et al.* 2005, Darwall *et al.* 2009, Smith and Darwall 2006, IUCN 2004, Kottelat and Freyhof 2007, Allen *et al.* 2010), but many regions of the world are yet to be comprehensively assessed. Fifty-six percent of the endemic fishes of the Mediterranean basin, 54% of endemic fishes of Madagascar, 38% of all European fishes, and 13.5% of endemic Eastern Himalayan fishes have been assessed as threatened (Smith and Darwall 2006, IUCN 2004, Kottelat and Freyhof 2007, Allen *et al.* 2010). This emerging level of threat is relatively high when compared to globally comprehensive assessments of amphibians (32%), mammals (23%) and birds (12%).

Women in paddy vyal (swamp) in Gudalur. © Keystone Foundation

Freshwater fish as a source of livelihood. Photographed at Krishna River at Wai. © Mandar Paingankar

1.3 Situation analysis for the Western Ghats region

This assessment is primarily focused on the Western GhatsBiodiversity Hotspot (see Figure 1.2), however due to the high level of connectivity within freshwater systems, with the rapid and easy movement of threats and species, it is sensible to broaden the assessment to include all those catchments that originate within the Hotspot, and therefore the entire Krishna, Godavari, Cauvery and Pennar basins are included with the area assessed through this project.

Subramanian (2010) divides the Western Ghats into eight riverine regions, namely, the Dhule-Tapi, Nashik-Mumbai-Pune, Koyna Valley-Sawanthawadi, Aghanashini Valley-Terekhol Valley, Sharavathy Valley-Pushpagiri, Kodagu-Wyanad-Nilgiri, Anamalai-Periyar and Agasthyamalai. The Dhule-Tapi region has five major streams and two protected areas; Nashik-Mumbai-Pune region has five major streams and six protected areas; Koyna Valley-Sawanthawadi has five rivers and three protected areas; Aghanashini Valley-Terekhol Valley has six streams and seven protected areas; Sharavathy Valley-Pushpagiri has seven major rivers and protected areas; Kodagu-Wyanad-Nilgiri has four major rivers and 10 protected areas; Periyar-Anamalai has seven major rivers and 12 protected areas; and Agasthyamalai has five major rivers and four protected areas.

As the rivers flow eastwards, the number of protected areas decrease in numbers, with most of the protected areas within the Western Ghats region established for conservation of forestry produce, some water harvest areas, and occasionally for terrestrial plants and mammals. There are no protected areas created exclusively for freshwater biodiversity conservation without a utilitarian value such as a dam and reservoir for drinking water supply or irrigation or power generation. The Western Ghats directly supplies approximately 120 million people with drinking water, irrigation and hydro-powered electricity, while the extended part of the assessment region spreading across peninsular India supports approximately 400 million people in seven states (Census 2011). The rivers of the Western Ghats provide drinking water, power, transport, livelihoods, food, and jobs for all living in peninsular India, with the Krishna, Godavari and Cauvery river systems sustaining one of the world's heaviest population densities.

The largest rivers in the Western Ghats region are the Godavari (1,500 km long, 340,000 km^2 catchment area), Krishna (1,300 km, 260,000 km^2) and Cauvery (750 km, 72,000 km^2) in that order. The Godavari River flows through the states of Maharashtra and Andhra Pradesh supporting extensive cultivation in both the states. The Krishna River arises in Maharashtra and along its journey several other major rivers originating in the Western Ghats, namely, Bhima, Koyna, Tunga, Bhadra, Ghattaprabha and Mallaprabha join it before

it flows into the Bay of Bengal. It covers the three states of Maharashtra, Karnataka and Andhra Pradesh, providing irrigation to nearly 10% of the croplands in India. The Cauvery River arising in Kodagu District of Karnataka State flows through Tamil Nadu before joining the Bay of Bengal. The only westerly flowing river, the river Tapi, which forms the northern limit of the Western Ghats, originates in the Satpura range in Madhya Pradesh and flows into the Arabian sea. It has a total length of about 725 km covering an area of approximately 65,000 km^2. Many other rivers not mentioned here play an equally important role in supporting people's livelihoods.

The Western Ghats also supports some unique freshwater biomes that provide homes to an extensive array of wildlife, including plants. Some such areas include the Myristica swamps in Kerala and Karnataka, the laterite rock pool habitats in Maharashtra, Karnataka and Kerala, and the peat bogs in Karnataka. These highly restricted, fragmented and unique systems support species of plants and amphibians that are endemic to those habitats.

1.3.1 Regional threats

As elsewhere in the country, the economic boom and a rapidly increasing human population have become the major drivers of threats to the freshwater ecosystems that include rivers, lakes, freshwater marshes, and the typical Western Ghats habitats of Myristica swamps, peat bogs and lateritic rock pools. Expanding human needs, development, increasing demand for resources, space and water have caused and continue to cause massive losses of habitats, biodiversity, water resources, clean environment, and potable water. Recent census figures (Census 2011) indicate an average annual growth rate of 2.5% in the Western Ghats region and the population is expected to increase by more than 50% in the next 40 years to about 600 million people. Cincotta *et al.* (2000) indicate a staggering 350 individuals per square kilometer in the Western Ghats hotspot, the highest density of humans within any of the global biodiversity hotspots. This high population density and growth will continue to create a huge demand on the freshwater ecosystems of the Western Ghats and will increase deforestation, damming and water abstraction, mining and quarrying, pollution, over harvesting, and exotic alien species.

Deforestation: Forest loss in the Western Ghats has been so rapid that out of the original 182,500 km^2 of primary vegetation only 12,450 km^2 (i.e. 6.8%) remains (Myers *et al.* 2000, Nihara *et al.* 2007). The Western Ghats have been under the influence of forestry activities for close to two centuries with most of the areas clear felled or logged at least once during that time. Currently, most remaining forests in the Western Ghats are in protected areas or reserve forests, managed by the forest departments, and a few patches of forests that are managed by local communities. Stream vegetation and riparian forests have also been subjected to similar threats with direct impacts to biodiversity and in increased sediment loads, erosion, flash floods, loss of niche habitats such as stagnant pools, inconsistent flow, and disappearance of primary and secondary streams. Soil erosion from rains has been calculated

Bison swamps at Upper Bhavani, Nilgiris. © Keystone Foundation

Ephemeral flush vegetation on seasonally wet rock outcrops in Maharashtra. © Aparna Watve

Torme swamp of Siddapur Taluk, Uttara Kannada District, Karnataka with *Semecarpus kathalekanensis*, a tree endemic to Myristica swamp. © Shrikanth Gunaga

Damming and waste disposal, Marapalam, Coonoor © P. Mohana

as 40 tonnes for 2 acres (0.81 ha) of deforested land compared to 0.3–1 tonnes from forested land (Rai and Proctor 1986) indicating a huge added sediment load to rivers downstream from large areas of deforestation.

The remaining extent of natural habitat has been reduced significantly, leaving only small fragments of wilderness, especially of evergreen forests that are often no larger than a few square kilometers (Daniels 1992). Changes to the Western Ghats have taken place ever since the first people settled there; however, major changes have taken place since the 1800s with the establishment of tea and coffee plantations and open land cultivation. Gadgil and Meher-Homji (1986) estimated a 65-91% decline in evergreen forest habitats of the Western Ghats since the early 1900s. Ramesh (2001) estimated a decline of 12% in the primary forests of the Western Ghats in the state of Karnataka. Forty percent of primary forest has been converted to agriculture or plantation between 1920 and 1990 (Menon and Bawa 1997). Open cultivation and conversion to plantations of tea, coffee, eucalyptus, wattle and teak, with additional losses due to expansion of road network, expansion of human settlements, and construction of reservoirs have been the principal causes for forest loss. It is estimated that between 1973 and 1995, 25% of the original forest cover was lost in the southern Western Ghats (Jha *et al.* 2000).

Dams: Dams give rise to a range of upstream and downstream impact such as: disruption of fish migration routes and breeding patterns, changes to flow regimes, increased sedimentation within reservoirs, and indirect impacts associated with development near to new reservoirs (Nilsson *et al.* 2005) and increased human settlement (Smakhtin and Anputhas 2006). Check dams (small, temporary or permanent dams on minor channels) and minor dams have been a traditional practice in the region, most often on a temporary basis to help reduce interruptions to water supply during the dry summer months. However, in the last 110 years, large dams have been constructed with permanent alteration to landscapes and flow regimes.

Subramanian (2010) reports a total of 871 dams constructed by 2000 with a total surface area of the reservoirs of 3,169 km^2. There are 13 mega dams with a surface area of more than 50 km^2 and 34 large dams with a surface area of 16–50 km^2. Satellite imagery also indicates the Godavari and Krishna rivers are most heavily dammed followed by the Cauvery River.

Mining: In the last two decades mining in the Western Ghats has become a very important source of raw materials such as iron ore and bauxite. To meet the growing demands for urbanization, housing and infrastructure there has also been an increase in quarrying in the region for granite, limestone and other types of stone. Riverine habitats are under severe threat from sand mining to feed the increasing demands. While some mines have been closed due to severe impacts on the environment, for example, the iron ore mine in Kudremukh that was closed due to its severe impact to the riverine ecosystem in the region, states such as Goa have new mines being established to meet the demands for bauxite. New quarries are being developed throughout southern India to supply the demand for granite. Mining poses a major

immediate problem to the upper catchments of rivers in the region, with negative impacts on the water quality and biodiversity downstream (Subramanian 2010), however, the long-term impacts remain largely unknown.

Other threats to freshwater ecosystems include pollution from industry, agriculture and urbanization; overharvesting of resources such as fisheries; destructive fishing practices such as dynamiting and poisoning; introduction of exotic aliens such as commercial fishes, biological control agents and food resources; an expanding tourism industry within biodiversity rich and sensitive areas; a lack of baseline data on species distributions and ecological requirements, and a lack of political will to conserve biodiversity (Molur 2009).

1.3.2 Regional use and value of wetlands and their biodiversity

Rivers and wetlands are a key component of the hydrological cycle that maintains freshwater supplies and are a vital source of water and food supply for people. Many communities are directly dependent upon the resources that wetlands provide in the Western Ghats region. However, the sustainable practices of the past are rapidly disappearing due to the explosive growth in human populations and the associated overexploitation of natural resources. All species, irrespective of their economic value or distribution, play an important role in supporting ecosystems.

1.4 The precautionary approach to species conservation

In many cases where the economic value of a freshwater system and its associated biodiversity has been determined as high, it often remains a difficult task to justify the need to conserve all species. This is particularly true where the diversity is already exceptionally high, such as in the freshwater fish communities of some catchments within the Western Ghats. In such cases fishery managers may argue that it would be easier to manage a fishery of just a few fast-growing and commercially valuable species than to manage the multi-species fisheries typical of these catchments. However, we know too little about species-ecosystem interactions to reliably predict the impacts of removing either single species or groups of species from a system. The message given here is to adopt the precautionary approach where it is assumed that all species are important to ecosystem functions and may one day be key components of fisheries or their supporting food webs.

1.5 Objectives of this study

A lack of basic information on freshwater species distributions and threatened status in the Western Ghats region has long been an issue for freshwater ecosystem managers in the region. In response to this information shortfall, the *Western Ghats Freshwater Biodiversity Assessment* project, coordinated by

Houseboats for tourism in Vembanad Lake. © N.A. Aravind

IUCN with Zoo Outreach Organisation aimed to:

(i) establish a core of regional experts trained in the use of biodiversity assessment tools;

(ii) collate all existing information as required to assess the conservation status and distributions of freshwater species throughout the inland waters of the Western Ghats region; and

(iii) store, manage, analyse and make widely available that biodiversity information within the IUCN Red List and throughout the region and beyond.

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Alien carp such as *Cirrhinus mrigala* and *Cyprinus carpio* create resource competition for native species. Pictured here are fish collected from Dhom Reservoir for sale in the market of Wai. © Mandar Paingankar

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A tributary of Chalakkudy River at Parambikulam. © Payal Molur

Chapter 2. Assessment methodology

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2.1 Selection of priority taxa

In the majority of cases, large-scale biodiversity assessments have focused on a limited range of taxonomic groups, most often including those groups that provide obvious benefits to humans through direct consumption, or the more charismatic groups, such as mammals and birds. In the case of aquatic systems, it is wetland birds and fishes that have received most attention. It is, however, important that we take a more holistic approach by collating information to conserve those other components of the food web essential to the maintenance of healthy functioning wetland ecosystems, even if they are neither charismatic nor often noticed. Clearly, it is not practical to assess all species. Therefore, a number of priority taxonomic groups were selected to represent a range of trophic levels within the food webs that underlie and support wetland ecosystems. Priority groups were selected to include those taxa for which there was thought to be a reasonable level of pre-existing information. The taxonomic groups selected were fishes, molluscs, odonates (dragonflies and damselflies), and aquatic plants.

Although fish and plants provide clear benefits to the livelihoods of many people throughout the region, either as a source of income or as a valuable food supply, benefits provided by the other taxa may be indirect and poorly appreciated but nonetheless important. Given the wide range of trophic levels and ecological roles encompassed within these four taxonomic groups, information on their distributions and conservation status, when combined, will provide a useful indication of the overall status of the associated wetland ecosystems.

2.1.1 Fishes

Arguably, fishes form the most important wetland product at a global scale, and are often referred to as a "rich food for poor people" (WorldFish 2005). They provide the primary source of protein for nearly one billion people worldwide (FAO 2010) and food security and employment for many more (Coates 1995, Dugan *et al.* 2010). Asia accounts for 66.4% of global inland catches, and with over 950,000 tonnes landed in 2008, India has the third largest inland fishery in the world (FAO 2010). Fish supplies essential nutrition for the poorest communities, and accounts for 30% of protein in typical diets across Asia (WorldFish 2005). The fishing industry also provides employment and income for many people.

For the purposes of this assessment, freshwater fishes are defined as those species that spend all or a critical part of their life cycle in fresh waters. Those species entirely confined to brackish waters are also assessed. There are almost 13,000 freshwater fish species in the world, or about 15,000 species if brackish water and anadromous species are included (Lévêque *et al.* 2008). Prior to the start of this project in 2009, the risk of global extinction had only been assessed for 6% (53 species) of freshwater fish species of India as posted on the IUCN Red List of Threatened Species.

2.1.2 Molluscs

Freshwater molluscs are one of the most diverse and threatened groups of animals (Vaughan *et al.* 2004, Lydeard *et al.* 2005). They are mostly unobtrusive, and are not normally considered charismatic creatures, rarely attracting the attention of the popular media, unless in a negative light, as some species play a significant role (as a vector) in the transmission of human and livestock parasites and diseases. This is unfortunate, as they also play a key role in the provision of ecosystem services and are essential to the maintenance of wetlands, primarily due to their contribution to water quality and nutrient cycling through filter-feeding, algal-grazing and as a food source to other animals (see Strayer *et al.* 1999, Vaughan *et al.* 2004,

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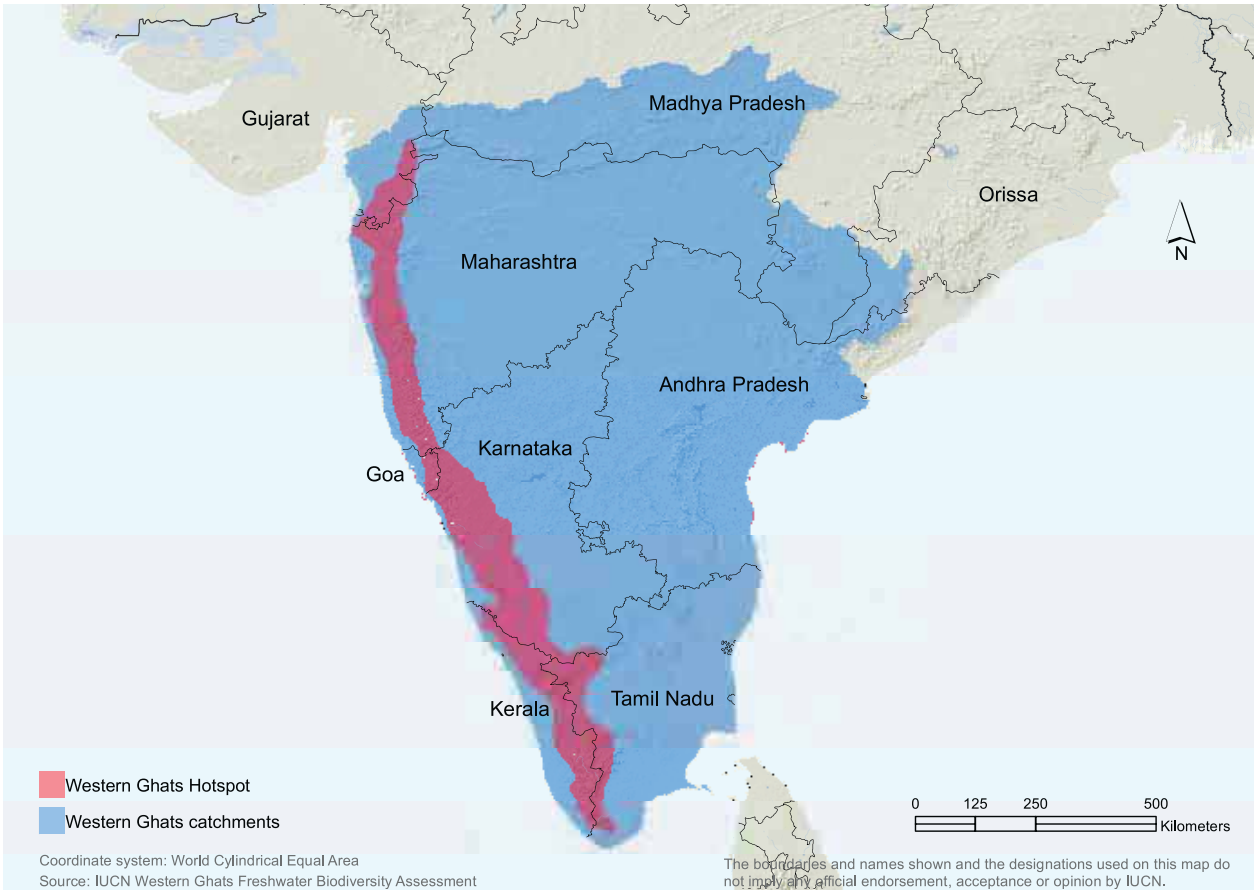

Figure 2.1. Map showing the Western Ghats Hotspot and the wider catchment areas that delineate the project region.

Howard and Cuffey 2006, Vaughan *et al.* 2008). Some species are of high commercial value as food or ornaments (e.g., clams and some mussels and snails). There are just under 5,000 freshwater mollusc species (Bogan 2008, Strong *et al.* 2008) for which valid descriptions exist, in addition to a possible 4,000 undescribed gastropod species (Strong *et al.* 2008). Of these, only one species from India had had its conservation status assessed before this assessment project began in 2009.

2.1.3 Odonates

Larvae of almost all species of dragonflies and damselflies (order Odonata) are dependent on freshwater habitats. The habitat selection of adult dragonflies strongly depends on the terrestrial vegetation type, but their larvae develop in water where they play a critical role with regards to water quality, nutrient cycling, and aquatic habitat structure. The larvae are voracious predators, often regarded as important in the control of insect pest species. A full array of ecological niches are represented within the group and, as they are susceptible to changes in water flow, turbidity or loss of aquatic vegetation (Trueman and Rowe 2009), they have been widely used as an indicator of wetland quality. There are 5,680 extant described species. However, even though the group is well studied, it is believed that the actual number is close to 7,000 species (Kalkman *et al.* 2008). Of these, 119 species of odonates present in India had had their risk of extinction assessed using the IUCN Red List Global Categories and Criteria by the time this project started.

2.1.4 Aquatic plants

Aquatic plants are the building blocks of wetland ecosystems, providing food, oxygen and habitats for many other species. They are also a hugely important natural resource, providing direct benefits to human communities across the world. Numerous aquatic plants are highly valued for their nutritious, medicinal, cultural, structural or biological properties. They are also key species in the provision of wetland ecosystem services, such as water filtration and nutrient recycling. An aquatic plant is defined here as a plant that is physiologically bound to water (a hydrophyte) or as a terrestrial plant whose photosynthetically active parts tolerate long periods submerged or floating (a helophyte) (Cook 1996). According to Cook (1996) aquatic plants represent between one and two percent of the approximately 300,000 species of vascular plants, equivalent to between 2,900 and 5,800 species (Chambers *et al.* 2008, Vié *et al.* 2008). Only 17 species of Indian aquatic plants had been assessed for the IUCN Red List before this assessment began.

For this project, the conservation status of all aquatic plant species from 42 selected plant families was assessed (see Chapter 7). The selection of families was based on the following criteria: i) the family contains a relatively large proportion of aquatic species; ii) there is a reasonable level of available information on the relevant species; iii) the taxonomy is relatively stable; iv) the selected families would, when combined, cover a wide range of ecological niches and contain a substantial number of species; and v) the family is widely represented at the global scale.

2.2 Western Ghats region delineation

This project focuses on the Western Ghats Biodiversity Hotspot (part of the Western Ghats and Sri Lanka Hotspot) as delineated by Myers (2000), Mittermeier *et al.* (2004) and CEPF (2007) (see www.biodiversityhotspots.org). However, we have widened the project area of interest to incorporate all catchments that drain from the Western Ghats Hotspot (see Figure 2.1). This wider 'catchment' approach takes into consideration the high levels of interconnectivity within freshwater systems, as impacts in one part of a river can easily and quickly be transported downstream (or upstream) and threaten freshwater biodiversity many miles from the original impact. To exclude from this assessment the species found outside the Hotspot, would not follow the principles of 'Integrated River Basin Management' (IRBM) which calls for the management (including conservation) of rivers to be undertaken at the catchment level so the effects of any management proposals are developed with all stakeholders (including biodiversity) throughout the catchment.

For detailed maps of the rivers, with names of those within the Western Ghats Hotspot, please see Appendix 2. These river names are referred to throughout the analysis.

2.3 Data collation and quality control

Information was sourced and collated for all known species within the priority taxonomic groups (see Section 2.1). Experts from across India and beyond (as necessary) were identified by IUCN, the project partners Zoo Outreach Organisation (ZOO), and through consultation with the relevant IUCN Species Survival Commission (SSC) Specialist Groups. These experts were trained in use of the project database, the Species Information Service (SIS), application of the IUCN Red List Categories and Criteria (IUCN 2001), and Geographic Information Systems (GIS) for digitally mapping species distributions.

Western Ghats training workshop, Karunya University, Coimbatore, India, January 2010.

Western Ghats first review workshop, Karunya University, Coimbatore, India, October 2010.

Following the training workshop, selected experts were contracted to collate species lists for the region from the priority taxonomic groups, and input within the SIS, all available information on each species. The required data fields within SIS are summarized in Table 2.1; some are free text fields allowing the assessors to add general information, such as for species distributions, habitat preferences and ecology, whereas other fields are based on classification schemes using pre-defined lists to record against. Standard classification schemes allow for consistency in analysis across other groups or geographic regions. For more information on the classification schemes employed visit the IUCN Red List website http://www.iucnredlist.org/technical-documents/classification-schemes.

Spatial distribution data were sourced for the production of species distribution maps (see Section 2.4). All species from the selected taxonomic groups were then assessed at the global scale, using the IUCN Red List Categories and Criteria (Version 3.1; IUCN 2001) (see Section 2.5). Species information and conservation assessments were then reviewed at a second workshop, where each species assessment was evaluated by at least two independent experts to ensure that: i) the information presented was both complete and correct; and ii) the Red List Categories and Criteria had been applied correctly.

2.4 Species mapping

Species distributions were, with the exception of some plants that could only be mapped to country boundaries, mapped to individual river/lake sub-basins, as delineated by HydroSHEDS (Hydrological data and maps based on SHuttle Elevation Derivatives as multiple Scales) using GIS software (Lehner *et al.* 2008), which identified 723 individual sub-basins within the project region (see Figure 2.2). River sub-basins were selected as the spatial units for mapping species distributions as, even though it is recognised that species ranges may not always extend throughout a river sub-basin, it is generally accepted that the river/lake basin or catchment is the most appropriate management unit for inland waters.

Point localities (the latitude and longitude where the species has been recorded), and other published data were used in most cases to identify which sub-basins are known to currently contain each species. Using expert opinion, coarse scale distribution records and unpublished literature it has been possible to identify, for many species, sub-basins where a species is 'probably' present; its presence within that sub-basin has not yet been published or confirmed in these parts of the range are labelled as "inferred basins". For many of the plant species, distribution maps are entirely based on inferred basins, as digitized point localities or detailed distribution information

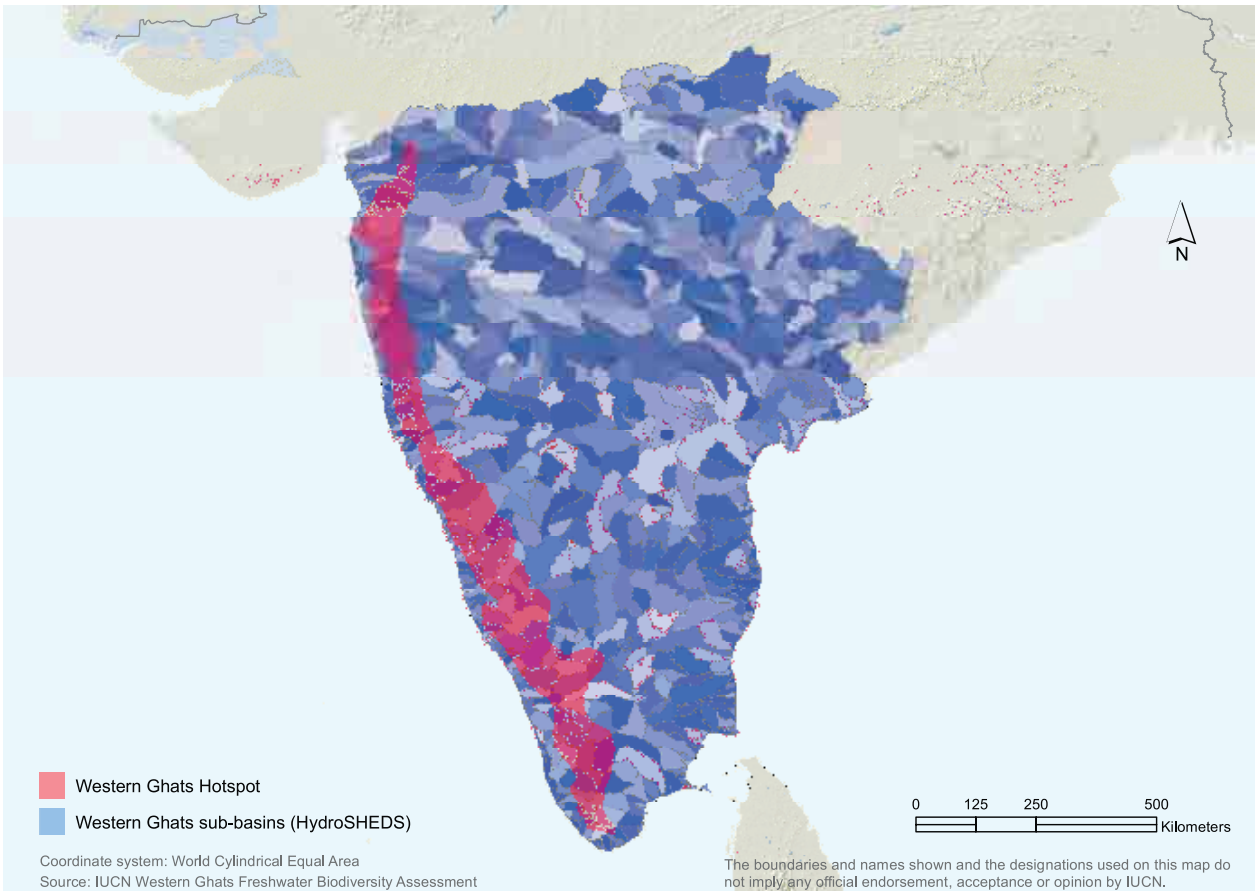

Figure 2.2 River basins as delineated by HydroSHEDS and as used to map and analyse species distributions.

were not available. Finally, many of the widespread plant species were mapped to country boundaries in the absence of more detailed distribution information.

2.5 Overlap with other Red List assessment projects

Some species present within the Western Ghats project region were assessed through other ongoing assessments that overlap the Western Ghats assessment region. These projects include the Eastern Himalaya Hotspot assessment (see Allen *et al.* 2010), the HighARCS project (ongoing) and the Sample Red List Index (SRLI) project (ongoing). Due to delays in outputs from some of these projects some species, in particular plants, have not been finalised meaning that their Red List category is tagged as being 'draft'. While we do not expect these Red List categories to change, they have not yet been peer reviewed.

2.6 Assessment of species threatened status

The risk of extinction for each species was assessed according to the IUCN Red List Categories and Criteria (Version 3.1; IUCN 2001). As such, the categories of threat reflect the risk that a species will go extinct within a specified time period. A species assessed as "Critically Endangered" is considered to be facing an extremely high risk of extinction in the wild. A species assessed as "Endangered" is considered to be facing a very high risk of extinction in the wild. A species assessed as "Vulnerable" is considered to be facing a high risk of extinction in the wild. All taxa assessed as Critically Endangered, Endangered or Vulnerable are described as "threatened". To distinguish between the three threatened categories, there are five criteria with quantitative thresholds (Table 2.2), reflecting biological indicators of populations threatened with extinction.

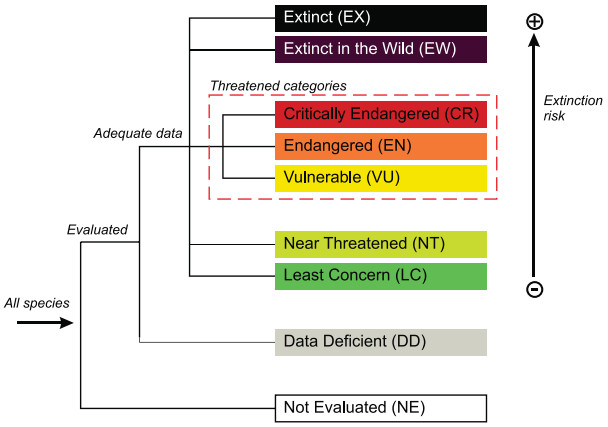

Figure 2.3 IUCN Red List Categories at a global level.

For an explanation of the full range of categories, and the criteria that must be met for a species to qualify under each category, please refer to the following documentation: The IUCN Red List Categories and Criteria: Version 3.1, which can be downloaded from http://www.iucnredlist.org/technical-documents/categories-and-criteria.

Species summaries and distribution maps are presented for all species assessed on the accompanying DVD. An example output is given in Appendix 1.

2.7 Nomenclature

Taxonomic schemes are constantly changing as results from ongoing studies, in particular with the introduction of molecular techniques, are made available. Taxonomy is also a somewhat controversial field, and in many cases it is difficult to find a universally agreed taxonomic hierarchy. In this case, the taxonomy followed is that adopted by the IUCN Red List which, where possible, employs existing published world checklists. Fish classification follows the online Catalog

Table 2.1. Data fields within the Species Information Service (SIS) as required to compile a species assessment. Text = text field; CS = Classification Scheme

		Fields		
Taxonomy	Higher taxonomy	Synonyms	Common names	
Geographic range	General information (text)	Countries of Occurrence (CS)	Biogeographic realm (CS)	
Population	General information (text)	Population trend (CS)		
Habitat and ecology	General information (text)	Habitats (CS)	System (CS)	Movement patterns (CS)
Use and trade	General information (text)	Utilisation (CS)	Harvest trends (CS)	
Threats	General information (text)	Threats (CS)		
Conservation measures	General information (text)	Conservation measures (CS)		
Red List assessment	Red List Category and criteria (CS)	Red List assessment rationale (text)	Assessor & Evaluator names	Assessment date
Bibliography	References			

Table 2.2 Summary of the five criteria (A-E) used to detemine the category of threat for a species.

Use any of the criteria A–E	Critically Endangered	Endangered	Vulnerable
A. Population reduction	**Declines measured over the longer of 10 years or 3 generations**		
A1	≥ 90%	≥ 70%	≥ 50%
A2, A3 and A4	≥ 80%	≥ 50%	≥ 30%
A1. Population reduction observed, estimated, inferred, or suspected in the past where the causes of the reduction are clearly reversible AND understood AND have ceased, based on and specifying any of the following: a) direct observation; b) an index of abundance appropriate to the taxon; c)a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality; d) actual or potential levels of exploitation; e) effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.			
A2. Population reduction observed, estimated, inferred, or suspected in the past where the causes of reduction may not have ceased OR may not be understood OR may not be reversible, based on (a) to (e) under A1.			
A3. Population reduction projected or suspected to be met in the future (up to a maximum of 100 years) based on (b) to (e) under A1.			
A4. An observed, estimated, inferred, projected or suspected population reduction (up to a maximum of 100 years) where the time period must include both the past and the future, and where the causes of reduction may not have ceased OR may not be understood OR may not be reversible, based on (a) to (e) under A1.			
B. Geographic range in the form of either B1 (extent of occurrence) and/or B2 (area of occupancy)			
B1. Extent of occurrence (EOO)	< 100km²	< 5,000km²	< 5,000km²
B2. Area of occupancy (AOO)	< 10km²	< 500km²	< 2,000km²
AND at least 2 of the following:			
a) Severely fragmented, OR Number of locations	= 1	≤ 5	≤ 10
b) Continuing decline in any of: **(i)** extent of occurrence; **(ii)** area of occupancy; **(iii)** area, extent and/or quality of habitat; **(iv)** number of locations or subpopulations; **(v)** number of mature individuals.			
c) Extreme fluctuations in any of: **(i)** extent of occurrence; **(ii)** area of occupancy; **(iii)** number of locations or subpopulations; **(iv)** number of mature individuals.			
C. Small population size and decline			
Number of mature individuals	< 250	< 2,500	< 10,000
AND either C1 or C2			
C1. An estimated continuing decline of at least: (up to max. of 100 years in future)	25% in 3 years or 1 generation	20% in 5 years or 2 generations	10% in 10 years or 3 generations
C2. A continuing decline AND a) and/or b)			
a i). Number of mature individuals in each subpopulation	< 50	< 250	< 1,000
a ii) % individuals in one subpopulation	90-100%	95-100%	100%
b) Extreme fluctuations in the number of mature individuals			
D. Very small or restricted population			
EITHER Number of mature individuals	< 50	< 250	< 1,000 (D1)
AND/OR Restricted area of occupancy			Typically < 20km² or number locations ≤ 5 (D2)
E. Quantitative analysis			
Indicating the probability of extinction in the wild to be:	≥ 50% in 10 years or 3 generations (100 years max.)	≥ 20% in 20 years or 5 generations (100 years max.)	≥ 10% in 100 years

of Fishes maintained at the California Academy of Sciences (Eschmeyer 2010). Odonate classification generally follows the World Odonata List maintained at the University of Puget Sound (Schorr and Paulson 2010). There is currently no widely accepted single taxonomy for molluscs, and we therefore follow the standards recommended by the IUCN SSC Mollusc Specialist Group. For plants, where appropriate, we follow the World Checklist of Selected Plant Families hosted by the Royal Botanic Gardens, Kew (WCSP 2010), but other more specialist lists are also followed, such as the Checklist of World Ferns (Hassler and Swale 2010) and AlgaeBase (Guiry and Guiry 2010). For more information on the taxonomic standards of the IUCN Red List, visit http://www.iucnredlist.org/technical-documents/information-sources-and-quality#standards.

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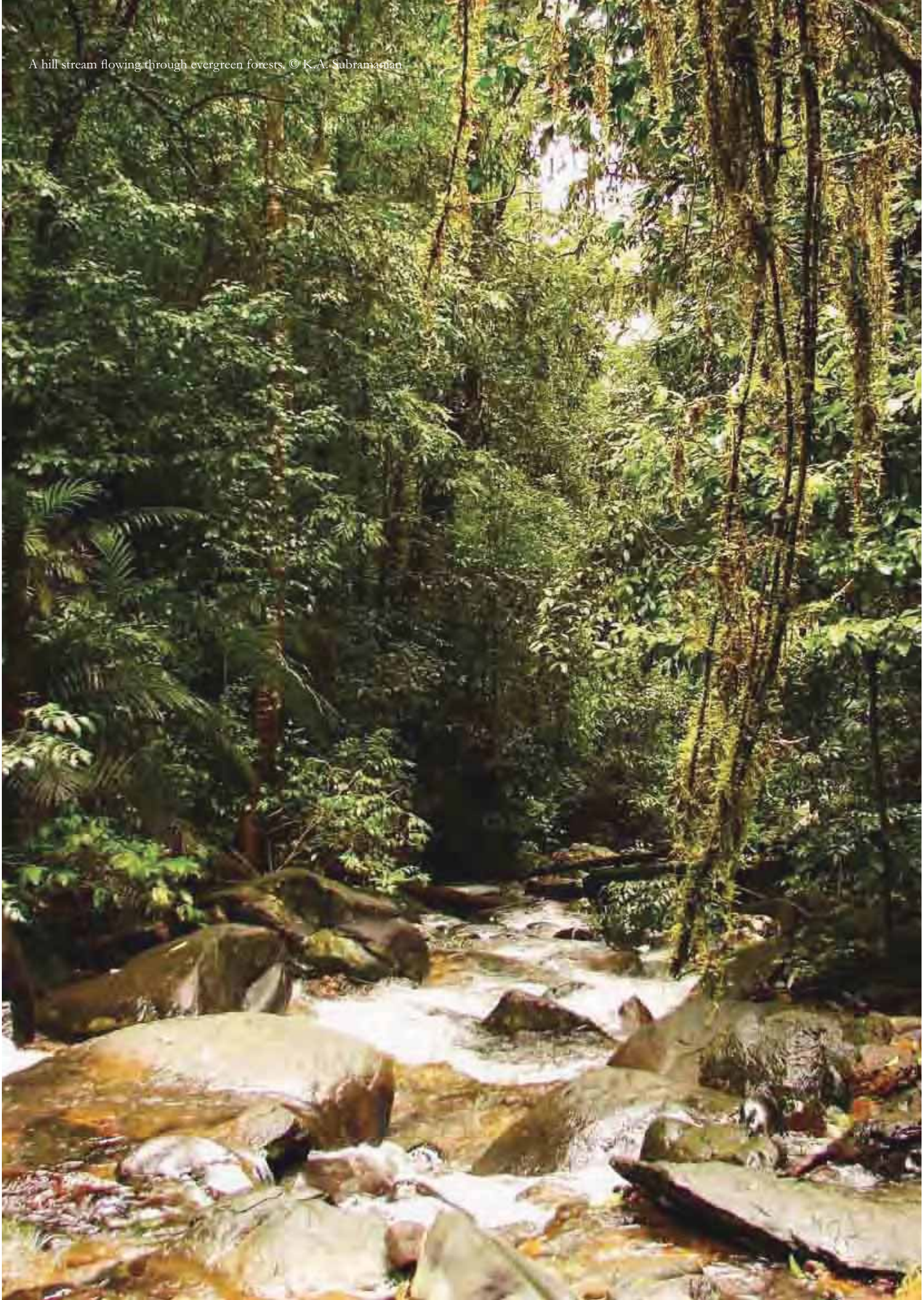

A hill stream flowing through evergreen forests. © K.A. Subramanian

Chapter 3. The status and distribution of freshwater fishes of the Western Ghats

Neelesh Dahanukar[1], Rajeev Raghavan[2, 3], Anvar Ali[2], Robin Abraham[4] and C.P. Shaji[5]

3.1 Overview of Western Ghats fish fauna

The Western Ghats and the associated river drainages are rich in freshwater fish diversity (Kottelat and Whitten 1996, Shaji *et al.* 2000, Dahanukar *et al.* 2004). The Western Ghats assessment region (Figure 2.1) does not only contain the Western Ghats Hotspot as defined by Myers *et al.* (2000), but also associated river basins including Narmada, Tapi, Godavari, Krishna, Cauvery and all other river systems in southern India. Abell *et al.* (2008) defined the global freshwater ecoregions based on distribution and composition of freshwater fish species. The Western Ghats assessment region falls under five freshwater ecoregions, namely Narmada-Tapi, Northern Deccan Plateau (excluding Mahanadi River basin), Southern Deccan Plateau, Southern Eastern Ghats and the Western Ghats (Figure 1.2).

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3.1.1 Freshwater fish diversity

Currently, 290 species of freshwater fishes belonging to 11 orders, 33 families and 106 genera are recognized from the Western Ghats assessment region. Since the western face of the Western Ghats is close to the Arabian Sea, a number of secondary freshwater fishes are also found here. Out of the total 290 species, at least 35 can also live in marine and/or brackish water habitats. Cypriniformes (178 species) is the most speciose order followed by Siluriformes (50 species), while the most speciose families are Cyprinidae, which are the carps and true minnows (72 species); Balitoridae, river loaches (34 species); Bagridae, bagrid catfish (19 species); and Sisoridae, sisorid catfish (12 species).

The Western Ghats also has a rich endemic fish fauna of 189 species, belonging to seven orders, 23 families and 69 genera. Twelve genera, *Betadevario*, *Dayella*, *Horabagrus*, *Horalabiosa, Hypselobarbus*, *Indoreonectes*, *Lepidopygopsis*, *Longischistura*, *Mesonoemacheilus*, *Parapsilorhynchus*, *Rohtee* and *Travancoria*, are endemic to the Western Ghats.

3.1.2 Geographical factors contributing to the distribution of freshwater fishes

Rivers in the Western Ghats assessment region can be divided into two categories, west flowing rivers and east flowing rivers. Excluding two west flowing rivers in the north, the Tapi and Narmada, which originate in the Satpura Hill ranges, the remaining west flowing rivers of the Western Ghats are relatively small, originating in the Western Ghats and draining into the Arabian Sea. East flowing rivers, on the other hand, are relatively larger river systems that originate in the Western Ghats (except Pennar River system) and drain into the Bay of Bengal. Since the Western Ghats forms a barrier between the east and west flowing rivers, the fish species composition of the west and east flowing rivers have substantial differences. For instance, Johnson and Arunachalam (2009) studied the distribution of freshwater fishes from rivers of southern Western Ghats and showed that the species composition and their abundance differ in the west and east flowing rivers, with several species endemic to only the west flowing rivers. High levels of endemic species diversity, with several point endemics, in the west flowing rivers can be partially attributed to the fact that these rivers are small and have rarely connected with each other. This is true for almost all the Kerala part of the Western Ghats which has high levels of endemism (Kurup 2002, Kurup *et al.* 2004). This may also be true of the west flowing rivers of the central and northern parts of the Western Ghats, but the lack of studies in these regions obscures our understanding of the true patterns in fish diversity of these areas.

The east flowing rivers of the Western Ghats assessment region (except some in Tamil Nadu) drain into one of the four major river systems, namely Godavari, Krishna, Cauvery and Pennar. Most of the fishes in these river systems have a wide distribution and very few are point endemics. Further, since the Godavari and Krishna river systems are connected to each other at the estuaries near the Bay of Bengal, they share several common fish species.

Parapsilorhynchus discophorus (VU) from Koyna River. © Neelesh Dahanukar

3.1.3 Taxonomic issues with freshwater fishes

The currently recognized 290 species is likely to be a very gross under representation of the true freshwater fish diversity of this area. While descriptions of new species from less explored areas are likely to occur, resolution of taxonomic problems in currently recognized species could also contribute to better understanding of fish species richness of this region. Incorrect synonymization has often undermined estimates of the true species richness in the Western Ghats. For example, until recently *Mystus seengtee*, a species endemic to the Western Ghats assessment region, was synonymized with the gangetic species *M. cavasius* (Chakrabarty and Ng 2005). Similarly, *Channa diplogramma*, a valid species restricted to the southern Western Ghats, was treated as a synonym of a widespread species *C. micropeltes* (Benziger *et al.* 2011). An additional problem with taxonomy is the presence of species complexes. Several related potential 'species' found in the Western Ghats are currently recognized as the same species. Recent revisions of the *Puntius filamentosus* group (Pethiyagoda and Kottelat 2005, Devi *et al.* 2010, Knight *et al.* 2011) suggest that there is a need for detailed taxonomic revisions of species in this area. There is also a lack of detailed taxonomic reviews such that checklists of fishes often misidentify species or carry over the mistakes of previous workers and create no end to the confusion (Raghavan 2011). To illustrate the point, Chandra and Sharma (2007) have compiled a list of 175 species from central India based on previous literature and mention *Barilius evezardi* as one of the species. *Barilius evezardi*, a species that has not been recorded from its type locality since its first description despite repeated surveys (Dahanukar 2010), has rarely appeared in the scientific literature and then with either very little information or just a mention of its name. As a result it remains a puzzle whether the subsequent reports of this species are reliable leading to the species being assessed as Data Deficient (Dahanukar 2010).

Indoreonectes evezardi (LC) is likely to be a species complex. Collected from Khandala, northern Western Ghats ecoregion. © Neelesh Dahanukar.

3.1.4 Limitations in data availability

The entire Western Ghats region has not been investigated in a standardised manner and there are several areas which remain unexplored. This is especially true for the rivers of the central and northern Western Ghats (Dahanukar *et al.* 2004), where the west flowing rivers are poorly studied. As a result, our understanding of the fish fauna of these areas is still far from complete. Given that the west flowing rivers of the southern Western Ghats harbour a rich diversity of fishes quite different from that of the east flowing rivers, it is possible that the west flowing rivers of the central and northern Western Ghats might also harbour a rich diversity of undescribed species. Extensive studies on the east flowing rivers such as the Krishna and Godavari are available (David 1963, Jayaram 1995) but not all tributaries of these river systems have been studied (Jadhav *et al.* 2011). This is especially true for the tributaries of Krishna and Godavari in the Western Ghats area which have a rich diversity of balitorid, cobitid and sisorid fishes. Similarly, very few studies are available on the Tapi and Narmada rivers. A book on the fish fauna of central India by Lakra and Sarkar (2007) gives some information on the fish fauna of this region, however, most of the species listed are found in the Ganga or Krishna and Godavari river systems. This is surprising because it is expected that these regions would have a more unique fish diversity given the geographical barriers created by the Satpura and Vindhya hill ranges.

3.2 Conservation status (IUCN Red List Category)

Analysis of the conservation status of freshwater fishes in the Western Ghats finds that the endemic species are far more threatened than the non-endemics (Table 3.1, Figure 3.1). Of the species for which sufficient data are available, 37% are threatened (assessed Critically Endangered, Endangered or Vulnerable), and 2% are Near Threatened (Figure 3.1). Of the 97 species which are threatened, only one species, *Tor khudree* (EN) is not endemic to the Western Ghats assessment region. Five percent of the fish species in the Western Ghats assessment region are assessed as Critically Endangered, the highest level of threat that can be assigned to a species in the wild. All these species are endemic to the study area (Table 3.2). Species such as *Hypselobarbus pulchellus*, *Mesonoemacheilus herrei* and *Psilorhynchus tenura* have been assessed as Critically Endangered owing to highly restricted geographical distributions and threats to their habitats, while other species such as *Barbodes wynaadensis* and *Hemibagrus punctatus* are assessed as Critically Endangered owing to drastic declines in their population. In addition, *Parapsilorhynchus prateri* and *Barbodes bovanicus* are assessed as Critically Endangered (Possibly Extinct) owing to their restricted distribution, threats to their habitats and no recent collections despite extensive surveys. A total of 54 species (20%) are assessed as Endangered (Table 3.1, Figure 3.1). *Tor khudree* is assessed as Endangered owing to high levels of exploitation as a food fish (Raghavan *et al.* 2011). The Western Ghats ecoregion has the highest number of Endangered species (Table 3.3). Species such as *Labeo potail*, *Pterocryptis wynaadensis* and *Schismatorhynchos nukta* have been assessed as Endangered owing to severe ongoing declines in their populations. *Garra hughi*, *Glyptothorax poonaensis*, *Horabagrus nigricollaris*, *Monopterus fossorius*, *Parapsilorhynchus elongatus* and *Travancoria elongata*, have all been assessed as Endangered owing to their restricted geographical distributions and ongoing threats to their habitats. *Garra kalakadensis*, *Hypselobarbus micropogon* and *Puntius denisonii* are assessed as Endangered owing to both population declines and restricted geographical range. Others, for example *Osteobrama bhimensis*, have been assessed as Endangered owing to restricted geographical range and threats to the habitat, but it is also suggested that there is a need to validate their taxonomy as they have a close resemblance to a widely distributed Least Concern species.

Thirty-one species of freshwater fish have been assessed as Vulnerable, all of which are endemic to the study area (Table 3.1). While most of these species are found in the Western Ghats freshwater ecoregion, several are found in more than one freshwater ecoregion (Table 3.4). Species such as *Carinotetraodon travancoricus* and *Horabagrus brachysoma* are assessed as Vulnerable owing to population declines of more then 30%, while other species such as *Balitora mysorensis*, *Batasio travancoria*, *Channa diplogramma*, *Devario fraseri*, *Gagata itchkeea*, *Glyptothorax trewavasae*, *Laubuca fasciata*, *Monopterus indicus*, *Nemacheilus keralensis*, *Parapsilorhynchus discophorus*, *Pseudosphromenus dayi* and

Table 3.1 Number of fish species of Western Ghats under each IUCN Red List category.

Global Red List Category	Number of fish species		
	Endemic	Non-endemic	Total
Extinct (EX)	0	0	0
Extinct in the Wild (EW)	0	0	0
Critically Endangered (CR)	12	0	12
Endangered (EN)	53	1	54
Vulnerable (VU)	31	0	31
Near Threatened (NT)	3	3	6
Least concern (LC)	66	95	161
Data Deficient (DD)	24	2	26
Total species	189	101	290

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

Puntius amphibius (DD) needs detailed taxonomic studies. Collected from Mutha River of Pune (Southern Deccan Plateau ecoregion). © Neelesh Dahanukar.

Table 3.2 Critically Endangered endemic species and their distribution in five ecoregions.

Species	Ecoregion
Barbodes bovanicus	Western Ghats, Southern Eastern Ghats
Barbodes wynaadensis	Western Ghats
Glyptothorax kudremukhensis	Southern Deccan Plateau
Hemibagrus punctatus	Southern Eastern Ghats
Horalabiosa arunachalami	Western Ghats
Hypselobarbus pulchellus	Western Ghats
Hypselobarbus thomassi	Western Ghats
Mesonoemacheilus herrei	Western Ghats
Parapsilorhynchus prateri	Northern Deccan Plateau
Psilorhynchus tenura	Southern Deccan Plateau
Puntius deccanensis	Southern Deccan Plateau
Puntius pookodensis	Western Ghats

Populations of *Schismatorhynchos nukta* (EN) have declined drastically possibly because of pollution, harvesting and competition created by introduced carps. Collected at Krishna River at Wai. © Neelesh Dahanukar

Table 3.3 Endangered endemic species and their distribution in five ecoregions.

Species	Ecoregion
Barilius canarensis	Western Ghats, Southern Deccan Plateau
Batasio sharavatiensis	Western Ghats
Botia striata	Southern Deccan Plateau
Crossocheilus periyarensis	Western Ghats
Devario neilgherriensis	Western Ghats
Etroplus canarensis	Western Ghats
Garra hughi	Western Ghats
Garra kalakadensis	Western Ghats, Southern Eastern Ghats
Garra surendranathanii	Western Ghats
Glyptothorax anamalaiensis	Western Ghats
Glyptothorax davissinghi	Western Ghats
Glyptothorax housei	Western Ghats
Glyptothorax madraspatanus	Southern Deccan Plateau, Southern Eastern Ghats, Western Ghats
Glyptothorax poonaensis	Southern Deccan Plateau
Homaloptera montana	Western Ghats
Homaloptera santhamparaiensis	Western Ghats
Horabagrus nigricollaris	Western Ghats
Horalabiosa joshuai	Southern Eastern Ghats
Hypselobarbus curmuca	Southern Deccan Plateau, Southern Eastern Ghats, Western Ghats
Hypselobarbus dubius	Southern Eastern Ghats
Hypselobarbus micropogon	Southern Eastern Ghats
Hypselobarbus mussullah	Southern Deccan Plateau, Southern Eastern Ghats, Western Ghats
Hypselobarbus periyarensis	Western Ghats
Labeo potail	Southern Deccan Plateau, Southern Eastern Ghats
Lepidopygopsis typus	Western Ghats
Longischistura striatus	Western Ghats
Monopterus fossorius	Western Ghats
Nemacheilus petrubanarescui	Western Ghats
Nemacheilus pulchellus	Western Ghats, Southern Eastern Ghats
Nemachilichthys shimogensis	Western Ghats, Southern Deccan Plateau
Osteobrama bhimensis	Southern Deccan Plateau
Osteochilus longidorsalis	Western Ghats
Parapsilorhynchus elongatus	Southern Deccan Plateau
Pseudeutropius mitchelli	Western Ghats
Pterocryptis wynaadensis	Southern Deccan Plateau, Southern Eastern Ghats, Western Ghats
Puntius arulius	Southern Deccan Plateau, Southern Eastern Ghats, Western Ghats
Puntius cauveriensis	Western Ghats, Southern Eastern Ghats
Puntius chalakkudiensis	Western Ghats
Puntius crescentus	Western Ghats
Puntius denisonii	Western Ghats
Puntius exclamatio	Western Ghats
Puntius fraseri	Northern Deccan Plateau
Puntius ophicephalus	Western Ghats
Puntius sharmai	Southern Eastern Ghats
Puntius tambraparniei	Southern Eastern Ghats
Schismatorhynchos nukta	Northern Deccan Plateau, Southern Deccan Plateau, Southern Eastern Ghats
Schistura nagodiensis	Western Ghats
Silonia childreni	Northern Deccan Plateau, Southern Deccan Plateau, Southern Eastern Ghats
Thynnichthys sandkhol	Northern Deccan Plateau, Southern Deccan Plateau
Tor kulkarnii	Northern Deccan Plateau
Tor malabaricus	Western Ghats, Southern Eastern Ghats
Travancoria elongata	Western Ghats
Travancoria jonesi	Western Ghats

Table 3.4 Vulnerable endemic species and their distribution in five ecoregions.

Species	Ecoregion
Balitora mysorensis	Southern Deccan Plateau, Southern Eastern Ghats, Western Ghats
Batasio travancoria	Western Ghats
Carinotetraodon travancoricus	Western Ghats
Channa diplogramma	Western Ghats, Southern Eastern Ghats
Cirrhinus cirrhosus	Northern Deccan Plateau, Southern Deccan Plateau, Southern Eastern Ghats
Devario fraseri	Northern Deccan Plateau, Western Ghats
Gagata itchkeea	Southern Deccan Plateau
Garra menoni	Western Ghats
Garra periyarensis	Western Ghats
Glyptothorax trewavasae	Southern Deccan Plateau
Horabagrus brachysoma	Western Ghats
Horalabiosa palaniensis	Western Ghats
Hyporhamphus xanthopterus	Western Ghats
Hypselobarbus kolus	Northern Deccan Plateau, Southern Deccan Plateau, Southern Eastern Ghats, Western Ghats
Laubuca fasciata	Western Ghats
Mesonoemacheilus pambarensis	Western Ghats
Monopterus indicus	Western Ghats, Southern Deccan Plateau
Nemacheilus keralensis	Western Ghats
Nemacheilus kodaguensis	Southern Eastern Ghats
Nemacheilus menoni	Western Ghats
Nemacheilus periyarensis	Western Ghats
Parapsilorhynchus discophorus	Southern Deccan Plateau, Western Ghats
Pseudosphromenus dayi	Western Ghats
Puntius arenatus	Southern Eastern Ghats
Puntius assimilis	Western Ghats
Puntius mudumalaiensis	Western Ghats
Puntius rohani	Southern Eastern Ghats
Puntius setnai	Western Ghats
Salmophasia belachi	Southern Eastern Ghats
Salmophasia horai	Southern Deccan Plateau, Southern Eastern Ghats
Schistura sharavathiensis	Western Ghats

Carinotetraodon travancoricus is assessed as Vulnerable owing to population declines of more then 30%. © Rajeev Raghavan

Harvesting is a threat to fish species such as *Tor khudree* (EN) and *Hypselobarbus kolus* (VU). Photograph taken at Krishna River at Wai, Southern Deccan Plateau ecoregion. © Mandar Paingankar.

Puntius arenatus have been assessed as Vulnerable owing to restricted distributions, fragmented populations and threats to their habitats. Several other species, such as *Garra menoni*, *G. periyarensis*, *Horalabiosa palaniensis*, *Hyporhamphus xanthopterus*, *Mesonoemacheilus pambarensis*, *Nemacheilus kodaguensis*, *N. menoni*, *N. periyarensis*, *Puntius assimilis*, *P. rohani*, *Salmophasia belachi* and *Schistura sharavathiensis*, are assessed as Vulnerable under the criterion D2 as they are point endemics and have a restricted distribution with plausible threats.

Only six species are assessed as Near Threatened, meaning that they are close to qualifying for a threatened category, of which three are endemic to the Western Ghats assessment region (Table 3.1). The endemic species are *Clarias dussumieri*, *Garra bicornuta* and *Mystus malabaricus*, while the non-endemic species are *Ompok bimaculatus*, *Wallago attu* and *Bagarius yarrelli*.

For the two dominant orders, Cypriniformes and Siluriformes, we find that out of the extant species for which we have sufficient data, 44% of Cypriniformes are threatened, while 39% of the Siluriformes are threatened (Figure 3.2). At the family level Sisoridae has the highest level of threat with 73% of species threatened, followed by Balitoridae (51%), Cyprinidae (44%) and Bagridae (27%) (Figure 3.3).

The results show that of extant endemic species for which sufficient data are available 58% (96 species) are threatened, while another 2% of species are Near Threatened (Table 3.1, Figure 3.1). An additional 24 endemic species are Data Deficient (Table 3.1), many of which are likely to be threatened. With more than 50% of the endemic species threatened, there is an immediate need for a better understanding of threats to fish species in the Western Ghats assessment region and for more focus on action for their conservation.

Analysis of the conservation status of all species shows that 161 fish species (61%) are Least Concern. These species fall into four categories: (1) secondary freshwater fish genera, such as *Ambassis*, *Anguilla*, *Awaous*, *Bathygobius*, *Oryzias*, etc., which have a wide distribution throughout the Asian coast; (2) species, such as *Labeo boggut*, *Mystus cavasius*, *Osteobrama vigorsii*, *Salmophasia balookee*, *Sperata aor*, *Sperata seenghala*, etc., which have wide distributions in India and adjacent countries; (3) species, such as *Barilius gatensis*, *Cirrhinus fulungee*, *Glyptothorax lonah*, *Mystus seengtee*, *Proeutropiichthys taakree*, *Rita gogra*, *Salmophasia novacula*, etc., which are endemic to peninsular India but are widely distributed with no known major threats, and; (4) species such as *Acanthocobitis botia*, *Channa gachua*, *Crossocheilus latius*, *Devario malabaricus*, *Garra mullya*, *Osteobrama cotio*, *Puntius ticto*, *Mastacembelus armatus*, *Notopterus notopterus*, etc., which are considered as widespread but are likely to be species complexes.

Twenty-six species are assessed as Data Deficient, meaning that their risk of extinction could not be evaluated (Table 3.1). Barring two species, *Anabas testudineus* and *Zenarchopterus dispar*, the remaining 24 species in this category are endemic to the Western Ghats assessment region. Endemic species which have been considered as Data Deficient include recently described species such as *Betadevario ramachandrani* and *Pseudolaguvia austrina*, or species with limited data such as *Neotropius*

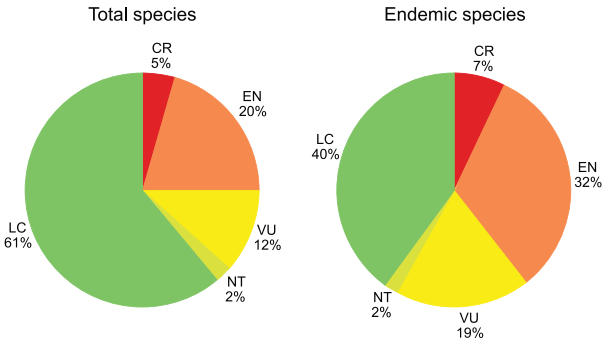

Figure 3.1 Percent of total and endemic freshwater fish species in each IUCN Red List Category in the Western Ghats assessment region.

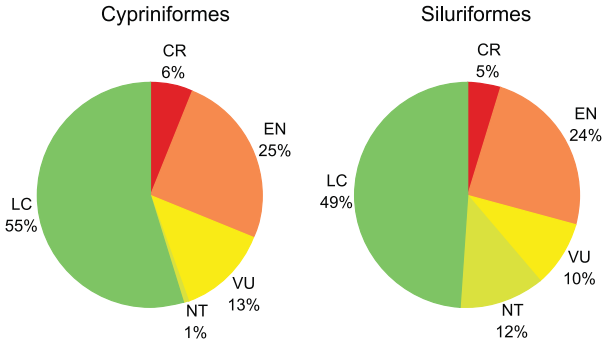

Figure 3.2 Percent of Cypriniformes and Siluriformes species (the two most speciose orders) in each IUCN Red List Category in the Western Ghats assessment region.

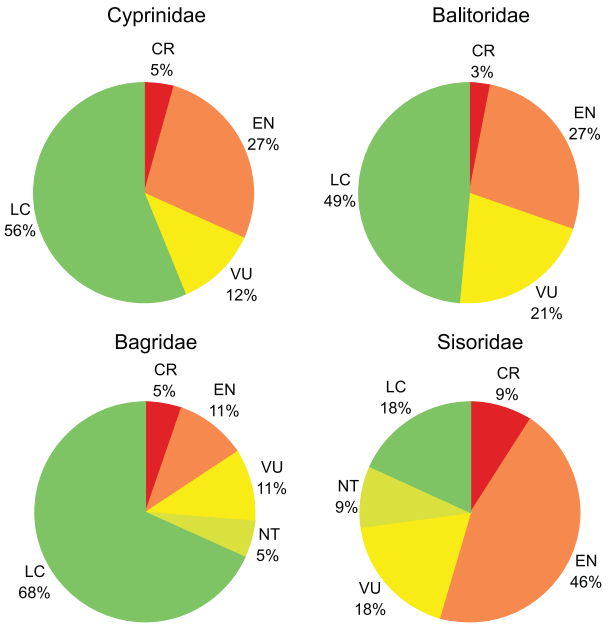

Figure 3.3 Percent of Cyprinidae, Balitoridae, Bagridae and Sisoridae species (the four most speciose families) in each IUCN Red List Category in the Western Ghats assessment region.

khavalchor, *Eutropiichthys goongwaree*, *Horaglanis alikunhii* and *Monopterus eapeni*, or species with taxonomic problems such as *Puntius amphibius* and *Ompok goae*.

A list of all species with their IUCN Red List Categories can be found on the accompanying data DVD.

3.3 Patterns of species richness

Dahanukar *et al.* (2004) listed 288 species of freshwater and secondary freshwater fishes from the Western Ghats and described their distributions by dividing the Western Ghats into six, 2° latitude zones. Even though their analysis revealed increasing levels of endemism in the southern Western Ghats, this distribution pattern based on latitudinal zones does not adequately reflect the biogeographic patterns of freshwater fish distributions across river systems. Therefore, we have based our discussion on an analysis of distributions across river sub-basins and freshwater ecoregions as defined by Abell *et al.* (2008).

3.3.1 All fish species

Hill streams and rivers of the Western Ghats biodiversity hotspot are more species rich than the western plains of peninsular India (Figure 3.4). The highest species richness (133-160 species per sub-basin) is found in the river drainages of southern Western Ghats including the Periyar, Chalakkudy, Bharatapuzha, Pamba, Chaliyar and upstream tributaries of Cauvery, Pambar, Moyar and Bhavani rivers. Upstream tributaries of Tunga, Bhadra, Krishna and Bhima rivers of the Krishna River system are also rich in fish fauna (114-132 species per sub-basin). The tributaries of Godavari, Narmada and Tapi in the northern Western Ghats have fewer species. The species distribution pattern suggests that the west flowing rivers are richer in fish fauna, especially in the Kerala and (southern part of) Karnataka states of the southern Western Ghats ecoregion. The northern parts of the Western Ghats ecoregion contain lower levels of species richness, however, this could be partially attributed to the lower nunber of surveys and studies undertaken in this region.

3.3.2 Threatened species

The distribution of threatened species (Figure 3.6) shows the Periyar, Chalakkudy and Pambar rivers to have the highest number of threatened species. Both the Periyar and Chalakkudy rivers are also rich in endemic species, including several point endemics, and face a number of threats to the fish fauna (Radhakrishnan and Kurup 2010, Raghavan *et al.* 2008a, 2008b; see also Box 1). Out of the 96 endemic threatened species, 50 are endemic to the Western Ghats ecoregion, 10 are endemic to Southern Eastern Ghats ecoregion, nine species are endemic to Southern Deccan Plateau ecoregion, three are endemic to Northern Deccan Plateau ecoregion, and the remaining 24 species are found in multiple ecoregions

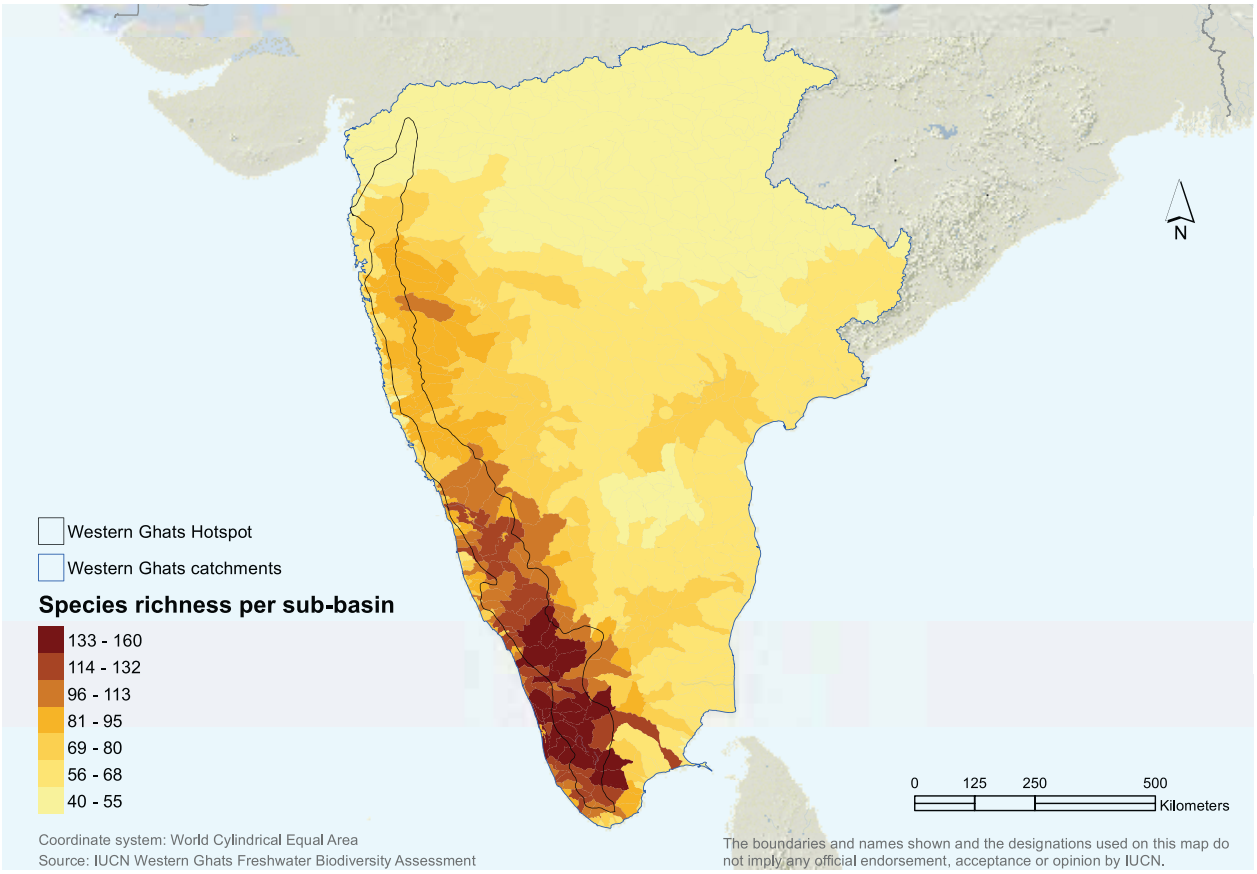

Figure 3.4 Total species richness in the Western Ghats assessment region.

(Tables 3.2, 3.3 and 3.4). The distribution of threatened species in the Western Ghats assessment region (Figure 3.6) overlaps strongly with the distribution of endemic species (Figure 3.5).

Critically Endangered

All Critically Endangered freshwater fish species of the Western Ghats are endemic to the study area. The Western Ghats ecoregion has the highest number of Critically Endangered species (7) all of which are restricted to the Kerala parts of the ecoregion (Table 3.2). *Hemibagrus punctatus* is endemic to the tributaries of the Cauvery River system in the Southern Eastern Ghats ecoregion and its populations have declined drastically in recent years to such an extent that it is now considered Possibly Extinct. Similarly, *Barbodes bovanicus*, another Possibly Extinct species endemic to the Western Ghats and Southern Eastern Ghats ecoregions has not been recorded in surveys undertaken in the past decade. *Glyptothorax kudremukhensis*, *Psilorhynchus tenura* and *Puntius deccanensis* are endemic to the Southern Deccan Plateau ecoregion, *G. kudremukhensis* and *P. tenura* have been recorded from Tungabhadra River system, while *P. deccanensis* is restricted to a small lake in Pune, Maharashtra where it has not been recorded since its initial description although several surveys have been conducted in and around the type locality. The only Critically Endangered species endemic to the Godavari River system is *Parapsilorhynchus prateri*, which has also not been recorded from its type locality in recent surveys and is considered Possibly Extinct.

Endangered

Among the 53 endemic and Endangered freshwater fish species, 27 are restricted to Western Ghats ecoregion, five are restricted to Southern Eastern Ghats, four are restricted to Southern Deccan Plateau and two are restricted to Northern Deccan Plateau ecoregion, while the remaining 15 species are known from multiple ecoregions (Table 3.3). Among the Endangered fishes, species belonging to three genera *Lepidopygopsis*, *Horabagrus* and *Travancoria* are endemic to the southern Western Ghats. *Puntius denisonii*, a species restricted to the Western Ghats of Kerala and southern Karnataka, is threatened by harvesting for the aquarium pet trade (Raghavan *et al.* 2009). *Schismatorhynchos nukta* is a unique fish species, with a single horn like projection between its eyes, and its closest relatives are distributed in Southeast Asia. Rapid declines in its populations (Ghate *et al.* 2002) and local extirpation from several areas (Kharat *et al.* 2003) including its type locality in Indrayani River of Pune, Maharashtra render it Endangered.

Vulnerable

All Vulnerable species of the Western Ghats assessment region are endemic, with species restricted to the Western Ghats ecoregion, four restricted to Southern Eastern Ghats and

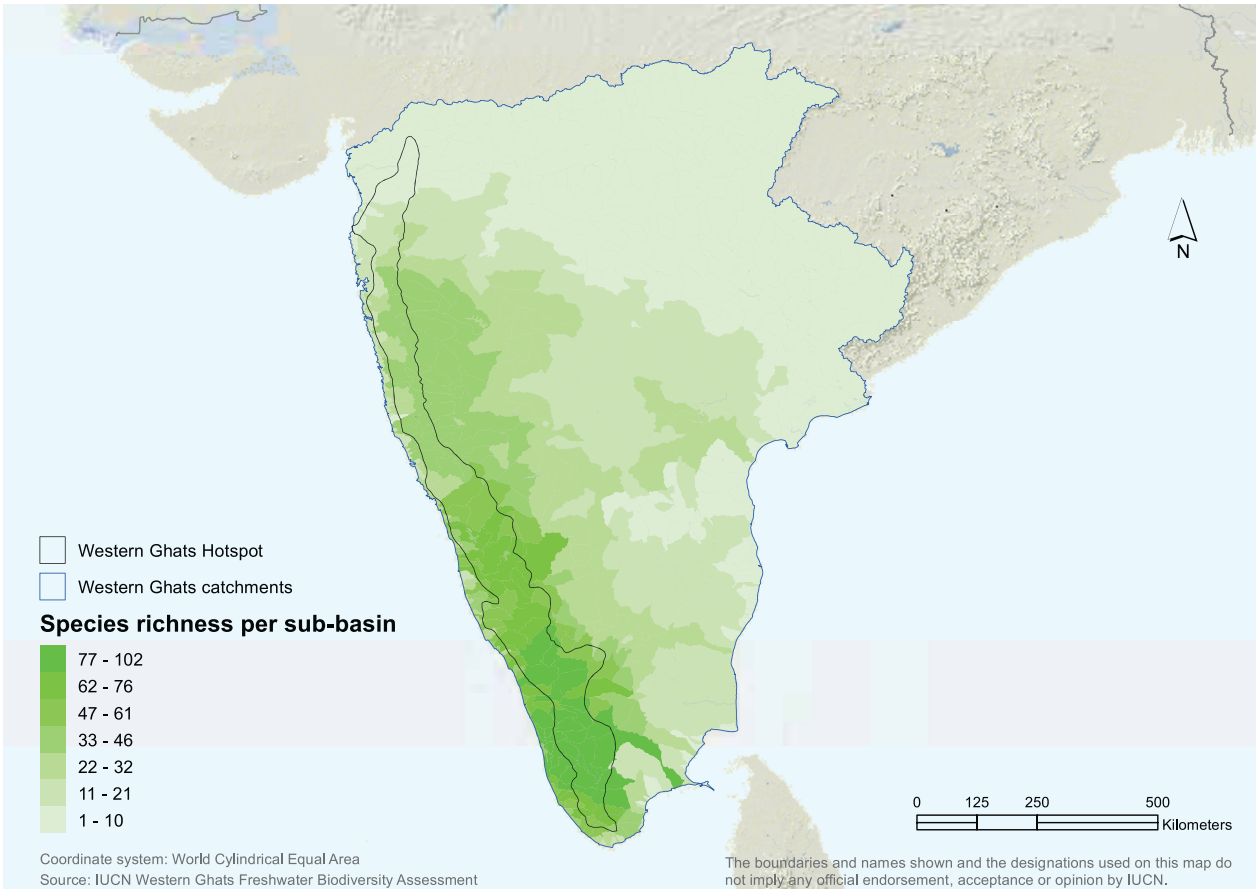

Figure 3.5 Endemic species richness in the Western Ghats assessment region.

two restricted to Southern Deccan Plateau, and the remaining eight species distributed across multiple ecoregions (Table 3.4). Among the Vulnerable species, *Channa diplogramma*, restricted to the Western Ghats and Southern Eastern Ghats ecoregions, was often considered as a synonym of the Southeast Asian species *Channa micropeltes*. Recent molecular evidence (Adamson *et al.* 2010, Benziger *et al.* 2011) has however established the validity of this species, and also reveals its unique evolutionary position at the base of channid evolution on account of the presence of gular scales (Benziger *et al.* 2011).

3.3.3 Restricted range and endemic species

The Western Ghats region contains a high level of freshwater fish endemism with 189 endemic species (65% of the total). However, even this is likely to be an underestimate as it is becoming clear that many species which show wide distributions in India are species complexes. Of 189 endemic species, 138 species are restricted to the Western Ghats Hotspot. The highest level of endemism (between 77-102 species per sub-basin) is found in the west flowing rivers Chaliyar, Bharatapuzha, Chalakkudy, Periyar, and Pamba in the Kerala part of the Western Ghats ecoregion and also in the upper tributaries of the east flowing rivers such as the Bhavani, Tambraparni and Cauvery river systems in the Southern Eastern Ghats ecoregion (Figure 3.5). Several of these river systems contain point endemic species restricted to only a small area. One such area is 'Periyar Lake-Stream System', which harbours several endemics (Box 1). Even though the highest endemism is restricted to the southern parts of the Western Ghats ecoregion (Figure 3.5), the other ecoregions also contain unique species compositions and endemic species.

Narmada-Tapi ecoregion

The Narmada-Tapi ecoregion is separated from the Ganges to the north and Deccan Plateau to the south by the geographical barriers created by the Satpura and Vindhya hill ranges. It is therefore expected that this ecoregion may have a unique fish fauna. Unfortunately, because of the lack of detailed taxonomic studies and taxonomic revisions, the likely distinct fauna of this region has not been revealed in the current assessment. This is because most of the recorded species to date are common to the Ganga or the Krishna and Godavari river basins. This suggests a need for detailed taxonomic studies in this ecoregion. *Barilius radiolatus*, an endemic species of Narmada River, is the only species endemic to the Tapi-Narmada ecoregion. This species was omitted from the present analysis in error. However, *B. radiolatus* is assessed as Data Deficient (Vishwanath 2010) owing to the very limited amount of available information on the species.

Northern Deccan Plateau ecoregion

From this ecoregion, only the Godavari River basin was considered for analysis in the current assessment. The

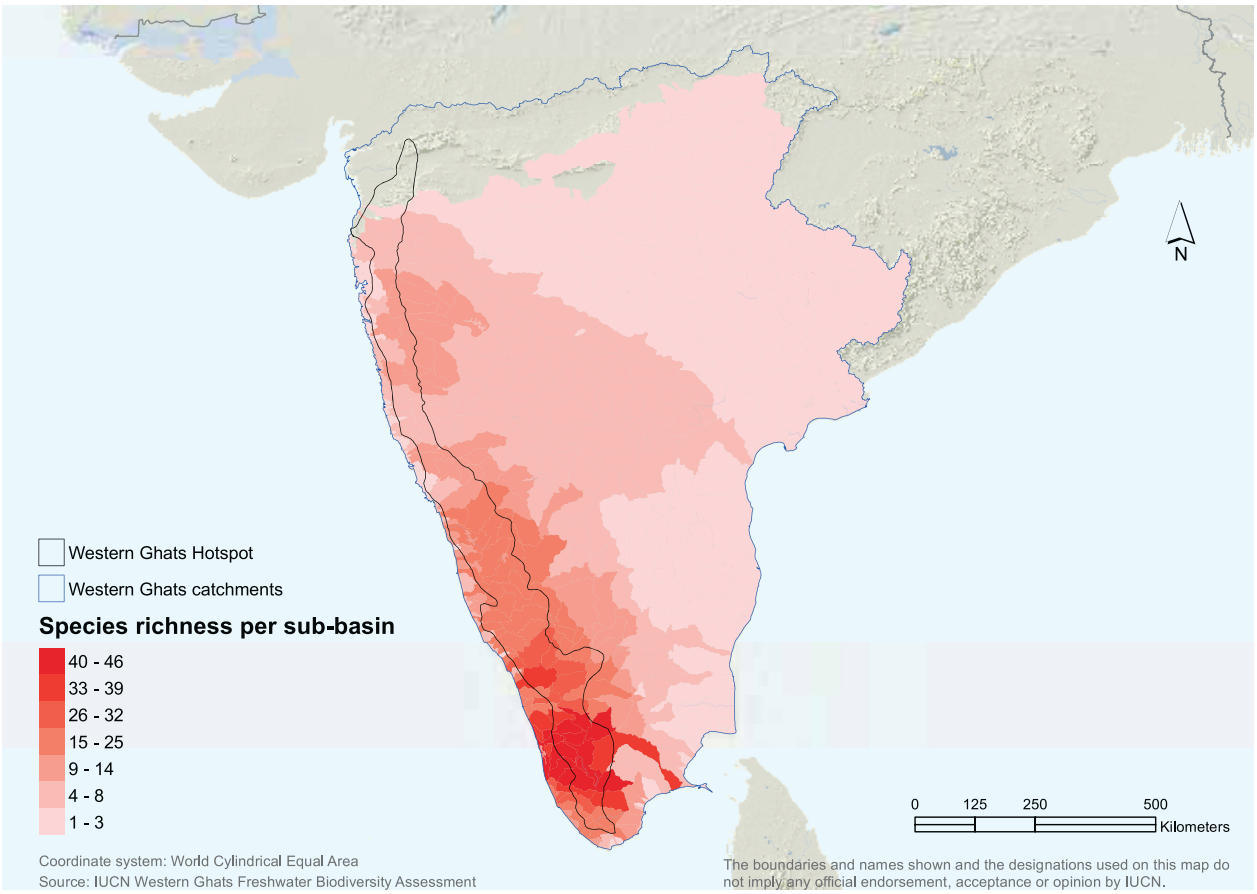

Figure 3.6 Threatened species richness in the Western Ghats assessment region.

Box 1. Periyar Lake-Stream System (Periyar Tiger Reserve): an irreplaceable site for freshwater fish conservation.

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The Periyar Lake-Stream System (PLSS) in the Periyar Tiger Reserve (PTR) harbours six globally threatened endemic freshwater fish species (Radhakrishnan and Kurup 2010) making it an important candidate Alliance for Zero Extinction (AZE) site. One of these six species, *Lepidopygopsis typus*, is monotypic and is the only member of the sub family Schizothoracinae (snow trouts) occurring south of the Himalaya. The ichthyofauna of the PLSS is however threatened by a variety of stressors including invasive alien species, increasing tourism and pollution.

Four alien fish species *Clarias gariepinus*, *Cyprinus carpio*, *Oreochromis mossambicus* and *Poecilia reticulata* are known to occur in the Periyar Lake (Radhakrishnan and Kurup 2010). Recent surveys in the upper streams of the Periyar River have recorded large shoals of *O. mossambicus* (K. Krishnakumar *pers. comm*.) indicating that alien fish species are colonizing new areas in the PLSS. None of these four species have been deliberately introduced into the PLSS, and so how they arrived remains unknown. Two of these species, *C. carpio* and *O. mossambicus* now dominate the fishery of Periyar Lake and are known to compete with Endangered species such as *L. typus* and *Crossocheilus periyarensis* (Arun 1999, Kurup *et al.* 2006). The biggest future challenge to fish conservation in PLSS will be the management and control of *C. gariepinus*, whose opportunistic strategy and ability to establish large and persistent populations makes it an imminent threat. The only native cichlid of PLSS, *Etroplus maculatus* was last recorded around 50 years ago (Abraham 1962). This species shares the same trophic niche with the exotic *O. mossambicus* and therefore, could have been exterminated from the Lake ecosystem by the proliferation of this invasive species.

The growing tourism industry in PTR is yet another threat to the fish fauna of PLSS. Approximately 0.4 million tourists visit the Periyar Lake annually. Large tourist boats as well as speed boats use the lake for sight seeing, discharging oil into the lake. In addition, the sewage waste from in and around Kumily town is discharged directly into the lake leading to high levels of nitrate, nitrite, phosphate, faecal coliforms, hydrocarbon and lead (Kurup 2004). Such large scale pollution may lead to severe disturbances to the habitats and physiological imbalances in several species of fish, subsequently leading to their population decline and extirpations.

Godavari River basin shows a relatively low endemism of freshwater fish species. Even though this pattern can be partly attributed to the Godavari and Krishna river systems being connected at their estuaries, it is more likely that the currently known species richness of this area is a gross underestimate. Further more, it is important to note that very few extensive taxonomic reviews of this river system have been conducted since Hora and Misra (1939). Three species, *Parapsilorhynchus prateri* (CR), *Puntius fraseri* (EN) and *Tor kulkarnii* (EN), which are endemic to the Godavari River basin, are assessed as threatened. Another species, *Clupisoma bastari*, endemic to the Godavari, is assessed as Data Deficient owing to limited information on its distribution and population trends.

Southern Deccan Plateau ecoregion

The Krishna River basin of the Southern Deccan Plateau ecoregion is one of the largest river basins in peninsular India. As a result, most species in this ecoregion are widely distributed. Nevertheless, at least 15 species of freshwater fish are endemic to this ecoregion. Some of the endemic species, such as *Garra bicornuta* (NT), *Hemibagrus maydelli* (LC) and *Nemacheilus rueppelli* (LC) are widely distributed in the Krishna River system, while others such as *Botia striata* (EN) and *Parapsilorhynchus discophorus* (VU) are relatively restricted in their distribution, and *Osteobrama bhimensis* (EN) and *Parapsilorhynchus elongatus* (EN) are point endemics that are found in the upper streams of the Bhima River, a major tributary of the Krishna River system. A number of endemic species including *Gagata itchkeea* (VU) and *Glyptothorax trewavasae* (VU) are suggested to have fragmented populations in the Krishna River system.

An endemic Endangered species, *Glyptothorax poonaensis*, has not been recorded from its type locality in the Mula-Mutha River of Pune since its discovery and is suspected to be locally extirpated (Kharat *et al.* 2003). In the absence of authentic reports of *G. poonaensis* from the Southern Deccan Plateau ecoregion for 70 years, the species was recently rediscovered here (Dahanukar *et al.* 2011). Unfortunately, increasing urbanization, deforestation, mining, pollution, alterations in the hydrological regime, and alien species are threatening the existence of the rediscovered population. *Psilorhynchus tenura*, a species assessed as Critically Endangered, owing to its restricted distribution in the upper catchment of the Tunga River and threats to the habitat, is a biogeographic puzzle as its closest relatives are distributed in Southeast Asia. Another Critically Endangered species, *Puntius deccanensis*, is restricted to a small lake in Pune, Maharashtra. Three endemic species of the Krishna River system, *Barilius evezardi*, *Eutropiichthys goongwaree* and *Neotropius khavalchor*, have been assessed as Data Deficient owing to limitations in the available data making assessment of the species difficult. *N. khavalchor* is possibly a widely distributed species; however, it is extremely rare and might only exist in fragmented populations, which could be the possible reasons why Menon (2004) suggested it to be a threatened species.

Southern Eastern Ghats ecoregion

The Southern Eastern Ghats ecoregion has several coastal river basins along with the Cauvery and Tambraparni rivers. It also holds a number of endemic species restricted to different river systems. For example, *Salmophasia belachi* (VU), a species of razorbelly minnow, is restricted to a reservoir on the Mysore plateau, *Puntius tambraparniei* (EN) is endemic to the Tambraparni River. *Puntius rohani* is a recently described species from the *Puntius filamentosus* complex, and is assessed as Vulnerable owing to its restricted distribution in the Kodayar River and possible threats to its habitat.

Western Ghats ecoregion

The Western Ghats ecoregion has the highest number of endemic species (Figure 3.3), with several point endemics. Several genera, such as *Betadevario*, *Dayella*, *Horabagrus*, *Lepidopygopsis* and *Travancoria* are also endemic to this ecoregion. While this ecoregion extends throughout the western face of the Western Ghats mountain ranges, its southern part is apparently richer in endemic species. This ecoregion spreads across the coastline of four states in India, namely Maharashtra, Goa, Karnataka and Kerala, from north to south. The Western Ghats ecoregion of Maharashtra is relatively less well studied and our understanding of the fish fauna of the area is poor. Similarly, even though the Goa part of the Western Ghats ecoregion is also very poorly explored, three species endemic to the Western Ghats ecoregion were described from the area. Of these three species, *Ompok goae* (DD) has taxonomic issues regarding its validity and systematic position; *Pangio goaensis* (LC), originally described from Goa is expected to have a wider distribution, even within Kerala; while, *Puntius setnai* (VU) is thought to be restricted only to the area around Goa. The Western Ghats ecoregion in Karnataka State also has several endemic species. *Nemacheilus kodaguensis* (VU) is restricted to the headwaters of the Cauvery River. A recent new genus and species, *Betadevario ramachandrani* (DD), which was descried from the Sita River drainage, indicates that our understanding of the fish diversity, even at the generic level is still far from being complete. Several other recently described species, such as *Batasio sharavatiensis* (EN), *Schistura nagodiensis* (EN) and *S. sharavathiensis* (VU), are also endemic to this area.

The Kerala part of the Western Ghats ecoregion is the most richest in endemic species and is the most diverse area in the entire Western Ghats assessment area. It not only hosts a plethora of endemic species but is also rich in point endemics, such as *Lepidopygopsis typus* (EN) and *Crossocheilus periyarensis* (EN), which are restricted to the Periyar River system. Several other species including, *Horabagrus nigricollaris* (EN), *Horaglanis alikunhii* (DD), *H. krishnai* (DD), *Mesonoemacheilus pambarensis* (VU), *Travancoria elongata* (EN), *T. jonesi* (EN) and *Dayella malabarica* (LC) contribute to the unique fish diversity in this area. This area also hosts a number of species of biogeographical significance as their closest relatives are found in northern India or Southeast Asia (Box 2). For example, a recently described species, *Pseudolaguvia austrina* (DD), is the first member of this genus recorded from southern India. The case of the endemic species *Bhavania australis* (LC) is similar, as the only other currently known species of *Bhavania* is found in northeastern India.

3.3.4 Data Deficient species

Twenty-six of the total 290 species are Data Deficient (Table 3.1). Of these, only two species, *Anabas testudineus* and *Zenarchopterus dispar*, are non-endemic to the Western Ghats assessment region. *Anabas testudineus* has been assessed as Data Deficient owing to taxonomic problems and the possibility that it is a species complex. It has been suggested that *Zenarchopterus dispar* is threatened in India because of its record from a single location, the Vembanad Lake. However, it is assessed as Data Deficient owing to lack of information about its status in Sri Lanka.

The highest numbers of Data Deficient species are found in the Bhavani, Bharatapuzha, Chalakkudy, Periyar, Pambar and Pamba river systems in the Kerala part of the Western Ghats ecoregion and in the upper tributaries of the Bhima River, a major tributary of Krishna River system, in the Southern Deccan Plateau ecoregion (Figure 3.7). The majority of Data Deficient species are distributed along hill streams in the Western Ghats Biodiversity Hotspot, which still harbour many undescribed new species.

Out of the total 24 endemic species, nine species, *Barilius evezardi*, *Neotropius khavalchor*, *Eutropiichthys goongwaree*, *Clupisoma bastari*, *Hypselobarbus lithopidos*, *Horaglanis krishnai*, *Monopterus eapeni*, *Monopterus roseni* and *Carinotetraodon imitator* have been

Glyptothorax davissinghi (EN), *Nemacheilus menoni* (VU) and *Pseudeutropius mitchelli* (EN). © Rajeev Raghavan/K. Krishnakumar/ Anvar Ali.

Box 2. Biogeographically important fish fauna of the Western Ghats and its conservation implications.

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Several species, including *Balitora mysorensis*, *Bhavania australis*, *Botia striata*, *Channa diplogramma*, *Lepidopygopsis typus*, *Pseudolaguvia austrina*, *Psilorhynchos tenura*, *Rohtee ogilbii*, *Schismatorhynchos nukta* and *Thynnichthys sandkhol*, which are endemic to the Western Ghats and associated river drainages have their closest relatives in Eastern Himalaya or Southeast Asia. This apparent Malayan affinity in the fish fauna of the Western Ghats is an enduring evolutionary conundrum that has fascinated ichthyologists (Hora 1944, Silas 1952, Jayaram 1977). Hora (1944), proposed the Satpura Hypothesis to explain this apparent disjunct distribution by suggesting that the Satpura Hill ranges in peninsular India connected the Malaya peninsula with the Western Ghats, and created passage for dispersal of species into the Western Ghats. Although the Satpura Hypothesis did not survive the growing evidence from further surveys, taxonomic revisions and recent work on phylogeny (including molecular phylogeny), our current understanding of factors affecting this disjunct distribution is still far from being complete. Karanth (2003) suggested that it is essential to first establish whether the apparent disjunct distributions are really true disjuncts or false disjuncts based on innacurate taxonomy. Recently, based on molecular phylogeny, Benziger *et al.* (2011) showed that the disjunct distribution seen in *Channa diplogramma*, with its close relatives in Southeast Asia, is indeed a true disjunct distribution, which can be possibly explained by vicariance. If this is true then it is possible that the fauna of the Western Ghats and its associated river drainages might represent relict populations of once widespread species (Jayaram 1977, Karanth 2003).

Channa diplogramma (VU) a species endemic to the southern Western Ghats has its closest relative *C. micropeltes* distributed in Southeast Asia. Adapted from Benziger *et al.* (2011).

Today, it is commonly accepted that India once formed part of ancient Gondwanaland, and was separated from other parts of this landmass approximately 150 mya (Kohler and Glaubrecht 2007). India-Madagascar rifted from eastern Africa 158-160 mya followed by the separation of peninsular India from Madagascar around 84-96 mya (Briggs 2003a). Eventually, it collided with Eurasia approximately 50 mya (Kohler and Glaubrecht 2007). The drifting Indian landmass has been perceived as a 'biotic ferry' and an evolutionary reservoir for Gondwanan groups (Briggs 2003b). The 'biotic ferry model' (Briggs 2003b) became the standard explanation for the evolution of distributional and genealogical patterns of groups with recent distributions in Africa, Madagascar, and India. Based on this model, a number of studies have suggested that Gondwanan lineages colonized South and Southeast Asia out of India (Bossuyt and Milinkovitch 2001, Wilkinson *et al.* 2002) and is usually referred to as the 'out of India' scenario (McKenna 1973). The cichlids of India (*Etroplus suratensis*, *E. canarensis* and *E. maculatus*) are known to be an example of Gondwanan teleost forms (Silas 2010, Sparks 2004).

Etroplus suratensis. © Rajeev Raghavan

assessed as Data Deficient due to the lack of sufficient information on current distributions and impacts of threats. *Barilius evezardi* and *Neotropius khavalchor* are restricted to the Krishna River system, while *Eutropiichthys goongwaree* is endemic to the Krishna and Pennar river systems of the Soutern Deccan Plateau ecoregion. *Neotropius khavalchor* is a lepidophagous species (eats scales of other fish species) and has been treated as threatened by Menon (2004). *Clupisoma bastari* is endemic to the Godavari River basin of the Northern Deccan Plateau ecoregion, while *Horaglanis krishnai*, *Monopterus eapeni*, *M. roseni* and *Carinotetraodon imitator* are endemic to the southern parts of the Western Ghats ecoregion. Three species *Horaglanis krishnai*, *Monopterus eapeni*, and *M. roseni* are subterranean and very little information is available on their distribution, population status and threats (Box 3). The distribution of *Hypselobarbus lithopidos* is difficult to determine and the exact type locality of *Carinotetraodon imitator* is not known as it was described using specimens from the aquarium trade (Britz and Kottelat 1999).

Seven species have been assessed as Data Deficient based on them being only recently described and known only from their type descriptions. All these species were described from the Western Ghats ecoregion. These species are *Betadevario ramachandrani*, *Glyptothorax malabarensis*, *Monopterus digressus*, *Horaglanis alikunhii*, *Pseudolaguvia austrina*, *Nemacheilus stigmofasciatus* and *Puntius muvattupuzhaensis*. Out of these, two species, *Betadevario ramachandrani* and *Nemacheilus stigmofasciatus*, are distributed in the Sita River drainage of the central Western Ghats ecoregion in Karnataka. *Betadevario ramachandrani* deserves a special mention as a new genus was established through its description (Pramod *et al.* 2010). The remaining five species were described from the Kerala part of the Western Ghats ecoregion. *Pseudolaguvia austrina* was described from the Bharatapuzha River drainage and it is the first representative of northeastern Indian genus *Pseudolaguvia* (Radhakrishnan *et al.* 2010). *Glyptothorax malabarensis* and *Puntius muvattupuzhaensis* are known from Valappattanam, Muvvatupuzha and Periyar river drainages. *Monopterus digressus* and *Horaglanis alikunhii* are subterranean species and the latter is currently known by a single specimen (Babu and Nayar 2004).

Two species, *Heteropneustes longipectoralis*, known from the Bharatapuzha River drainage of the Western Ghats ecoregion, and *Ompok goae*, known from the Western Ghats ecoregion of Goa State, have been assessed as Data Deficient owing to their doubtful taxonomic status. A further six taxa, *Hypselobarbus dobsoni*, *Osteobrama cotio peninsularis*, *Puntius ambassis*, *P. amphibius*, *P. mahecola* and *P. melanampyx* have been assessed as Data Deficient due to their synonymy with other species and frequent confusions in identification. Of these, *Osteobrama cotio peninsularis* is distributed in the Krishna River system of the Southern Deccan Plateau ecoregion. Even though there is doubt about the exact type locality and distribution of *Puntius amphibius*, it is also expected to be distributed in the Krishna River basin of the Southern Deccan Plateau ecoregion. *Puntius*

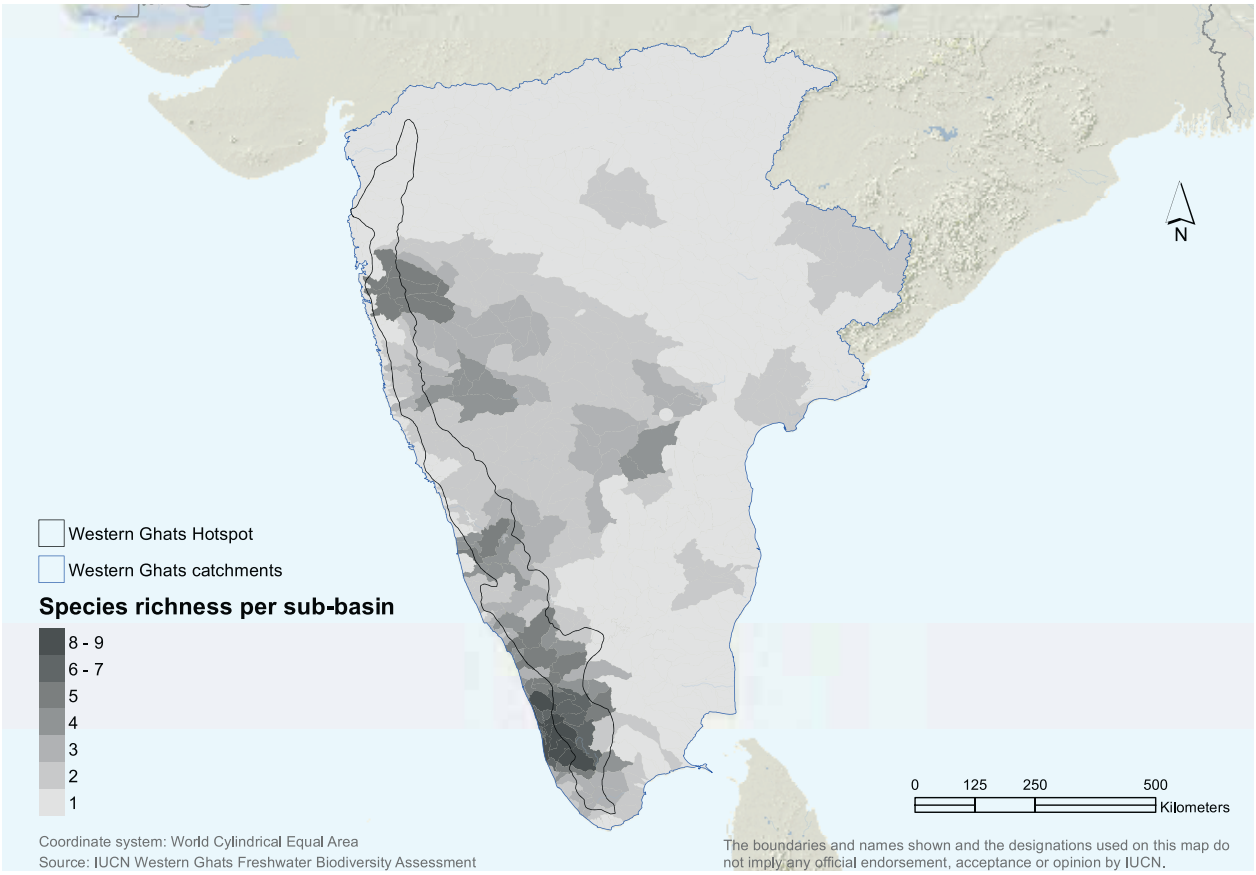

Figure 3.7 Distribution of Data Deficient species of in the Western Ghats assessment region.

Box 3. Subterranean fishes: enigmatic and poorly known.

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In the western periphery of the Western Ghats, subsurface material (mostly laterite) in the underground water-filled zone (water table, phreatic zone), contains networks of hollow spaces through which water flows, and can form subterranean conduits (Vincent and Thomas 2010). These subterranean systems harbour enigmatic and poorly known fish species belonging to the Clariidae and Synbranchidae families. Six species are currently known from the subterranean ecosystems in this region, viz. *Horaglanis alikunhii*, *H. krishnai*, *Monopterus digressus*, *M. eapeni*, *M. roseni* and *Kryptoglanis shajii*. Except for *M. digressus* (Vincent and Thomas 2010), there are very few records of the other five species since their description. Five of the six species have been assessed as Data Deficient. The sixth species, *K. shajii* has been described very recently (Vincent and Thomas 2011) and hence could not be assessed.

Although hypogean fishes are known to be susceptible to many threats including environmental degradation and hydrological manipulation (Fernandez *et al.* 2007), such threats often go unnoticed due to their cryptic nature. In Kerala, the main threats to the subterranean fish species include the indiscriminate introduction of the exotic predatory African catfish, *C. gariepinus* in the homestead wells, and reclamation of laterite soil areas for establishing brick kilns.

Any conservation management plan for these enigmatic fish species should involve local communities and should be based on an integrated approach of awareness, education and monitoring. There is an immediate need for protecting the public wells in and around the lateritic regions of Kerala from where most collections of these subterranean fishes have been made.

Kryptoglanis shajii is a recently described subterranean catfish from a well in Thrissur District, Kerala, southern Western Ghats. © Heok Hee Ng

Pookode Lake an AZE site. © Rajeev Raghavan

mahecola is suspected to be distributed in the Kerala part of the Western Ghats ecoregion and is known from Chalakkudy, Periyar and Neyyar river systems. The distributions of the remaining species are difficult to identify.

3.4 Threats to freshwater fishes of the Western Ghats

Deforestation and drainage basin alteration, river regulation, pollution, over-harvesting, invasive alien species and climate change are threatening freshwater ecosystems throughout monsoonal Asia (Dudgeon 2000a, 2000b, Ficke *et al.* 2007) including the Western Ghats (Dahanukar *et al.* 2004, Raghavan *et al.* 2008b, 2011). Analysis of threats affecting both threatened and non-threatened species suggests that pollution is the most important threat to the species in the Western Ghats assessment region followed by biological resource use, invasive alien species, residential and commercial development and natural system modifications (see chapter 7 for the quantitative analysis of threats). Pollution from domestic and urban waste water threatens the greatest number of species followed by agricultural and forestry effluents, and industrial and military effluents. Fishing and over harvesting are also major threats.

3.4.1 Pollution

Asian streams and rivers are grossly polluted and some are among the most degraded in the world (Dudgeon 2000a). Industrial, domestic sewage, and pesticide pollution have been causing serious impacts to fish life in many rivers of the Western Ghats assessment area. Most industries in India that are known to discharge into rivers lack operational waste treatment plants (Dudgeon 2000a), and those in the Western Ghats assessment area are no exception.

Studies of the effect of pollution on the fish and fisheries of the Western Ghats assessment area have been undertaken for many years, for example, David's (1956) comprehensive account of industrial pollution of the Bhadra River at Bhadravati. David (1956) observed both severe mortality and pathogenic conditions such as necrosis in fish populations subjected to industrial pollution. Chemical pollution from factories and plants situated in the Nilgiris, Mysore and Kodagu regions of the Western Ghats are known to have exterminated certain groups of hill stream fishes in the local aquatic habitats (Pandey and Das 2002) with certain neomacheline loaches recorded from the Bhavani River in Mettupalayam and Coimbatore districts reported to be no longer present (Pandey and Das 2002). The Western Ghats is home to a large number of tea and coffee plantations in the states of Kerala, Tamil Nadu and Karnataka. Pesticides including Endosulfan and derivatives of copper sulphate are being widely used in these plantations to protect the crops. Many freshwater fish species collected from first and second order streams flowing through tea plantations in Valparai in the Anamalai Hills of the Western Ghats were seen to be affected by fin and tail rot, and body ulcerations (Raghavan *et al.* 2008a). The presence of vast areas of rubber plantations and rubber related factories in the hills of central Kerala is another cause for concern. These factories are known to discharge the raw effluents and pesticides into streams that feed the larger rivers. The dumping of acidic waste from rubber plantations into streams has been recorded in the Ashambu Hills of the southern Western Ghats (Abraham *et al.* 2011). Even though this type of pollution has been found to cause fish kills and reduce fish diversity, focused studies are lacking. Kharat *et al.* (2003) suggested that organic and inorganic pollution in the Mula-Mutha River of Pune might have contributed to a decline in the populations of several species including *Labeo boggut* (LC) and *Proeutropiichthys taakree* (LC), both species described from this area 150 years ago. Ghate *et al.* (2002) stated that pollution could be a major factor leading to severe decline in the population of the endemic *Schismatorhynchos nukta*, now assessed as Endangered. Industrial pollution of rivers and its possible effects on biological diversity has also been discussed for other rivers including the Tapi (Shrivastava and Patil 2002), Narmada (Jain *et al.* 2008) and Kalu of Mumbai (Mhatre *et al.* 1980).

3.4.2 Biological resource use

Intensive harvesting of the fish resources for food and the aquarium pet trade is the second biggest threat to fishes of the Western Ghats. In Kerala, several food fish species have shown population declines of varying levels due to unmanaged exploitation. These include *Horabagrus brachysoma* (VU) (estimated 35% decline over the past 10 years), *Tor khudree* (EN) (60-70%), *T. malabaricus* (EN) (50-60%), *Hypselobarbus curmuca* (EN) (50%), *H. dubius* (EN) (30%), *H. kolus* (VU) (>30%) and *H. micropogon* (EN) (50%). Recent studies have demonstrated that *T. khudree* is subjected to unsustainable levels of harvest, and that the commercial fishery for this species in a few reservoirs of Kerala are in imminent danger of collapsing (Raghavan *et al.* 2011). Similarly, Prasad (2008) showed that *H. brachysoma* is being overfished in the Periyar River through artisanal fishery. Kharat *et al.* (2003) have suggested that overfishing has wiped out populations of *Labeo fimbriatus* (LC), *Schismatorhynchos nukta* (EN), *Tor khudree* (EN) and *Silonia childreni* (EN) from the Mula-Mutha rivers of the Southern Deccan Plateau ecoregion, while populations of other species such as *Labeo boggut* (LC), *Bangana ariza* (LC), *Proeutropiichthys taakree* (LC) and *Wallago attu* (NT) have also severely declined.

Unmanaged collection and trade of endemic freshwater fish for the aquarium pet trade is an emerging conservation issue in the Kerala part of the Western Ghats (Raghavan 2010). The fishery for native ornamental fish in the streams of Kerala is open access and devoid of any quotas or restrictions. A classical example of population decline of endemic freshwater fishes associated with the aquarium pet trade is that of the Red lined torpedo barbs *Puntius denisonii* (EN) and *P. chalakkudiensis* (EN). These two species are known to be overexploited in at least three rivers of the region from where they are collected for the pet trade (Raghavan *et al.* in preparation). The population decline of *P. denisonii* in various river systems ranges from 25 to 70% (Ali *et al.* 2010).

Fishing in the Bhavani River. © CRG

3.4.3 Invasive and other problematic species

Invasive species have been identified as another major threat to the fishes of the Western Ghats. Thirteen species of exotic fish, including *Clarias gariepinus*, *Cyprinus carpio, Oncorhyncus mykiss, Pangasianodon hypophthalmus*, *Oreochromis niloticus*, *O. mossambicus*, *Osphronemus goramy*, *Pterygoplichthys multiradiatus, Piaractus brachypomus, Trichopodus trichopterus*, *Xiphophorus maculatus, Poecilia reticulata* and *Gambusia affinis*, are currently distributed across river basins in the Kerala part of the Western Ghats, an area showing both highest number of endemics (Figure 3.2) and threatened species (Figure 3.6). Several of these species were introduced during the colonial times for enhancing fisheries in reservoirs, while others are typical invaders which may have escaped from illegal aquaculture facilities, live fish markets, home aquaria and/or ornamental fish breeding units. Of the 13 species, four (*C. carpio*, *O. mykiss*, *G. affinis* and *O. mossambicus*) are listed in the '100 of the World's Worst Invasive Alien Species' database (Lowe *et al.* 2000), while others have earned notoriety as pests in various regions of the world (Raghavan *et al.* 2008b). Most of these invasive species also occur in other parts of the Western Ghats assessment area and have been documented to affect local fish fauna adversely (Kharat *et al.* 2003, Knight 2010).

A classical example of an invasion facilitated by (illegal) aquaculture is that of the African catfish, *C. gariepinus*. African catfish escapees from aquaculture facilities located in various parts of Kerala have now started to appear in fish catches in rivers and lakes (Krishnakumar *et al.* 2011). Basheer (2003) reported that *C. gariepinus* is commonly caught by fisherman in the lower reaches of the Periyar River, while the Periyar Foundation (2006) indicates that this species is slowly appearing in commercial catches from Periyar Lake. Dahanukar *et al.* (2011) suggested that *C. gariepinus*, found in the Indrayani River of the Southern Deccan Plateau ecoregion, is a potential threat to the only existing population of the rare and Endangered sisorid catfish *Glyptothorax poonaensis*.

Recently, it was suggested that the aquarium trade is an important vector for exotic species in Kerala and that propagule pressure maybe an important determinant for invasion success (Krishnakumar *et al.* 2009). Four of the most popular and intensively marketed varieties of tropical aquarium fish species, *Pterygoplichthys multiradiatus, Trichopodus trichopterus, Xiphophorus maculatus* and *Poecilia reticulata* now show widespread distributions in the natural water bodies of the region ranging from high altitude streams to low land rivers, and natural lakes (Raghavan *et al.* 2008b, Krishnakumar *et al.* 2009). The most recent case of aquarium fish invasion in the natural waters of Kerala is that of the Amazonian pacu

The Red Lined Torpedo Barb *Puntius denisonii* (EN) which is overexploited for the pet trade. © William Darwall

An alien invasive species tilapia, *Oreochromis mossambicus*, dominates the fish catches in most of the rivers in the Western Ghats. © Neelesh Dahanukar

Alien carp such as *Cyprinus carpio* and *Hypophthalmichthys molitrix* create resource competition for native species. Fish collected from Dhom reservoir sold in the market of Wai. © Mandar Paingankar

Piaractus brachypomus, in the Chalakkudy River. Citing local fishers, Sudhi (2009) reported that at least 10-15 individual pacu's (maximum weight of 150g) are being netted daily from the various fish landing centres located in this river. These exotic species affect the native fish species through increasing competition for resources. One such example is the affect of *Poecilia reticulata* and *Gambusia affinis* on the native species *Aplocheilus lineatus*. Kharat *et al.* (2003) suggested the decline in *A. lineatus* populations in the Mula-Mutha River was due to the introduced species *P. reticulata* and *G. affinis* which share the same niche as *A. lineatus*.

In the last 10 years the Indian carps, *Catla catla, Labeo rohita* and *Cirrhinus mrigala* have been regularly released into the major rivers (Santha 2007) and reservoirs of Kerala as a means to increase inland fish production in the state (Nandakumar 2010). State fisheries officials often argue that these species probably don't breed under the ecological conditions of the local rivers, and serve to reduce fishing on indigenous fish varieties (Santha 2007). However, local fishers are critical of the introduction of transplanted carp as they believe that, in the long run, the exotic varieties could endanger the indigenous fish species (Santha 2007). Recently a proposal by the Kerala Fisheries Department to release Indian major carp in 16 reservoirs, several of them located inside protected areas, has met with strong opposition from conservationists and environmental activists (Nandakumar 2010).

3.4.4 Residential and commercial development

Residential and commercial developments are affecting many freshwater fish species. This includes endemics such as *Botia striata* (EN), *Gagata itchkeea* (VU), *Garra bicornuta* (NT), *Horadandia atukorali* (LC), *Monopterus indicus* (VU), *Mystus oculatus* (LC), *Neotropius khavalchor* (DD), *Puntius sharmai* (EN), *Rita gogra* (LC), *Rohtee ogilbii* (LC) and *Tor malabaricus* (EN) which are impacted by housing and urban areas. Commercial and industrial areas have been suggested to affect the populations of *Aspidoparia morar* (LC), *Eutropiichthys goongwaree* (DD), *Hemibagrus maydelli* (LC) and *Monopterus fossorius* (EN). Tourism and recreational areas are also impacting many endemic species such as *Garra surendranathanii* (EN), *Horabagrus nigricollaris* (EN), *Hypselobarbus periyarensis* (EN), *Nemacheilus triangularis* (LC), *Osteochilus longidorsalis* (EN), *Parapsilorhynchus elongatus* (EN), *Puntius tambraparniei* (EN) and *Travancoria elongata* (EN).

3.4.5 Natural system modifications

Natural system modifications caused by large dams and deforestation leading to siltation and sedimentation, and sand mining can adversely affect fish populations by altering or eliminating suitable habitats. Dams block the migration of fishes and can severely affect species which swim upstream to

Garra surendranathanii (EN), which may be threatened by the construction of a hydropower dam on Chalakkudy River © Rajeev Raghavan

Tourism on Periyar Lake. © CRG

breed (for example *Anguilla bicolor* (LC)). Dams also change downstream flow regimes altering habitat conditions and impacting species life cycles, they also create resevoirs or semi-lacustrine conditions, which are highly disliked by hill stream fishes adapted to rapid flowing water (for example species of the genus *Glyptothorax*). Dams have been built across all the major river systems of Kerala in the southern parts of the Western Ghats, creating around 53 reservoirs (Harikumar and Rajendran 2007) which obstruct the free movement of freshwater fish across these basins. The Periyar and Chalakkudy, two rivers in Kerala harbouring the highest numbers of threatened fish species have been dammed extensively. At least 16 dams have been built across the river Periyar in Kerala (http://expert-eyes.org/dams.html) and six dams have been built across the Chalakkudy (Raghavan *et al.* 2008a). Currently a proposal to construct a seventh dam at Athirapally has turned controversial. This project, if implemented, will have catastrophic impacts on the habitats of two Endangered endemic species (*Horabagrus nigricollaris* and *Travancoria elongata*). In the northern parts of the Western Ghats, large river systems including the Godavari and Krishna are also dammed extensively. Dahanukar *et al.* (2011) suggested that dams may threaten the existing population of the Endangered endemic sisorid catfish *Glyptothorax poonaensis* that is adapted for fast flowing hill steams by creating semi-lacustrine conditions.

Deforestation within drainage basins leads to increased sedimentation which causes degradation of lakes and rivers (Brewer *et al.* 2001 cited in Dudgeon 2003). Such alterations can affect the river bed habitat, by covering it in sediment which can degrade the breeding substrate of many fishes. The Kerala part of Western Ghats has been affected by habitat alteration due to indiscriminate deforestation and subsequent conversion of forest area into plantations for tea, coffee, rubber and cardamom. An annual decline of 0.9% in natural forest cover has been recorded in Kerala State during the period 1961-1988 (Prasad *et al.* 1998). The loss of forest cover at such alarming rates has important implications for freshwater fishes since a significant proportion of the riverine fish species of this region exploit allochthonous food resources (Arunachalam 2000). Severe deforestation is also affecting the Western Ghats of Maharashtra with almost 11% loss of dense forest during the period 1985-2005 (Panigrahy *et al.* 2010). Such deforestation, especially on the mountain tops, is likely to affect hill stream species belonging to genera including *Parapsilorhynchus* and *Nemacheilus* which require pebbles and gravel in the upstream areas where they migrate for breeding.

Sand mining is another threat affecting the breeding grounds of fishes, and is common in most of the rivers of the Western Ghats assessment area. In the Indrayani River of the northern Western Ghats, severe sand mining is a major threat to existing populations of *Glyptothorax poonaensis* (EN) (Dahanukar *et al.* 2011). Padmalal *et al.* (2008) have also documented extensive sand mining in the rivers draining the Vembanad Lake, Kerala, leading to 7-15 cm lowering in the river bed annually.

3.4.6 Other threats

Other factors such as agriculture and aquaculture, energy production and mining, transportation and service corridors, human intrusions and disturbance, and climate change and severe weather have also been identified as potential threats

Barrage on Valappattanam River, Kerala. © Rajeev Raghavan

Extensive sand mining is practiced in several rivers of southern India. Photograph taken at Indrayani River downstream of Markal in the Southern Deccan Plateau ecoregion where sand mining threatens species such as *Glyptothorax poonaensis* (EN). © Mandar Paingankar

to the fishes across the region. Agriculture and aquaculture have been identified as a potential threat to *Bhavania australis* (LC), *Hypselobarbus pulchellus* (CR), *Osteochilus longidorsalis* (EN), *Pseudosphromenus dayi* (VU), *Puntius cauveriensis* (EN) and *P. mudumalaiensis* (VU), through cultivation of annual and perennial non-timber crops, wood and pulp plantations, livestock farming and ranching and marine and freshwater aquaculture. Energy production and mining is suggested to be a potential threat to a number of species including *Glyptothorax housei* (EN), *Hypselobarbus thomassi* (CR), *Laubuca fasciata* (VU), *Lepidocephalus coromandelensis* (LC), *Nemacheilus petrubanarescui* (EN), *Psilorhynchus tenura* (CR) and *Thynnichthys sandkhol* (EN). Transportation and service corridors are identified as a potential threat to the Critically Endangered *Barbodes wynaadensis*. Climate change and severe weather is suggested as a threat to *Labeo kontius* (LC), *Batasio travancoria* (VU), *Devario neilgherriensis* (EN), *Mystus armatus* (LC) and *Barbodes wynaadensis* (CR).

Agricultural practices in swamps are a threat to some indigenous fish. © Keystone Foundation.

3.5 Conservation actions and recommendations

In spite of high endemism and threat levels, the fish fauna of Western Ghats are still poorly known. We still lack an understanding regarding the life history traits, population and ecology of most if not all of the native freshwater fishes of the region. This lack of knowledge has greatly impeded our ability to conserve these species and their habitats. The multi-stakeholder issues surrounding freshwater use in this region have also meant that native species fisheries are not valued highly. As a result, freshwater fishes occupy only a marginal space in the mind's of both the policy makers as well as the general public. As with other regions of the world, ecosystem services such as drinking water, irrigation and hydroelectric power are valued more highly than the fish fauna in the Western Ghats. All this has resulted in little or no investment towards conservation and management of freshwater fishes within the Hotspot.

Protection of freshwater biodiversity is a conservation challenge and a combination of strategies will be essential to conserve freshwater ecosystems and the taxa that inhabit them in the long term (Dudgeon *et al.* 2006). This applies in particular to the freshwater fishes and their highly threatened ecosystems in the Western Ghats.

3.5.1 Riparian reforestation

Given the importance of riparian zones and allochthonous food sources to the stream biota (Dudgeon 1999), there is a need to promote the regeneration of riparian vegetation along the river basins of the Western Ghats. Planting of indigenous tree species along the river margins can protect and stabilize the river margins. Regeneration of natural forests must be attempted in the adjacent areas of the riparian forest (Bachan 2003). Strict laws need to be developed and implemented to curb tree felling and deforestation in the Western Ghats eco-region. This would need to be subsequently supported by social forestry and afforestation programmes.

3.5.2 Management of dams

Rapidly increasing human populations and the need for energy sources in the states encompassing the Western Ghats has led governments to put forward plans for constructing new hydroelectric power projects. With a view to protecting riverine ecosystems and their endemic and threatened biota, construction of large dams should first consult the data provided through this current assessment to identify species at risk to such developments, undertake a full and comprehensive environmental impact assessment, and follow the framework set out in the World Commission on Dams report (World Commission on Dams 2000). In addition, attempts should be made to construct appropriate fish passages and ladders in the existing dams. Environmental impact assessments by neutral parties should be made mandatory before commissioning any kind of structure that impacts river flow or regulation.

3.5.3 Control over sand mining

Following detailed studies on the impacts of sand mining on the riverine ecosystems of Kerala, Padmalal *et al.* (2008) suggested many management measures including: an integrated environmental assessment; a management and monitoring programme for the sand extraction processes; physical, chemical and biological studies on the impacts of instream mining on a river basin scale, and; encouragement of alternatives to river sand for construction purposes. We support these recommendations.

3.5.4 Better control of water pollution

As the Western Ghats is the Global Hotspot with the highest human population density (Cinacotta *et al.* 2000) and population pressure (Shi *et al.* 2005), pollution from anthropogenic sources will no doubt increase. It will thus require a combination of strategies including: improved enforcement of pollution laws; best management practices for crop and livestock production; as well as construction of effluent treatment plants for the industry.

A programme was initiated in 1993–94 to identify polluting industries along the country's rivers in an effort to control industrial discharges (Ghosh and Ponniah 2008). The National River Conservation Authority (NRCA) in 1997 took a decision to identify the heavily polluting industries that were discharging effluents into rivers and lakes without the requisite effluent treatment systems, and to serve notice on them to comply with the requisite norms or face closure (Ghosh and Ponniah 2008).

In India, there are three Acts (River Boards Act 1956, Water Cess Act 1977, and Water Act 1974 amended in 1979) that have some form of regulatory control on fish habitat management. According to the River Boards Act, River Boards have to regulate and develop interstate rivers and river valleys. River Boards are responsible for: i) conservation, control and optimum utilisation of water resources of interstate rivers; ii) promotion and operation of schemes for irrigation, water supply, drainage, flood control, reforestation and navigation; and iii) control of soil erosion and prevention of pollution of waters of interstate rivers (I.7). The Water Cess Act (prevention and control of pollution) authorizes Water Boards and local authorities to levy and collect cess (a form of tax) on water consumed by persons engaged in certain industries, to augment their resources. The Water Act, defines water pollution, sewage effluents, sewer, industrial effluents, and streams. It was enacted to establish Central and State Water Boards. The functions of Central Boards are mainly advisory and supervisory, while the State Boards functions are more comprehensive (Ghosh and Ponniah 2008).

The Environment (Protection) Act, 1986 is an umbrella legislation that empowers the Government of India to take necessary measures to protect and improve the quality of the environment (http://www.envfor.nic.in/unccd/book01/UNCCD_BOOK.pdf). Beside these legislative measures, a National Conservation Strategy and Policy Statement on Environment and Development, 1992; National River Policy, 1988; a Policy Statement on Abatement of Pollution, 1992; and National Environment Policy, 2006, have also been drawn up. The National Environment Policy (NEP), 2006, is intended to be a guide to action in regulatory reform, programmes and projects for environmental conservation and review and enactment of legislation, by agencies of the central, state and local governments (Ghosh and Ponniah 2008).

3.5.5 Management of invasive species

Detailed investigations on the spread and impact of invasive species in the drainages of the Western Ghats are urgently needed. At least 300 exotic aquarium species are imported and traded in India, without any regulation. Although the aquarium trade industry is well organized, those concerned with its environmental soundness are not (Knight 2010). Thus, collaboration with the industry is essential for educating buyers, sellers, and the public, certifying stock, and preventing aquarium species from being released. In Periyar Lake, Kerala, the State Department of Forest and Wildlife, is promoting the fishery of invasive species including *O. mossambicus* and *C. carpio* as a means to control their proliferation. Practices

such as these must be given more attention, and strategies designed to improve their effectiveness. It is widely accepted that prevention is the most effective means of reducing the future costs of invasive alien species. There is an urgent need to formulate and implement a national level policy on the introduction of exotic species and their management. Risk assessment studies also need to be taken up for 'sleeper species', species that are yet to demonstrate their invasive capacity, but are deemed to have the potential to spread and have adverse impacts (De Milliano *et al.* 2010).

3.5.6 Education and community engagement

Conservation of freshwater fish resources, especially endemic species depends on stewardship and knowledge. An integrated approach of awareness, capacity building, monitoring and policy interventions is the key to conserving the freshwater fishes of Western Ghats. Recently, local fishers have been integrated into the research process for a participatory stock assessment of the Endangered Deccan mahseer, *Tor khudree* in Kerala (Raghavan *et al.* 2011) laying the foundation for co-management. The Kerala State Biodiversity Board has also started an initiative for river conservation involving local communities. This river fish monitoring program, envisaged to be an annual event aims to mobilize public participation and support for river monitoring and conservation (Kumar *et al.* 2010).

3.5.7 Flagships and conservation marketing

One of the ways that conservation organizations can create awareness and build public participation is through the use of flagship species, popular charismatic species that serve as symbols and rallying points to stimulate conservation awareness and action (Walpole and Leader-Williams 2002). The concept of 'state fish' was mooted by the National Bureau of Fish Genetic Resources, which 16 states have subsequently adopted (Devi 2010).

The Deccan mahseer, *Tor khudree,* and the red lined torpedo barb, *Puntius denisonii,* are two charismatic species endemic to the Western Ghats which can be used as potential flagships for raising the profile of freshwater ecosystems and their conservation.

3.5.8 Captive breeding and ranching

The Tata Power Company Ltd., Lonavla, Maharashtra conducted some pioneering work on the conservation, breeding and artificial propagation of mahseers and standardized the commercial seed production of five species, viz. *Tor khudree* (EN), *T. tor* (NT), *T. putitora* (EN) and *Hypselobarbus mussullah* (EN), and augmented the mahseer stocks in the reservoirs and rivers of the Western Ghats by supplying fry and fingerlings (Ogale 2002). The Regional Agricultural Research Station (RARS), Kumarakom, Kerala in collaboration with the National Bureau of Fish Genetic Resources (NBFGR) have also developed captive breeding protocols for several important food fishes of the southern Western Ghats including *Horabagrus brachysoma* (VU), *Labeo dussumieri* (LC), *Hypselobarbus curmuca* (VU) and *Etroplus suratensis* (LC), and have subsequently ranched them in the Vembanad Lake and its confluent rivers (Devi 2010). Captive breeding technology has also been developed for thirteen species of ornamental fish (Mercy 2006) but has been of little use in conservation and management (Raghavan 2010). Almost half the number of species for which captive breeding technology has been developed are either abundant in the wild (Least Concern species), or fetch lower prices when compared to some of the popular, rare and threatened species (Raghavan 2010).

3.5.9 Identifying KBAs/community and conservation reserves

Identifying, and focusing conservation actions on, key sites or areas are one of the most effective means to reduce biodiversity loss (Darwall and Vié 2005). Protected areas that can act as no-take zones, refugia or closed areas for fishing can be set up to protect individual or multiple threatened species. Community or conservation reserves can be set up outside the existing terrestrial protected area network in the Western Ghats. For more information on important sites for freshwater species of the Western Ghats see Chapter 7, where potential freshwater Key Biodiversity Areas (KBAs) are identified.

3.5.10 Live gene banking

Gene banks hold live animals or cryopreserved gametes, and contribute to conservation of threatened species by captive breeding and restocking in species specific recovery programmes (Lakra *et al.* 2007). The Regional Agricultural Research Station (RARS) of the Kerala Agricultural University (KAU) already has a successful collaborative programme with the National Bureau of Fish Genetic Resources (NBFGR) for captive breeding and milt cryopreservation of a number of commercially important and threatened freshwater species of the Western Ghats (for example *Horabagrus brachysoma* (VU)). There is also a plan to start a live gene bank for freshwater fish species at the RARS.

3.5.11 Implementation of domestic and international legislation

The Indian Wildlife (Protection) Act (WPA), 1972 (with amendments in 2002), which is still the most important legal system for protection of threatened flora and fauna in India, has been of considerable value in the conservation of higher vertebrates especially mammals. However, the WPA has been of little or no importance for protecting smaller and less charismatic taxa including freshwater fishes. No freshwater fish species in India is listed in any of the appendices of the WPA (Raghavan 2010).

The Department of Fisheries and Ports, Government of Kerala issued an order in 2009, that imposed restrictions upon catching and exporting *Puntius denisonii*, an Endangered species that is popular in the international aquarium trade. Several management measures including issue of quotas, restrictions on fishing gears, catch size and a seasonal closure of fishery

Captive breeding protocols have been developed for several important food fishes of the southern Western Ghats including *Horabagrus brachysoma* (VU) which is ranched in Vembanad Lake and its confluent rivers. © Rajeev Raghavan

were recommended (Mittal 2009). However, there has been little scientific input to the planning and implementation of this regulation and the strategy has been top-down with no stakeholder participation involved, raising questions about success of the strategy (Clarke 2009, Mittal 2009). What is required is a more collaborative effort involving various authorities, exporters and collectors for the successful implementation of these policies.

An urgent priority would be to place at least a few of the most important (threatened and endemic) species of freshwater fish in the WPA. As most of these species are forest-based fish, enforcement of management measures can only be successfully carried out if both the wildlife/forest departments and the fisheries department work together. Wildlife and forest departments are in a better position to monitor the harvests taken under their jurisdiction.

State wide legislation including the Inland Fisheries (Conservation Regulation and Development) Act of 1996 of the Government of Karnataka, and the recently passed Inland Fisheries Act of the Government of Kerala could also help conserve and manage the freshwater fish fauna of the Western Ghats.

3.5.12 Taxonomy research

There is an urgent need to undertake a thorough taxonomic review of several genera and species of freshwater fishes. There are still many species entrapped in synonymy, as well as a number of invalid species currently considered as valid in this region. In addition, there are also 'species complexes' comprising of many cryptic species. Many species discovered several years ago are still not described and hence remain 'nomina nuda' (Box 4). Furthermore, a number of areas, especially in the northern parts of the Western Ghats, are still very poorly surveyed and have a potential for contributing new species.

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Box 4. Taxonomic uncertainties and conservation.

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All conservation – indeed, almost all biology – is based on taxonomy (Morrison *et al.* 2009). Detailed discussion regarding the importance of taxonomy and its implications to conservation have been discussed at both global (Dubois 2003, Mace 2004) and local levels (for the Western Ghats); (Daniels 1997). In the Western Ghats, taxonomic uncertainties have created much confusion for this conservation assessment process, through three routes.

A - *Puntius rohani* (holotype); B - *P. rohani juvenile*; C - *P. rohani*; D - *P. filamentosus*; E - *P. filamentosus* juvenile; F - *P. tambraparniei*; G - *P. tambraparniei juvenile*; H - *P. exclamatio*; I, J - *P.as similis*; K - *P. arulius.* Adapted from Devi *et al.* 2010

(1) Species merging, species splits and ill-defined species boundaries can cause confusion in assessments. The concept of species is central to the assessment of conservation status. A species risk of extinction is likely to change when either, (a) the species is found to be a species complex with several more restricted species, or (b) a geographically restricted species is synonymized to a more wide spread species. It is possible that several widespread Least Concern species, such as *Channa gachua*, *Devario aequipinnatus*, *Indoreonectes evezardi* and *Puntius filamentosus*, are species complexes comprising of several species which could be restricted in their distribution. An excellent example comes from the recent description of *Puntius rohani* from the *Puntius filamentosus* species complex (Devi *et al.* 2010). While *P. filamentosus* is considered as a Least Concern species, owing to its wide distribution, *P. rohani* is assessed as Vulnerable because of its restricted distribution and possible threats to its habitat. Conversely, there are species described from the Western Ghats which have a doubtful taxonomy and if they are synonymized to widely distributed species their conservation status is likely to change. For example, *Osteobrama bhimensis*, an Endangered species, is currently known from a single location in Ujani Wetland, with several threats to the habitat. However, this species is remarkably similar to a widespread species *Osteobrama vigorsii* described from 100 km upstream of Ujani Wetland. If *O. bhimensis* is synonymized to *O. vigorsii*, it will be a subpopulation of a Least Concern species.

Box 4 (Continued). Taxonomic uncertainties and conservation.

(2) Naming species without a formal description creates confusion regarding its validity and distribution. There are strange cases of several 'nomina nuda[1]' among freshwater fishes of the Western Ghats. Examples include *Homaloptera silasi*, *Garra travancoria*, *Garra nilamburensis*, *Pangio bashai*, *Tor moyarensis* and *T. remadevii*. Although the names of some of these species have routinely appeared in many publications and checklists since 2004, none of these species have been formally described. Although an attempt to describe *Tor remadevii* was made through a paper in the published proceedings of an international conference (Kurup and Radhakrishnan 2007), due to the limited circulation of this publication, this species has not been recognized as yet by the international community, and does not find a place in taxonomic databases like the Catalog of Fishes (Eschemeyer and Fricke 2011). Clearly, without names and full taxonomic, ecological, geographical and phylogenetic vocabulary, the language of conservation and sustainability cannot develop (Reid 2010). One can only conserve what is known and accepted as taxonomically valid, particularly in the context of national and international codes (Reid 2010). Several of the 'nomina nuda' that we have referred to are possibly point endemics, and therefore of high conservation concern. If these 'nomina nuda' were officially described and recognized, they would have qualified for either 'Vulnerable' or a higher threat category and attracted conservation attention.

(3) Reporting range extensions of species without giving proper taxonomic comments, and description or information on the voucher specimens creates confusion regarding the validity of the proposed range extension. Because of lack of information on the population status, conservation assessments of freshwater fishes are often based on criterion B (geographic range of the species) and an incorrect range extension could result in the species being assessed as Least Concern; when in fact the species is restricted in distribution. For example, *Botia striata* is assessed as Endangered because of its restricted distribution in southern tributaries of the Krishna River system and threats to its habitat. However, if the record of this species from southern India by Johnson and Arunachalam (2009) is considered valid then the species may become Least Concern.

[1]A name which is unavailable because it does not have a description, reference or indication; specifically a name published before 1931 which fails to conform to Article 12, or after 1930 but fails to conform to Article 13 of the International Commission of Zoological Nomenclature.

Botia striata (EN) is endemic to the Krishna River system and its record from Kerala needs taxonomic validation. Specimen collected from Koyna River. © Neelesh Dahanukar

A local fisherman on Periyar Lake. © Rateesh/CRG

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A rivulet of Kabini River. © Rajeev Raghavan

Chapter 4. The status and distribution of freshwater molluscs of the Western Ghats

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4.1 Overview of freshwater molluscs of the Western Ghats: Geomorphological factors affecting distribution

4.1.1 Introduction

Freshwater environments are some of the most fragile and highly threatened ecosystems in the world. These ecosystems have been constantly manipulated by humans to satisfy their needs with little or no thought to the long term effects on them (Kaufman 1992). Molluscs are an important group for freshwater biodiversity, and where abundant play an important role in ecosystem functioning (Vaughn *et al.* 2004). They form an important component of most biological monitoring programmes that rate water quality and status of aquatic systems based on invertebrate assemblages (Ponder 1994, Seddon 1998, Strong *et al.* 2008). Bivalves in particular, as they accumulate toxic substances to a greater extent than other organisms, are used to monitor water quality (Salanki *et al.* 2003). Molluscs show a great specialization of ecological niches in freshwater environments, making them more vulnerable to

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modifications in their environment (Bouchet 1992, Lydeard *et al.* 2004). Consequently, freshwater molluscs have suffered a severe decline in diversity, distribution and abundance due to human induced alteration of habitats, pollution, siltation, deforestation, poor agricultural practices, the destruction of riparian zones and invasion by introduced species (Biggins *et al.* 1995, Pimm *et al.* 1995). Non-marine molluscs, which includes land and freshwater molluscs, comprise the largest number of recorded extinctions in the last 300 years (Groombridge 1992). Hence, conservation efforts are urgently needed to maintain and recover these unique components of aquatic biodiversity.

4.1.2 Diversity of freshwater molluscs of the Western Ghats

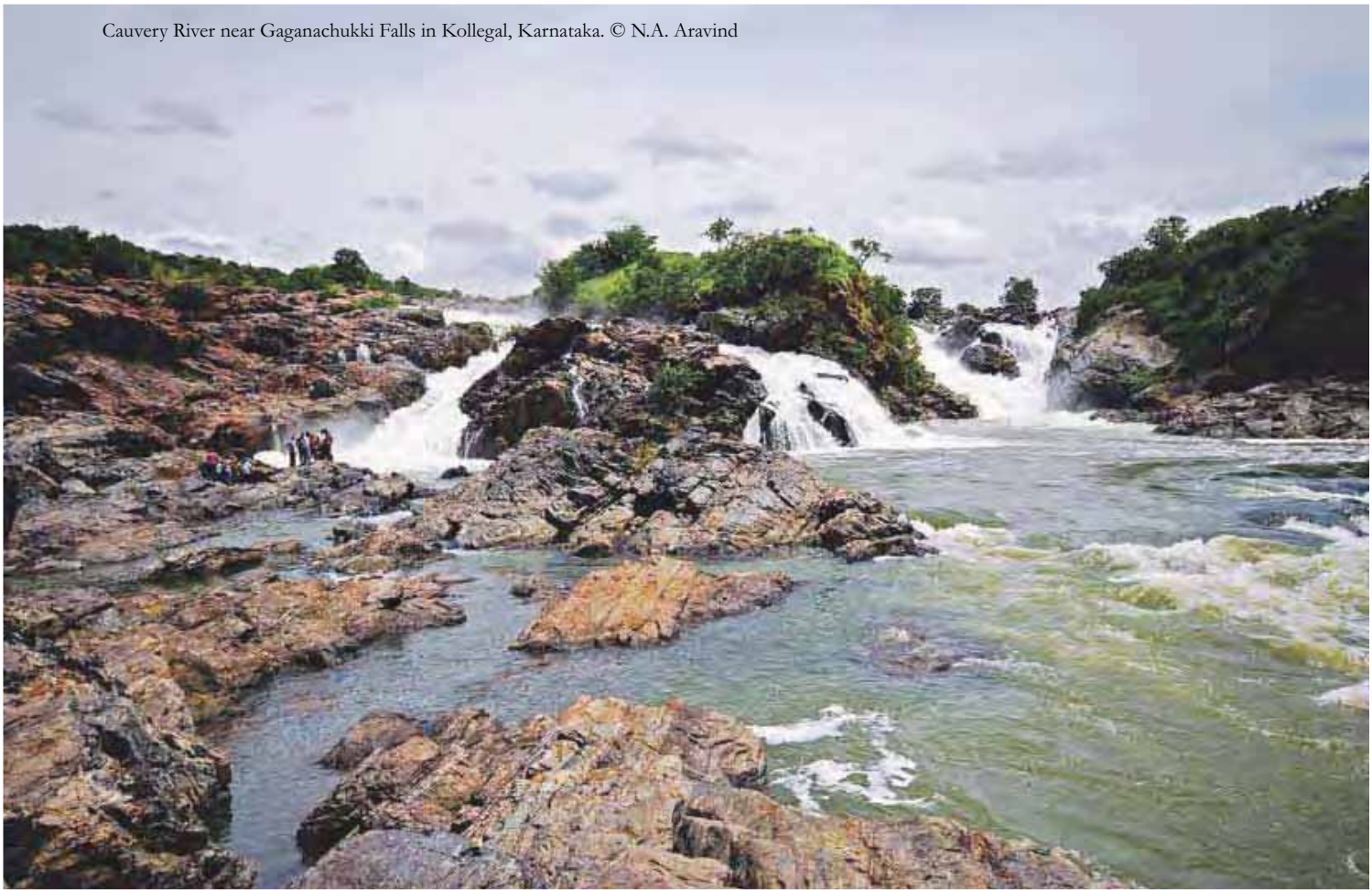
Nearly 212 species of freshwater molluscs have been reported from the Indian administrative limit (Subba Rao 1989). Of these, only 60 species were recorded from the Western Ghats Hotspot by Shivaramakrishnan *et al.* (1998), however it is likely that many species were missed. This is substantiated by recent records of species such as *Arsidopsis footi, Neritina reticulata,* two species of *Paracrostoma* and five new species of *Cremnochonchus* from the Western Ghats. This region is also home to some of the most important zoogeographical and Gondwanaland relict species, such as *Pseudomulleria dalyii*, (Etheridae), a cemented freshwater pearl species and three species of *Cremnochonchus* (Littorinidae), which are gastropods found in the spray zones of waterfalls at high elevations in the Western Ghats. With very few ecological studies having been carried out on these unique and cryptic freshwater taxa in India, it is critical to work out their habitat requirements and distributions to allow conservation strategies to be developed. Through this project we aim to fill this data gap through the assessment of the distribution and conservation status of all Western Ghats freshwater molluscs, and provide analyses and recommendations that will aid malacological conservation in the region.

4.1.3 Secondary freshwater species (brackish water species)

In the Western Ghats assessment region, two species of Neritidae (*Neritina pulligera* and *Neritina violacea*), three species from Corbiculidae (*Villorita corbiculoides, V. cornucopia,* and *V. cyprinoides*) and two species from Iravadiidae (*Iravadia funereal* and *I. ornata*) are found exclusively in brackish water. The genus *Villorita* (Corbiculidae) is confined to the backwaters and estuaries of the west coast. These species cannot withstand high salinity levels and are usually found in the upper regions of the backwaters where the salinity is below 15 percent. Here they burrow into the soil to escape unfavourable condition during summer when salinity increases above 15 percent (Cherian 1968).

4.1.4 Zoogeographical significance of the Western Ghats molluscan fauna

Many species are widely distributed in India and its neighbouring countries. However, some species are highly restricted in distribution particularly in streams of the Western Ghats. For example, *Cremnochonchus syhadrensis, C. conicus* and *C. carinatus* belong to the family Littorinidae (periwinkles) and are the



Cauvery River near Gaganachukki Falls in Kollegal, Karnataka. © N.A. Aravind

only freshwater genus in an otherwise entirely marine family, they are adapted to the spray zone of perennial waterfalls from a few localities in the Karnataka and Maharashtra region of the Western Ghats. Another restricted range species is *Pseudomulleria dalyi* (Etheridae), an endemic cemented bivalve confined to couple of rivers in the central Western Ghats that is also a rare Gondwanaland relict (Madhyastha 2001). The family Etheridae shows unique discontinuous distribution, with recognized genera, viz., *Acostea* (South America), *Pseudomulleria* (India) and *Etheria* (Africa) (Smith 1898, Bogan and Hoeh 2000). The hill stream genus *Turbinicola* (Pilidae), that is an inhabitant of streams around Khandala, in Maharashtra resembles the South American hill stream genus *Asolene*, suggesting convergent evolution (Prashad 1928). Some species such as *Sulcospira huegeli* show a disjunct distribution, being found in the central and southern Western Ghats and in northeastern Indian states (Subba Rao 1989). Recently, two new species of freshwater molluscs belonging to the genus *Paracostoma* have been described from the Western Ghats (Köhler and Glaubrecht 2007). The genus *Paracostoma* is monophyletic and is restricted to few streams in the central Western Ghats and nested within a clade of Southeast Asian taxa composed of *Brotia* and *Adamietta*. These authors argue that the *"origins of the Indian biota are more complex and diverse than assumed under the standard Mesozoic vicariance model"*. Hence, zoogeographically, the Western Ghats freshwater molluscs offer a great opportunity for biologists.

4.1.5 Earlier studies on the Western Ghats freshwater mollusc

Studies on freshwater mollusc in India and Western Ghats in particular are far from complete. A few sporadic studies were carried out in northern Western Ghats, mainly from Pune, by Tonapi (1971), and Tonapi and Mulherkar (1963). Recently, Patil and Talmale (2005) reviewed land and freshwater molluscs of Maharastra State and listed 72 species and varieties. Most of these studies were concentrated on distributional aspects and none of the authors studied ecology. In India very scant attention has been paid to the biology and ecology of molluscs and in particular of bivalves (Subba Rao 1989) and therefore the ecological needs of a great majority of the Indian freshwater molluscs is not known. Apart from Volume IV of Fauna of British India by Preston (1928), there are only two other books that deal with Indian freshwater molluscs, these are Subba Rao (1989) and Ramakrishna and Dey (2007). The book on "*Indian Freshwater Molluscs*" gave updated information on the distributions with maps (Ramakrishna and Dey 2007). All these books failed to give ecological information about the species. However, a few recent studies have tried to address some ecological questions at Nagarahole National Park (Ganesh *et al.* 2002) and at the Western Ghats scale (Aravind and Madhyastha *in preparation*).

We would like to emphasize that this assessment is based on the best available data including published literature, data available online and from our own unpublished field data. For the Western Ghats Hotspot assessment region (Figure 2.1) we have identified a total of 77 species, which includes 52 gastropod and 25 bivalve species.

It should be recognised that many taxonomic problems exist in the current literature and further work is required to resolve these issues. Inconsistencies between available data clearly indicate that the taxonomic situation is still a major problem in establishing a database for freshwater mollusc species conservation planning in the region.

4.2 Conservation status (IUCN Red List Category)

The summary presented here is based on an assessment, following application of the IUCN Red List Categories and Criteria (IUCN 2001), of all 77 species of freshwater molluscs that we have identified as being present in the Western Ghats Hotspot assessment region (nine of which are draft assessments yet to be peer reviewed). This assessment includes 52 (67.5%) species of gastropods and 25 (32.5%) species of bivalves (Table 4.1). Of extant species for which sufficient data are available to assess the risk of extinction, seven species (12%) are assessed as threatened (Table 4.1, Figure 4.1); *Cremnochonchus syhadrensis, C. carinatus, Arcidopsis footei* and *Pseudomulleria dalyi* are assessed as Endangered (EN); *Cremnochonchus conicus, Parreysia khadakvaslaensis* and *Scaphula nagarjunai* are assessed as Vulnerable (VU) (Table 4.2). The majority of species (88%) are assessed as Least Concern. There are an additional 19 species that are listed as Data Deficient (Table 4.1) of which 14 are gastropods and five bivalves, representing a quarter of all known species in the region. Some of the DD species are known only from 19th or 20th century descriptions and have not been collected since, further expert surveys across the region are required to determine the conservation status of these species. A list of all species with their IUCN Red List assessment can be found on the accompanying data DVD.

Table 4.1 Number of species of freshwater mollusc in each Red List category.

Global Red List Category	Number of species	%
Extinct	0	0.0
Extinct in the Wild	0	0.0
Critically Endangered	0	0.0
Endangered	4	7
Vulnerable	3	5
Near Threatened	0	0.0
Least Concern	51	88
Data Deficient	19	N/A
Total	**77**	

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

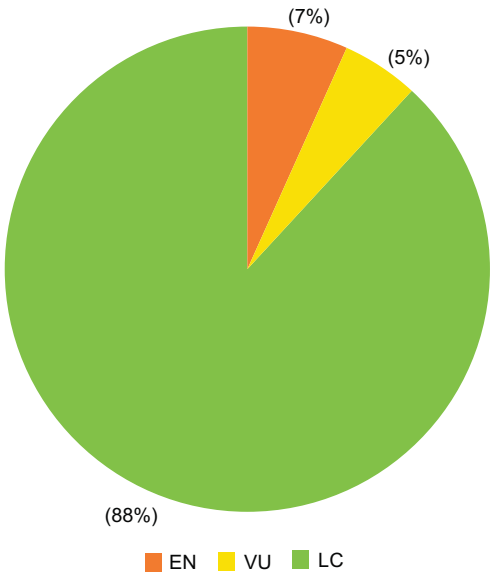


Figure 4.1 Percent of freshwater mollusc species in each Red List category.

4.2.1 Gastropods

Twelve Gastropoda families in 23 genera, comprising 52 species (Table 4.3) from the Caenogastropoda and Pulmonata are reported from the region. The Thiaridae is the most dominant family representing 23% of species within the region followed by Bithyniidae and Lymnaeidae with 13% each. In terms of genera representation, the Bithyniidae has the highest number of genera with 21%, followed by Thiaridae and Planorbidae with 13% each. Three species of gastropods, all belonging to the family Littorinidae (*Cremnochonchus syhadrensis* (EN), *C. carinatus* (EN) *and C. conicus* (VU)), out of 52 are threatened and the rest are either DD or LC.

All three species belonging to the family Littorinidae are highly habitat specific and found in the spray zones of waterfalls where they hibernate during the summer in crevices. *Sulcospira huegelii* (Thiaridae) shows adjunct distribution, as it is found both in the Western Ghats as well as in the mountain streams of northeastern India. *Lymnaea luteola, L. acuminata, Indoplanorbis exutus* and *Gyraulus convexiusculus* (all LC) are very generalist species and common throughout the Indian subcontinent.

Table 4.2 Threatened freshwater molluscs of the Western Ghats assessment region.

Class	Family	Binomial	RL Cat	Endemic to WG
Gastropoda	Littorinidae	*Cremnochonchus carinatus* (Layard, 1854)	EN	Endemic
Gastropoda	Littorinidae	*Cremnochonchus conicus* (Blanford, 1870)	VU	Endemic
Gastropoda	Littorinidae	*Cremnochonchus syhadrensis* (Blanford, 1863)	EN	Endemic
Bivalvia	Unionidae	*Arcidopsis footei* (Theobald, 1876)	EN*	Endemic
Bivalvia	Unionidae	*Parreysia khadakvaslaensis* (Ray, 1966)	VU*	Endemic
Bivalvia	Etheriidae	*Pseudomulleria dalyi* (Smith, 1898)	EN*	Endemic
Bivalvia	Arcidae	*Scapbula nagarjunai* Janakiram and Radhakrishna, 1984	VU	Endemic

* Indicates draft Red List assessments yet to be peer reviewed

Table 4.3 Gastropods of the Western Ghats assessment region.

Family	Genus	Species	Data Deficient	Least Concern	Vulnerable	Endangered
Ampullariidae	1	4	2	2		
Bithyniidae	5	7	1	6		
Bullinidae	1	1		1		
Hydrobiidae	1	2		2		
Iravadiidae	1	3	2	1		
Littorinidae	1	3			1	2
Lymnaeidae	2	4	2	2		
Neritidae	2	3		3		
Pachychilidae	2	3	2	1		
Planorbidae	3	7		7		
Thiaridae	3	12	5	7		
Viviparidae	1	3		3		
12 Families	**23**	**52**	**14**	**35**	**1**	**2**

Table 4.4 Freshwater bivalves of the Western Ghats assessment region.

Family	Genus	Species	Data Deficient	Least Concern	Vulnerable	Endangered
Arcidae	1	2		1	1	
Corbiculidae	2	8	4	4		
Etheriidae	1	1				1
Sphaeriidae	1	1		1		
Unionidae	3	13	1	10	1	1
Total	**8**	**25**	**5**	**16**	**2**	**2**

4.2.2 Bivalves

A total of five families of freshwater bivalves have been reported from the Western Ghats assessment region. These five families are comprise of eight genera and 25 species. The family Unionidae is the dominant group containing 52% of species found in the region, followed by Corbiculidae (32%) (Table 4.4). The families Etheriidae and Sphaeriidae are represented by only one species each. The threatened species are spread across three families, Arcidae (*Scaphula nagarjunai* (EN)), Etheriidae (*Pseudomulleria dalyi* (EN)) and Unionidae (*Arcidopsis footei* (EN) and *Parreysia khadakvaslaensis* (VU)). *Scaphula nagarjunai*, is endemic to the Krishna River basin in Andhra Pradesh; *Pseudomulleria dalyi* to the Tunga and Bhadra rivers in central Western Ghats; *Parreysia khadakvaslaensis* is confined to the river Thamini close to Khadakvasla Dam near Pune; and *Arcidopsis footie* is only known from the Tunga River in the Kudremukh region, and at Ghattaprabha Falls and Ghattaprabha River in the Krishna River in northern Karnataka.

4.2.3 Habitat requirements

A large proportion of the gastropods are found only in lentic habitats (54%, 28 species) with the families Arcidae, Corbiculidae, Iravadiidae, Etheridae and Neritidae being exclusively lentic (Table 4.5). There are no bivalves that are exclusive to lentic habitats though two species, *Lamellidens marginalis* and *Corbicula striatella,* are found in both lentic and lotic habitats. The gastropod genus *Cremnochonchus* is exclusive to spray zones of waterfalls. Species such as *Thaira tuberculata*, *Lymnaea luteola, L. acuminata, Indoplanorbis exutus* and *Gyraulus convexiusculus* are all common, even occuring in polluted waters.

Type locality of *Cremnochonchus carinatus* in Mahabaleshwar from where the species is extirpated. © N.A. Aravind

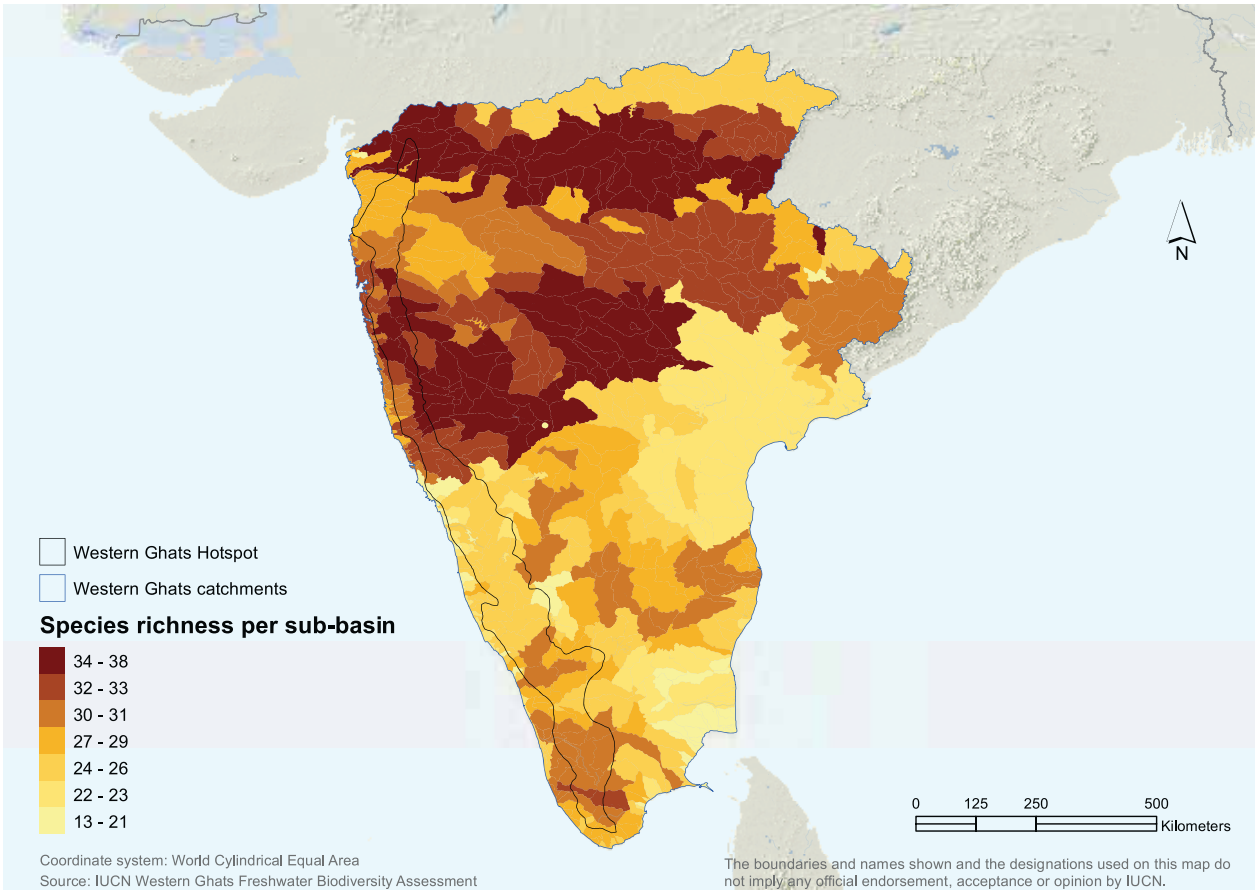


Figure 4.2 Species richness of freshwater molluscs in the Western Ghats assessment region.

Table 4.5 Habitat associations of freshwater molluscs in the Western Ghats region.

	Number of Species	Lotic	Lentic	Both
Bivalvia	25	23		2
Gastropoda	52	21	28	3
Total	**77**	**44**	**28**	**5**

4.3 Patterns of species richness

4.3.1 All molluscs

The areas of highest species richness of freshwater molluscs of the Western Ghats assessment region (between 34-38 species per sub-basin) are seen in the northern part of the region in the Purna River, upper Godavari (Wardha River) and lower Narmada draining the Gavilgad and Satpura mountain ranges on the Madhya Pradesh–Maharashtra border, the Manjira (upper Godavari catchment) in southeastern Maharashtra (draining the Balaghat mountains) and the upper Krishna and Bhima rivers in southern Maharashtra and northern Karnataka (from the Mahadev mountain range). On the western side of the Western Ghats the catchments with the highest level of species richness are the upper Ulhas, Savitri and Vashisthi in western Maharashtra. Species richness then declines to the southeast, with the lowest species richness in Andhra Pradesh, Karnataka and Tamil Nadu, however there is a rise in species richness in Kerala with many areas having between 30-31 species per sub-basin.

The results shown here are contrary to the general belief that species richness decreases from south to north. However, this is probably due to the fact that a large number of studies have been conducted in the northern Western Ghats when compared to the central and southern parts. With more survey work, relative species richness is likely to increase in the southern and central areas. This is exemplified by the fact that recent report of two new species of *Paracrostoma* from central Western Ghats (Köhler and Glaubrecht 2007) and at least five new species of *Cremnochonchus* (Aravind *et al. in preparation*)

4.3.2 Threatened species

Only seven species of molluscs from the Western Ghats region have been assessed as threatened. Figure 4.3 shows that the highest richness of threatened species (three species per sub-basin) occurs in the Western Ghats Hotspot in Karnataka and Maharashtra, with the upper Tungabhadra catchment, including the Tunga and Varada and a few west flowing rivers including the Sharavathi (Karnataka) and the west flowing Savitri in Maharashtra. The remaining threatened species are found in south-western Maharashtra and northern Karnataka in the upper Krishna (including the Bhima and Nira rivers)

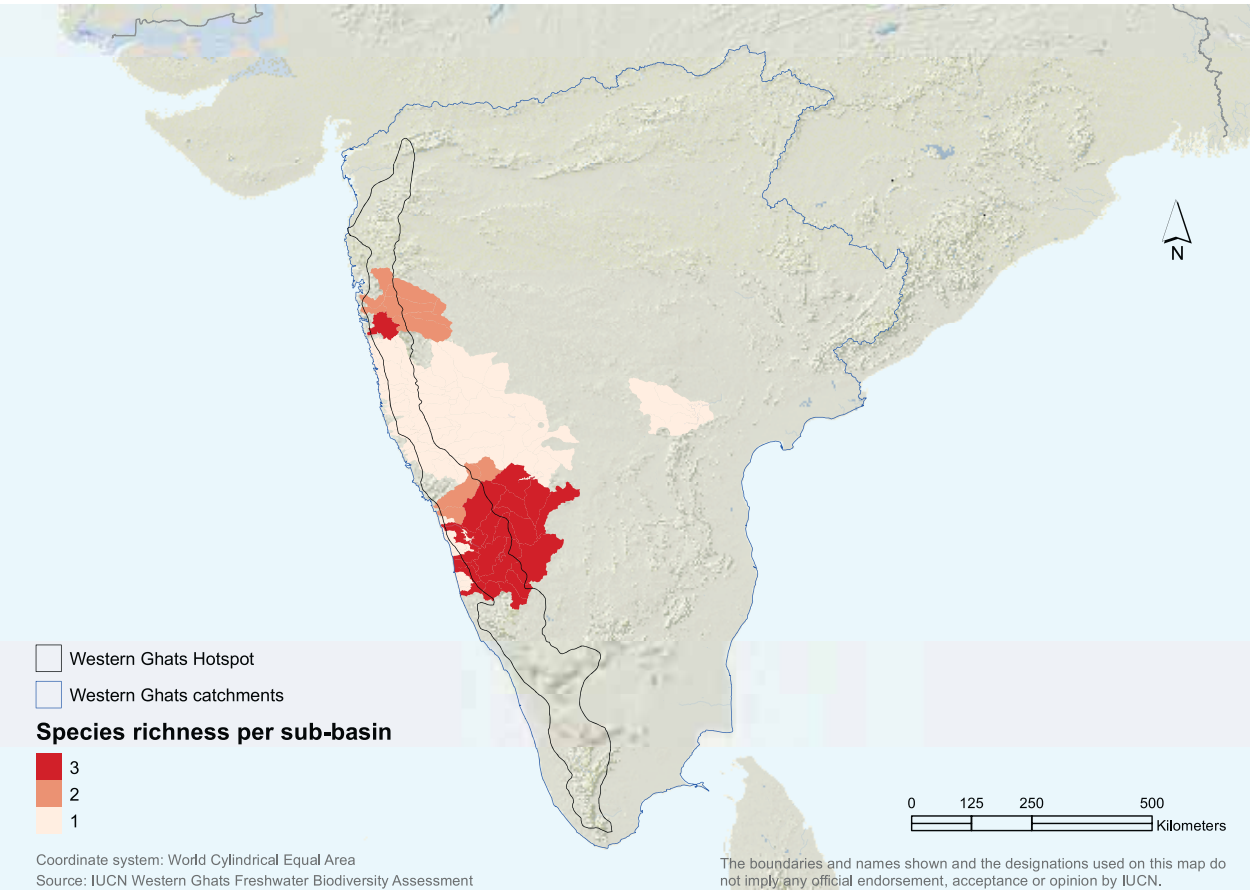


Figure 4.3 Species richness of threatened freshwater molluscs in the Western Ghats assessment region.

and a number of west flowing rivers (including the Kalinadi, Terekhol, Shastri and Vashisthi).

The southern Western Ghats does not have any threatened species. As with the species richness (4.3.1, Figure 4.2) this is probably due to the fact that there have been relatively few studies on the freshwater molluscs in the region. More detailed studies in this part would likely identify more threatened species (possibly many are currently listed as DD).

4.3.3 Endemic species

The Western Ghats assessment region has 28 species of freshwater molluscs that are endemic, this constitutes 36% of the fauna. The majority are found within the Western Ghats Hotspot itself. The number of endemic species is highest (between eight and nine species per sub-basin) in the west flowing rivers of Manimala, Pambayar and Achankovil in southern Kerala (Figure 4.4). High levels of endemism (six to seven species per sub-basin) are found in two groups, the first is in the central part of the Hotspot in southern Karnataka in west flowing rivers including the Sharavathi and Netravathi, and the east flowing upper Tunga River. The second group are in the west flowing rivers of southern Kerala; Bharatapuzha, Karuvannur, Periyar, Thodupuzha, Meenachil and Kallada, and the west flowing upper Chittar, Vaipar and Vaigai in southern Tamil Nadu. The results shown here are in contrast to the species richness described in 4.3.1. (Figure 4.2) where the highest richness is in the northern Western Ghats.

4.4 Major threats to freshwater molluscs

The Western Ghats is the origin for 37 west flowing and three large east flowing rivers with numerous tributaries (Srikantha *et al.* 2007). These rivers and their tributaries are increasingly vulnerable due to a wide variety of anthropogenic activities. Through this study the major threats to Western Ghats molluscs have been identified as agricultural and urban water pollution, over harvesting, dams, urban development and mining (see Chapter 7 for quantitative analysis).

4.4.1 Pollution

The most common sources of pollution in the Western Ghats Hotspot assessment region are sedimentation due to agriculture, urban runoff and sewage, industrial effluents from shrimp and fish processing industries (Laxmilatha and Appukuttan 2002), mining, heavy industries such as iron ore, paper and textile mills, and washing and bathing. Runoff and sedimentation has significantly increased due to deforestation in the last three decades and unsustainable land use practices coupled with heavy monsoons (especially in the western region of the Ghats). Sedimentation of rivers reduces habitat heterogeneity by filling the gaps between gravels, particularly affecting bivalve populations (USGS 2010). However, some gastropod species such as *Lymnaea luteola, L. acuminata, Indoplanorbis exutus* and *Gyraulus convexiusculus* (all LC) are highly tolerant and can be found in large numbers in organically

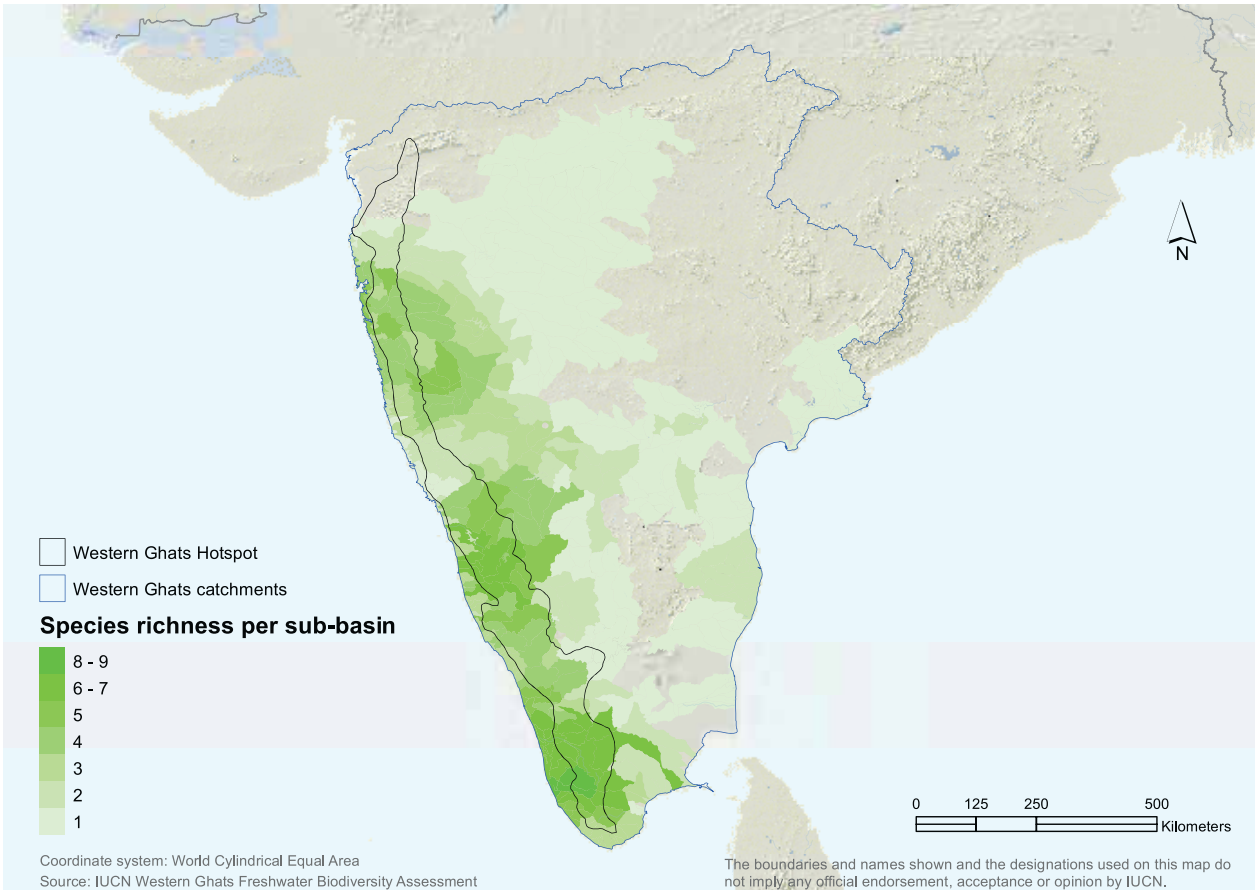


Figure 4.4 Species richness of endemic freshwater molluscus in the Western Ghats assessment region.

polluted lentic habitats (Rajan and Murugan 2001). Many bivalves are extremely sensitive to water pollution, as they accumulate toxins quickly (Salanki *et al.* 2003), and have been adversely affected in polluted habitats. Another major source of pollution, often neglected, is tourism, for example in Vembanad Lake, where it is estimated that there are more than 5,000 houseboats in operation. Anthropogenic (washing and bathing), agricultural pollution and fishing using chemicals are all major threats to the subpopulation of *Pseudomulleria dalyii* (EN) in the Tunga River (Madhyastha 2001). More research is needed on the impact of pollution upon the molluscs of the Western Ghats, as it is expected that many local extirpations have happened unnoticed.

4.4.2 Harvesting

Species belonging to *Parreysia, Lamellidens, Corbicula* are extensively harvested for human consumption especially in the coastal regions of Karnataka and Kerala. The size and impact of this harvest on the population is not known, however for most of these species it is not thought to be so significant as to cause them to be threatened. *Villorita cornucopia* (LC) and *V. cyprinoides* (LC) are harvested extensively from the wild population in Kerala region and are of commercial importance. The black clam (*V. cyprinoides*) contributes nearly 45,000 tons (mostly from Vembanad Lake), or about two-thirds of the total clam harvest in Kerala (Narasimham *et al.* 1993, CMFRI Annual Report 2009). Extensive harvest from the wild could be a potential threat to this species and monitoring the level of harvest and the species population is recommended. *P. dalyi* (EN) is the only threatened mollusc species impacted by harvesting. Its population in the Tunga River is impacted through the overharvesting (using dynamite and chemicals) of the fishes that provide *P. dalyi* with a host to complete its life cycle.

4.4.3 Water abstraction and dams

Water abstraction, water diversion and construction of dams are major threats to freshwater molluscs. There are many small, medium and large dams (including reservoirs) in the assessment region. In addition, there are several small and medium dams that have been proposed for hydro-electric projects. The proposed Gundia hydel project in Hassan District of Karnataka would submerge almost 1,900 acres of primary evergreen forest and seriously affect the river ecosystem. If these projects are implemented they could seriously affect the aquatic mollusc fauna across the region. With only a few exceptions, most species of unionoids prefer to live in free-flowing and shallow waterways (Salmon and Green 1983). There is ample evidence to show that dams contribute to the overall depletion of unionoid populations by restricting their distributions and isolating populations from each other (see review in: Watters 1996, Watters 1999).

Pseudomulleria dalyi (EN) is one of six threatened species that are known to be currently (or in the near future) impacted

by dams in the Western Ghats region. The Upper Bhadra Project, which has been in development for decades and is now set to go ahead, will include the construction of a dam on the Bhadra River. The flooding of this area will most likely be fatal for the subpopulation of *P. dalyi* at this location, it is currently only known from four other locations (Madhyastha 2001). Also, a recent increase in the height of Tunga Dam near Shimoga has submerged a newly identified population of *P. dalyi*. *Arcidopsis footei* (EN) is another threatened species impacted by dams. At one of the few known locations for this species, the Ghattaprabha River, the Idkal dam has resulted in the drying up of the river during the summer months, leaving hardly any water to support the species. It is now feared that the species is extirpated from this area (Madhyastha and Mumbrekar 2006). The same species is also likely impacted by a dam that has been constructed across the Tunga River at Gajanur, Shimoga in Karnataka and recently another dam project is taking place in the upper Tunga River, to increase the height of the existing dam (Madhyastha and Mumbrekar 2006). It is likely that water withdrawal, alterations to the hydrological regime and siltation are occurring throughout its range and resulting in localized declines. The data on the impact of dams and water abstraction on freshwater mollusc populations in this region, is far from complete. However drawing from case studies, McAllister *et al.* (2001) presented a range of upstream and downstream impacts of large dams that include variation of flow regimes, increased sedimentation, loss of fish-hosts, and habitat degradation. These impacts are likely to be applicable to the Western Ghats assessment region as well.

4.4.4 Invasive species

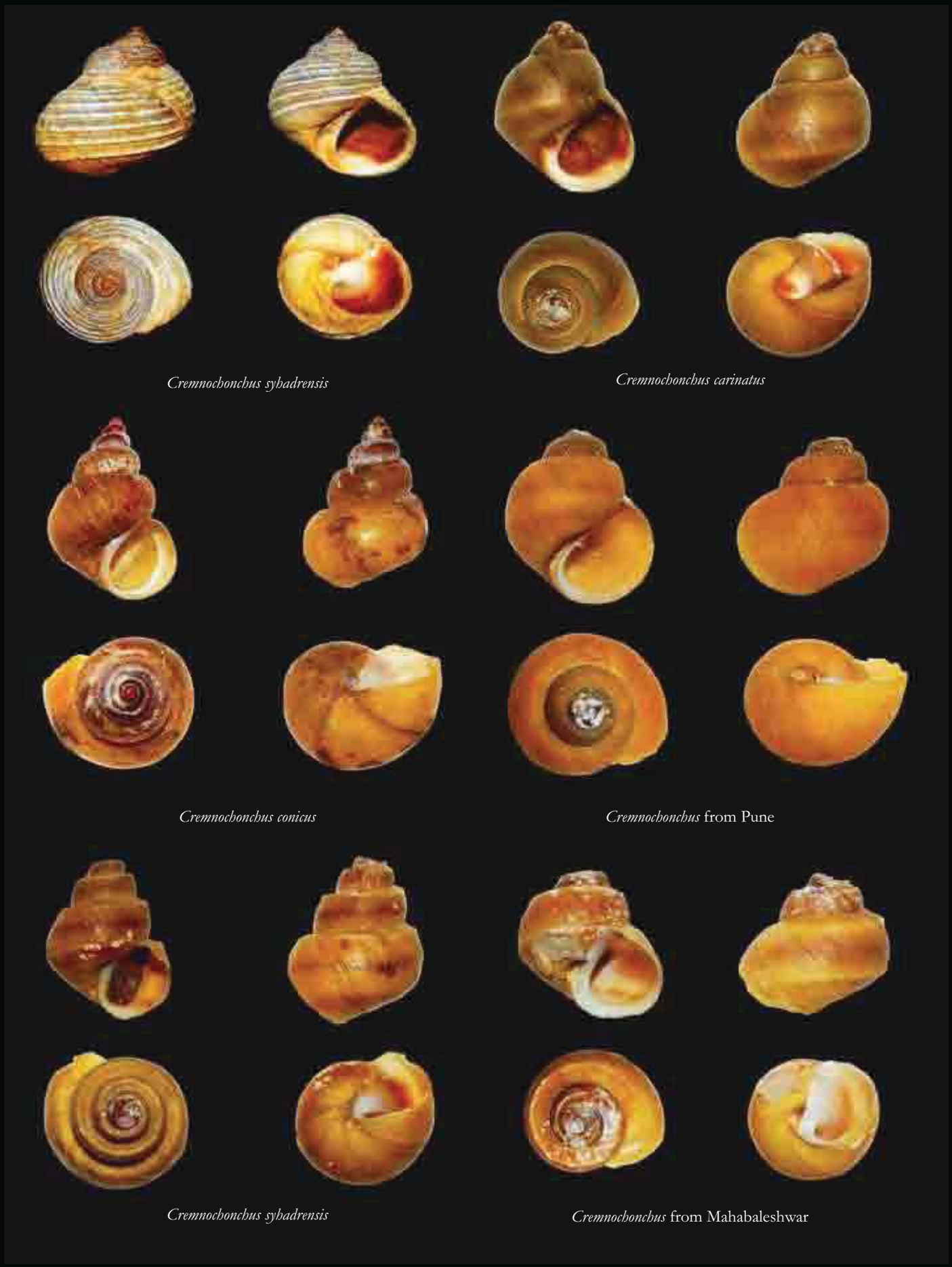
In the Western Ghats region, there are no molluscan invasives in the freshwater environment. However, other invasives, particularly plants, are very numerous in the freshwater ecosystems especially in lentic habitats. Plant species such as *Eichhornia crassipes*, *Ipomea* sp., *Pistia* sp. and *Salvinia* sp. are prevalent in most of the lentic ecosystems in this region. The presence of these invasive species might favour generalist species such as *Lymnaea luteola, L. acuminata, Indoplanorbis exutus* and *Gyraulus convexiusculus*. These invasives increase turbidity levels and cause anoxic condition when they die and decompose. These changes in conditions are very likely to have a serious impact upon freshwater mollusc fauna, especially bivalves. As with many of the threats discussed here, there is little research into the effects of these invasives in the aquatic ecosystems on the freshwater molluscan fauna in the Western Ghats.

4.4.5 Urban development

Developmental activities such as road widening and construction of bridges across rivers have a negative impact on the river ecosystem, through the temporarily filling of the river, dredging to erect pillars, and consequent pollution from oil spills from heavy machinery. This relatively small scale but very widespread threat has taken a toll on the freshwater biota in the Western Ghats region. For example, on-going road widening work of NH 17 from Mangalore to Kundapura on the western coast of India has resulted in disturbance of eight west flowing rivers which have their origin in the Western Ghats. The real estate boom and resulting construction work

Invasive plant species in a lake in southern Western Ghats. © N.A. Aravind

Diversity of the genus *Cremnochonchus* in the Western Ghats. © N.A. Aravind



Cremnochonchus syhadrensis

Cremnochonchus carinatus

Cremnochonchus conicus

Cremnochonchus from Pune

Cremnochonchus syhadrensis

Cremnochonchus from Mahabaleshwar

along the banks of the rivers and dumping of debris has only worsened the situation. A detailed study on the impact of these activities on the freshwater molluscs needs to be undertaken as a priority.

4.4.6 Mining

India is growing at a rate of nine percent of GDP per year. This is one of the highest growth rates in the world with most of the growth happening in the industrial sector. To meet the demand for construction of new roads, infrastructure, housing, etc., huge amount of sand is mined both legally and illegally. In Madhya Pradesh, major rivers like Narmada, Chambal, Betwa, Wainganga and numerous rivulets and streams are being mined for sand. Similarly, in Kerala, Bharatapuzha River and Vembanad Lake are victims of indiscriminate sand mining and dredging. Even though there are restrictions, illegal sand mining continues to occur in many parts of India. This illegal mining of sand coupled with the lack of governance and policy is causing degradation of river ecosystems and threatening aquatic biota.

Sand mining and dredging disturbs habitat through changing the physical structure of the riverbed, impacting water quality, reducing habitat heterogeneity and therefore leading to a change in the community composition and to the local extirpation of species. Among molluscs, the bivalves are more seriously affected. Being burrowers and filter feeders, any change in the porosity of the soil and turbidity will have a negative impact on populations. In the Western Ghats, there are no studies that have addressed the impact of sand mining on freshwater molluscs. Hence, there is an urgent need to study the impact of sand mining on mollusc biodiversity.

4.4.7 Other threats

Other threats that can potentially impact freshwater molluscs are closure of the Thaneermukham Barrage near Vembanad Lake, frequent dredging (Laxmilatha and Appukuttan 2002), and dumping of organic waste from slaughter.

4.5 Conservation recommendations

Below are the most important conservation recommendations for freshwater molluscs of the Western Ghats. An overarching theme for all these is the need for recent reliable data on the species and their habitats. Without this, the design of effective conservation plans will be impossible.

4.5.1 Species-specific conservation programmes

There are no species-specific programmes in place for any freshwater mollusc in the Western Ghats region, as is the case for the Eastern Himalaya region (see Budha *et al.* 2011). This is mainly because a lack of data on species distributions, ecology, population trends and threats has held back the development of any conservation planning. Seven species have been assessed as threatened for this region. Budha *et al.* (2011) state that conservation actions for threatened molluscs species need to include conservation of habitats, restricting construction of dams, preventing forest loss and degradation in catchments and reducing pollution, and that the establishment of protected areas need to encompass aquatic habitats and their watersheds. This approach should also be applied in the Western Ghats region. For example, *Pseudomulleria dalyii* (EN) is found only in five locations and has an estimated extent of occurrence of less than 5,000 km^2. The construction of dams on Tunga and Bhadra rivers and water pollution in the Tunga River are causing major habitat degradation affecting their specialised habitat, rocky river bottoms. Conservation measures need to protect the habitat, by providing the correct flow regimes with suitable quality of water, required by species. Finally, full Environmental Impact Assessments (EIAs) that take into consideration molluscan fauna and their habitat need to be taken for every development that may impact freshwater systems. The data in this report, and on the IUCN Red List along with the species distribution shapefiles will provide an initial information source for EIAs but will not replace the critical field surveys that are needed.

4.5.2 Research actions

Freshwater molluscs of the Western Ghats region are better known than in other parts of India or other species rich areas within South and Southeast Asia. This assessment is based on the scattered published work, mostly coming from the northern Western Ghats and our own field studies. Still, a large amount of work needs to be done examining the ecosystem services these species provide, the impact of aquatic invasive plants, the distribution patterns, population status and dynamics of molluscs, and their species-specific threats. Most of the DD species identified here have not been collected since their description (often in 19th or early 20th century) or have very meagre collection details. In many cases, the description of the species is based on either single specimen or very few specimens and no natural history or ecology is detailed. It is important to revisit the type localities of these species to get adequate information on ecology and threats, to see if they are still present or have already become extinct, and in many cases to confirm their taxonomic status (Budha *et al.* 2011).

Freshwater molluscs are the carrier for Schistosomiasis (bilharzia) in humans. The only report of this disease in the assessment region is in Gimi Village in Ratnagiri District of Maharashtra State (Gaitonde *et al.* 1981). The freshwater mollusc species *Ferrissia tenuis* (LC) (Bourguignat 1862*)* is a target species for control programmes against *Schistosoma haematobium*. Other species from which schistosome infection has been reported are in *L. exustus* and *L. luteola.* The question of the transmission of urinary Schistosomiasis elsewhere in India still remains a mystery. Future research should focus on this.

4.5.3 Conservation education and awareness

Like many of the lower taxa, molluscs have very poor public image when compared to large and charismatic animals such as the tiger, elephant, rhino etc. This is particularly true in the emerging economies and is no different in India. The

conservation of molluscs at a national or state government level is practically unheard of (Budha *et al.* 2011). Recently, Budha *et al.* (2011) while assessing the conservation status of freshwater molluscs of the Eastern Himalaya Hotspot, stated *"An effort has to be made to create awareness among the public, forest managers and policy makers on the importance of lesser-known groups such as molluscs and how these species can be conserved. Until now, no such attempts have been made in this region. One of the reasons for lack of awareness is that no popular, easy to use illustrated guide on freshwater molluscs exists".* This comment is relevant to the Western Ghats also, and it highlights the fact that we are behind in producing guides, posters and other educational materials that will raise the profile of molluscs and ensure their contribution to ecosystem services is widely acknowledged and understood.

4.5.4 Policy

In India, the Wildlife (Protection) Act, 1972 provides a framework for conservation of threatened flora and fauna. However, this legislation fails to include any freshwater molluscs found in India. This assessment, will provide a base of information to help identify molluscs that require inclusion in the Act and other policies related to conservation in India.

4.5.5 Freshwater molluscs and livelihoods

Freshwater mollusc species, such as *Parreysia* sp., *Lamellidens* sp., *Corbicula* sp., *Villorita cornucopia* and *Villorita cyprinoides* are extensively used as food and to sell by low-income groups, for whom freshwater resources are often of vital importance in sustaining livelihoods and food security. For example, in the 32 fishing villages around Vembanad Lake in Kerala, about 6,500 people are involved in the black clam fishery (*Villorita cornucopia* and *V. cyprinoides*). For most people in these villages, the black clam fishery is their main source of income (Kripa *et al.* 2004, Sathiadhas *et al.* 2004). In Aghanashini estuary, on the western coast of India, *V. cyprinoides* is collected mostly by women (Boominathan *et al.* 2008). Sporadic and scattered information is available on the use of other freshwater molluscs in this region. For example, *Pila globosa* (LC) (apple snail) is used for treating sore eyes in southern India (Boominathan *et al.* 2008) and it is also used in treating wounds in poultry (Madhyastha, N.A. *pers. observ.*). The tradiational uses of different species of freshwater molluscs by the conmunities and the traditional knowledge associated with it needs to be documented. Hence, conservation actions should consider livelihood and gender issues of the communities who are dependent on these resources for their subsistence and accordingly design conservation measures that are more inclusive in strategy (Budha *et al.* 2011).

4.6 Conclusions

Seventy-seven species of freshwater molluscs were recorded in the Western Ghats Hotspot assessment region and all have been assessed according to the IUCN Red List Categories and Criteria (IUCN 2001). Of these seven species (12%) were identified as threatened, and 51 species (88%) as Least Concern with an additional 19 species listed as Data Deficient. The Western Ghats has comparatively low levels of endemicity (36%) for freshwater molluscs when compared to terrestrial snails (76%; Aravind *et al.* 2005). The taxonomy of the Western Ghats freshwater molluscs is relatively well known, but in spite of this, there are several species that have not been collected since their description. There is an urgent need for further research into (i) the ecology, distribution and long term population trends in the freshwater molluscs across the region, and (ii) impact major threats such as pollution, urbanization, invasive species, etc. on the population needs to be documented. The picture may change as more data become available in the near future for this region. There is a need to raise awareness about the importance of molluscs to ecosystems and people, and this will need to involve many different stakeholders particularly local communities.

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Waterfall in central Western Ghats from where a new species of *Cremnochonchus* has been collected. Inset top: *Sataria everzardi*. Inset bottom: hibernating *Cremnochonchus syhadrensis*. © N.A. Aravind

Chapter 5. The status and distribution of dragonflies and damselflies (Odonata) of the Western Ghats

K.A. Subramanian[1], Francy Kakkassery[2] and Manoj V Nair[3]

5.1 Overview of the regional fauna

The rivers, streams and associated wetlands of the Western Ghats Hostspot assessment region (Figure 2.1) have a high diversity and endemism of odonates. The odonate fauna of the region is comprised of 174 species with 69 endemics (Fraser 1924, 1932, 1933-36, Davis and Tobin 1984, 1985, Prasad and Varshney 1995, Subramanian 2009). Recent studies based on field surveys have provided valuable information on the geographic distribution and habitat needs of many of the odonates in the region (Peters 1981, Rao and Lahiri 1982, Prasad 1987, Mathavan and Miller 1989, Radhakrishanan 1997, Emiliyamma and Radhakrishnan 2000, 2002, Jaffer *et al.* 2002, Subramanian and Sivaramakrishanan 2002, Radhakrishnan and Emiliyamma 2003, Emiliyamma *et al.* 2005, Subramanian 2005, 2007). These studies indicate that the hill streams and rivers of Kodagu, Wyanad, Nilgiris and Anamalais have high diversity and endemism. In the current assessment of conservation status using the IUCN Red List Categories and Criteria a total of 174 species including 56 endemic species have been assessed.

The freshwater systems of the Western Ghats, such as forest streams, rivers, Myristica swamps, coastal marshes, ponds and lakes provide a wide range of habitats for odonates. In addition to this, large number of manmade wetlands such as canals, ponds, lakes, reservoirs, paddy fields, fisheries and aqua culture ponds, wells etc., are also utilised. With this diversity of freshwater habitats comes a diverse odonate fauna. Odonata communities of forested streams, rivers and Myristica swamps are characterized by species from families such as Gomphidae, Macromidae, Cordulidae, Rhynocyphidae, Euphaeidae, Protoneuridae and Platystictidae. In wetlands such as coastal marshes, ponds, lakes, reservoirs and paddy fields, species from Libellulidae, Aeshinidae, Coenagrionidae dominate along with a few species from Gomphidae, Cordulidae, Lestidae and Protoneuridae.

5.1.1 Endemism in the Western Ghats assessment region

The suborders Zygoptera (damselflies) and Anisoptera (dragonflies) are represented by eight and six families, respectively, in the Western Ghats. Zygoptera has 29 genera and 67 species, of which 25 are endemic. The Anisoptera has 53 genera, 107 species with 31 endemics. The families Libellulidae (49 species, Anisoptera), Gomphidae (26 species, Anisoptera) and Coenagrionidae (25 species, Zygoptera) are the most species-rich in the Western Ghats; however the families with a high percentage of endemism are Platystictidae, Protoneuridae, Lestidae, Chlorocyphidae, Gomphidae, Cordulegasterdiae and Corduliiidae. Families such as Platycnemidae and Calopterygidae have no endemic species in the Western Ghats (Figures 5.1, 5.2).

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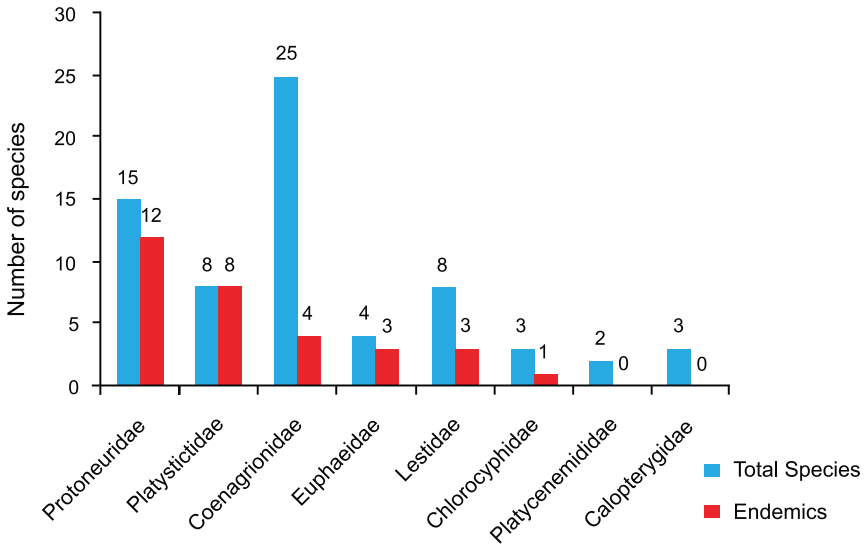

Figure 5.1 Diversity and endemism of Zygoptera in the Western Ghats hotspot assessment region.

A damselfly basking on an aquatic plant in Cauvery River in Kushalnagara. © Sanjay Molur

Disparoneura apicalis (female). © Francy Kakkassery

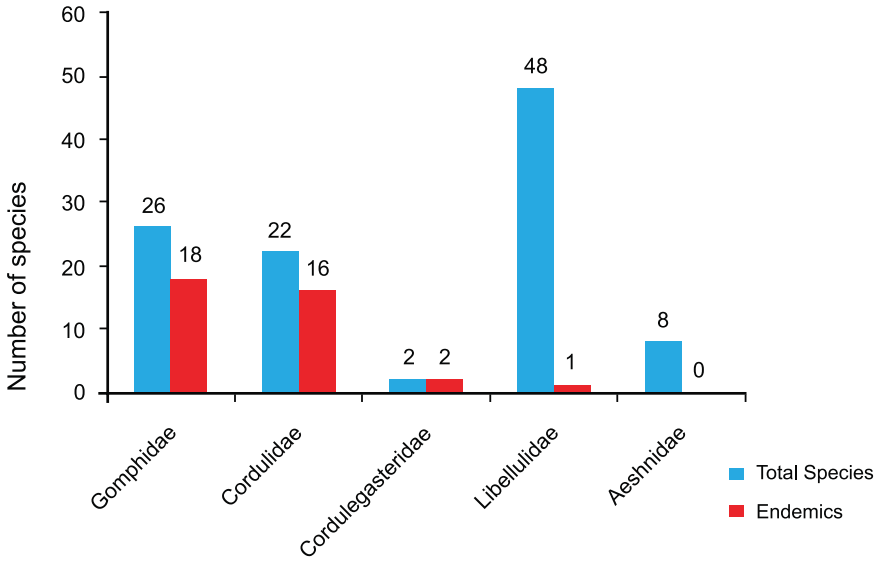

Figure 5.2 Diversity and endemism of Anisoptera in the Western Ghats hotspot assessment region.

Three monotypic endemic odonates are known from the Western Ghats. Previously, all three species, viz., *Phylloneura westermanni, Melanoneura bilineata* (Protoneuridae) and *Calocypha laidlawi* (Chlorocyphidae) were reported from Nilgiri-Wyanad-Kodagu region, north of the Palghat gap. However, recent studies have discovered populations of *P. westermanni* and *C. laidlawi* in Uttara Kannada and Kollam districts, respectively (Subramanian 2007).

Endemic odonates of the Western Ghats are mostly found in riverine habitats such as montane streams and rivers. A large proportion (82%) of the endemics survive exclusively in riverine habitats. The non-endemics on the other hand are generalists and have wider habitat preferences than endemics, including both natural and man made lotic to lentic habitats (Subramanian 2007). Over a quarter (28%) of non-endemic species use, but are not restricted to, riverine habitats.

5.2 Conservation status (IUCN Red List Category)

Using the IUCN Red List Categories and Criteria (IUCN 2001) the risk of extinction has been assessed for 171 odonate species (three species have unfortunately not been assessed as they were missing the original species list). Of extant species for which sufficient data are available, 3.2% (four species) are assessed as Vulnerable, 4.8% Near Threatened and 92% Least Concern (Table 5.1, Figure 5.3). An additional 46 species, a quarter of the species in the assessment region, have been classified as Data Deficient, meaning their risk of extinction could not be assessed.

5.2.1 Threatened species

All but one threatened and Near Threatened species are endemic to the Western Ghats region; *Indothemis carnatica* (NT) is also present in West Bengal, Sri Lanka and Thailand. Also, all species but *I. carnatica* are exclusively found in forested hill streams. Damselflies such as *Melanoneura bilineata* (NT), *Phylloneura westermanni* (NT) and *Platysticta deccanensis* (VU) are also found in Myrisitca swamps, which are a relict, threatened forest swamp ecosystems of the Western Ghats. *Chlorogomphus xanthoptera* (VU) is currently only known from four localities (about 300 km apart) in the Western Ghats to the south of the Palghat gap. No recent information is available on the species population, however the habitat (montane forests and torrential hill streams) has been impacted by the expansion of tea plantations which has led to increasing levels of water pollution (Kakkassery 2010). *Disparoneura apicalis* (VU) is

Table 5.1 Number of species of odonata in each Red List category

Red List Category	No. species	%
Extinct	0	0.0
Extinct in the Wild	0	0.0
Critically Endangered	0	0.0
Endangered	0	0.0
Vulnerable	4	3.2
Near Threatened	6	4.8
Least Concern	115	92
Data Deficient	46	N/A
Total	**171**	

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

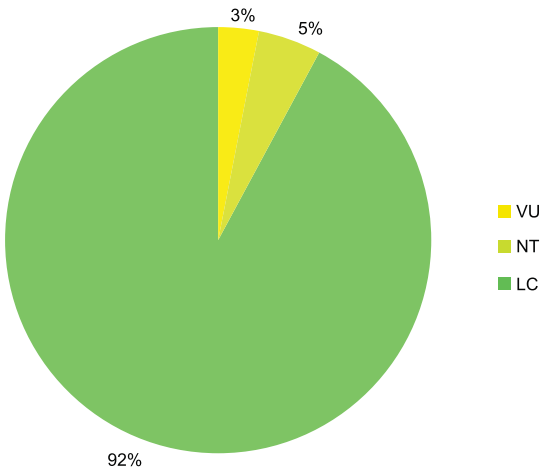

Figure 5.3 Percent of Odonata species in each Red List category.

Disparoneura apicalis (male) (VU). © Francy Kakkassery

Table 5.2 Threatened and Near Threatened odonate species of the Western Ghats Hotspot region.

Family	Binomial	Category
Gomphidae	*Heliogomphus promelas* (Selys, 1873)	NT
Cordulidae	*Idionyx galeata* Fraser, 1924	NT
Gomphidae	*Megalogomphus hannyngtoni* (Fraser, 1923)	NT
Protoneuridae	*Melanoneura bilineata* Fraser, 1922	NT
Protoneuridae	*Phylloneura westermanni* (Selys, 1860)	NT
Libellulidae	*Indothemis carnatica* (Fabricius, 1798)	NT
Gomphidae	*Chlorogomphus xanthoptera* (Fraser, 1919)	VU
Protoneuridae	*Disparoneura apicalis* (Fraser, 1924)	VU
Platystictidae	*Platysticta deccanensis* Laidlaw, 1915	VU
Platystictidae	*Protosticta sanguinostigma* Fraser, 1922	VU

known only from upper reaches of the river Cauvery in Kushalnagara (Kodagu, Karnataka) and Kuruva Islands (Wyanad, Kerala). In both the locations, the rivers and riparian forests are impacted by tourism related activities (Kakkassery 2010). *Platysticta deccanensis* (VU) is currently reported from a few locations in Kodagu (Karnataka), Thrissur, Ernakulam and Thiruvanthapuram (Kerala) districts. The habitat of the species is impacted by degradation of streams and riparian forests (Subramanian 2010). *Protosticta sanguinostigma* (VU) is only known from three to four localities (catchments) in the southern Western Ghats where they prefer unpolluted streams with good riparian forest cover. However, due to the expansion of agriculture in the catchment areas of these streams, the species is being impacted by pollution. More surveys are needed to update the data available for the species (Subramanian 2010).

Phylloneura westermanni, a Near Threatened species. © K.A. Subramanian

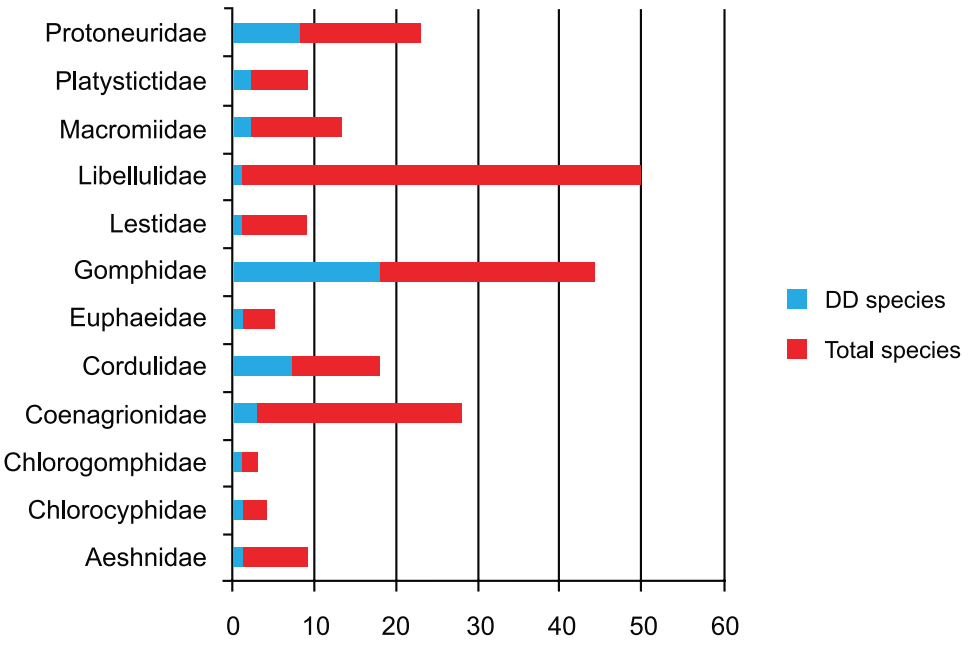

Figure 5.4 Proportion of each family containing DD species. Only those families with DD species are included.

5.2.2 Data Deficient species

Of the 46 DD species, more than half are endemic to the region (25 species). Families containing the most DD species (Figure 5.4) are Gomphidae with 18 species (which equates to 69% of the family being DD), Protoneuridae with eight (53%) and Cordulidae with seven (64%). Many of these species are found in hill streams and are known only from the type locality or from a limited number of recordings (mostly historical). Most of the Data Deficient species are elusive and have short flight period and are therefore often missed in routine biodiversity surveys. Some DD species may be threatened but due to lack of information the criteria could not be applied, for example *Calocypha laidlawi* which is a Myristica swamp forest specialist only known from a limited area in southern India (Sullia area and adjacent parts of Kerala and Karnataka), where human population pressure is high. However, there are only a few known records for this species which date from the 1920s and 1930s, and there has been a lack of recent sampling in the area.

5.3 Patterns of species richness

5.3.1 All odonate species

The diversity of Odonata in the Western Ghats is not evenly distributed. The highest levels of species richness (112-128 species per sub-basin) is found in the hotspot in southern Karnataka and northern Kerala (Figure 5.5). This includes the hilly tracts south of Udupi to Mysore, in Karnataka which encompasses the upper Cauvery catchment, the coastal rivers of northern Kerala from Kasaragod to Palghat (districts) including the Chaliyar, Kuttyadi and Vallappattanam rivers and also the upper Cauvery in north-western Tamil Nadu in the Bhavani and Moyar rivers. Areas of high species richness (between 85-111 species per sub-basin) are found spreading south within the Western Ghats Hotspot in Kerala and Tamil Nadu, including the upper Cauvery (Amravati River), Vaigai and Chittar rivers and the west flowing Bharatapuzha and Periyar rivers. Species richness then declines northwards through the hotspot and then eastwards to Andhra Pradesh.

While the maps indicate diversity of Odonata across river-basins (as this is how the species were mapped), in reality the diversity is better related to forests, where high richness is found in the forested upper catchments than in the downstream plains which are dominated by agriculture. This is especially true in the eastern basin of Western Ghats where the higher diversity is restricted to the forested upper catchments in the Western Ghats.

Chlorogomphus campioni, a Data Deficient species.
© K.A. Subramanian

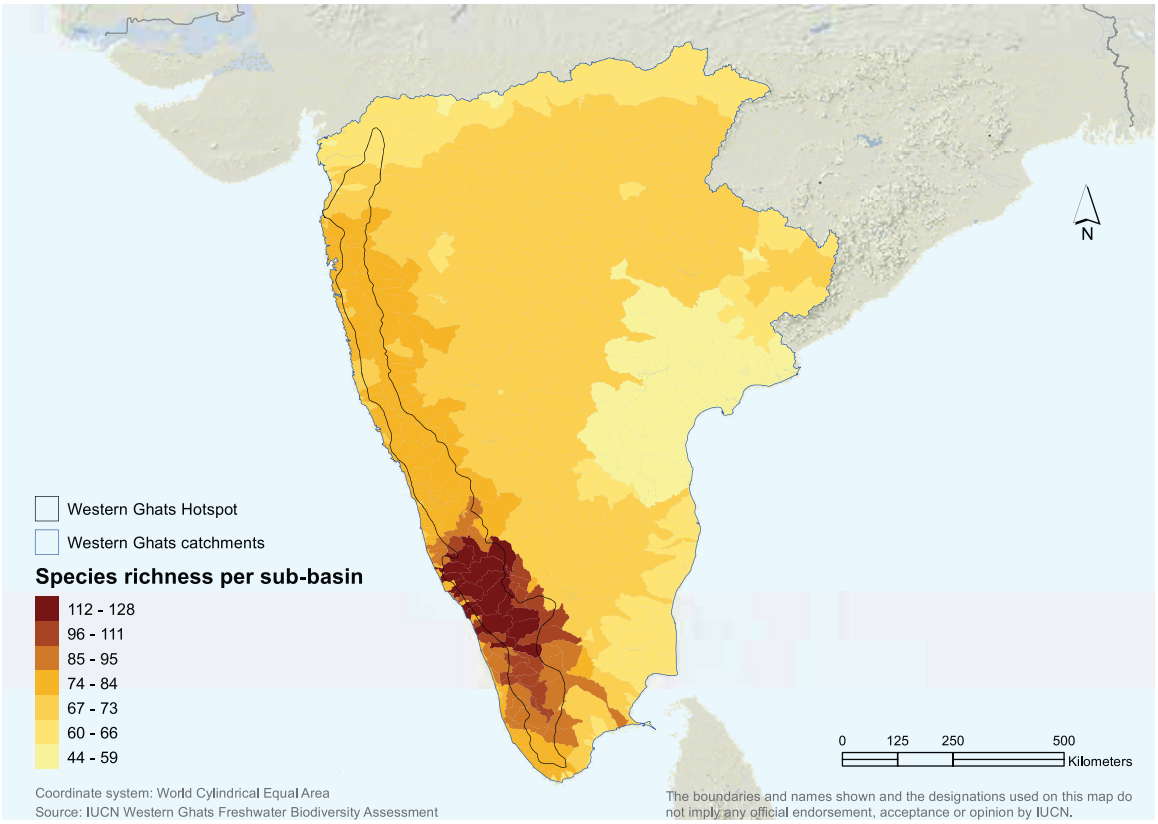

Figure 5.5 Species richness of odonates in the Western Ghats assessment region.

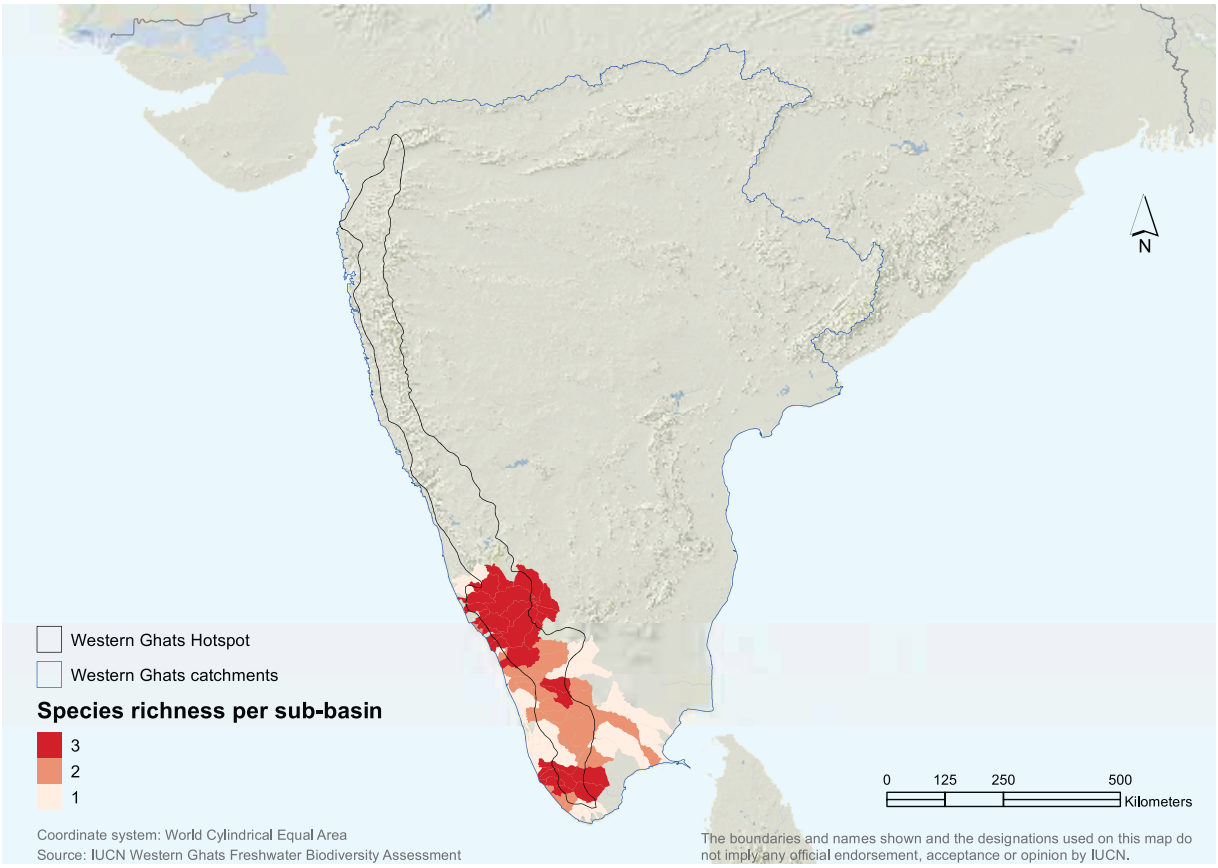

Figure 5.6 Species richness of threatened odonates in the Western Ghats assessment region.

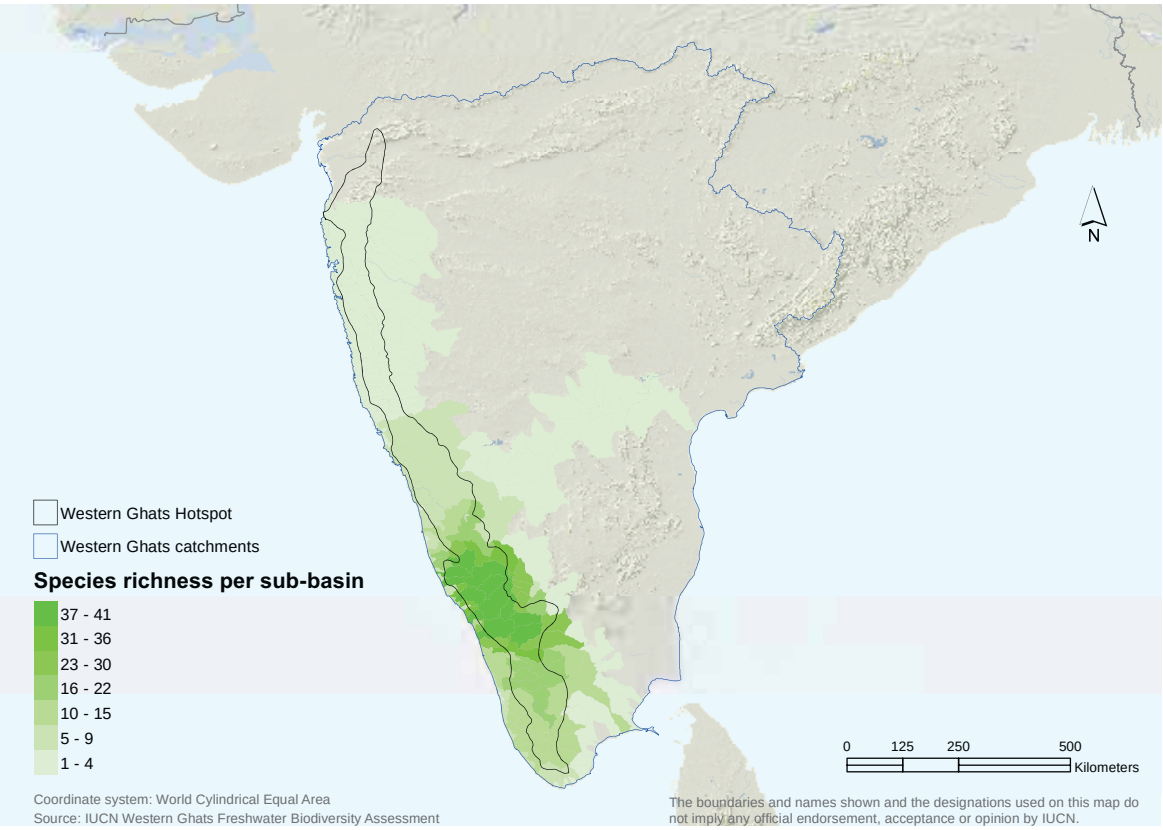

Figure 5.7 Species richness of endemic odonates in the Western Ghats assessment region.

To some extent, the species richness maps also indicate sampling patterns. The Kodagu, Nilgiris and Anamalai hills, which are relatively species rich areas are better surveyed for Odonata. Areas south of the Palghat gap, where richness declines in the upper catchments of Periyar, Pamba, Achankovil, Neyyar, Vaigai and Tambraparni, are poorly surveyed. Similarly, little information is available from upper catchments north of Kodagu such as Netravati, Sharavathi, Kalinadi, Mandovi, Savitri, Sashtri, and Vasishti.

5.3.2 Threatened species

All the threatened species are exclusively found in forested hill streams or high altitude shola grasslands of the southern Western Ghats Hotspot (Figure 5.6). Areas containing the most threatened species (three per sub-basin) are the upper Cauvery in southern Karnataka, coastal streams of northern Kerala including the Valappattanam, Kuttyadi and Chaliyar, the upper Bharatapuzha in Kerala/Tamil Nadu, the Kallada and Achankovil of southern Kerala and upper Chittar of southern Tamil Nadu.

5.3.3 Endemic species

Endemic odonates of the Western Ghats region are almost totally confined to the Hotspot (Figure 5.7), and the areas of highest endemism (31-41 species per sub-basin) reflect the areas of highest species richness (Figure 5.5) such as the upper Cauvery (southern Karnataka), coastal rivers of northern Kerala and the Bhavani and Moyar (both upper Cauvery system) in north-western Tamil Nadu.

5.4 Major threats to Odonata

Major threats to Western Ghats odonates have been identified as agriculture, urban development and water pollution and are discussed below (see also Chapter 7 for a quantitative analysis of threats).

5.4.1 Agricultural pollution

In terms of geographic spread and impact, agricultural activity and associated habitat modification, stream flow regulations, pesticide, fertilizer and sediment runoff are the greatest threats to the odonate diversity of the Western Ghats. These chronic threats are spread over time and space in intensity and impact, making it difficult to monitor and predict the consequences on odonate diversity. Impact of non-point source chemical pesticides such as organochlorines, organophosphates and synthetic pyretheroides on odonates of the Western Ghats is not known. However, the total absence of endemic fauna in streams running through various commercial plantations, such as tea, coffee, cardamom and rubber, in recent field studies indicates that chemical pesticides may indeed be causing serious damage to the odonate fauna.

A degraded river: Kalpathypuzha, a tributary of Bharatapuzha, Palakkad District, Kerala. © K.A. Subramanian

Specific habitat modifications such as conversion of Myristica swamps to areca nut and other plantations are fast denuding important habitats for endemic odonates, especially the monotypic species such as *Phylloneura westermanni* (NT)*, Melanoneura bilneata* (NT) and *Calocypha laidlawi* (DD). Riparian deforestation for agricultural development, along with diversion of streams and indiscriminate construction of dams, drastically alters the flow dynamics of the streams and fundamentally changes the larval habitats.

5.4.2 Urban and industrial development

Urban and industrial developments across the Western Ghats region present a major threat due to the resulting decline in habitats such as water bodies. Conversion of ponds, tanks and pools for agricultural purposes, semirural and urban expansions, industrial developments and road construction cause irreparable damage to habitats that support odonates. In addition, sand mining, riparian deforestation, soil erosion and dumping of solid waste also threaten the habitats of odonates.

5.5 Conclusions and conservation recommendations

The river basins and associated freshwater ecosystems of the Western Ghats are global hotspots for odonates with high levels of endemism. Even though only 3.2% (four species) of the species are known threatened, over a quarter of the odonates in the region (46 species) have been assessed as DD. Many of these species are likely to be threatened as they are only known from historical records, often just the type specimens, and urgently need more survey work to identify their current ranges, populations and threats.

Research is also required in those large areas where there is insufficient information on odonate diversity and distributions such as those south and north of the southern Karnataka–northern Kerala habitats and eastwards into the Deccan plateau.

Many of the endemic odonates such as *Disparoneura apicalis* (VU) (Protoneuridae), *Platysticta deccanensis* (VU) (Platystictidae), *Melanoneura bilineata* (NT) (Protoneuridae) or *Idionyx* spp. (Cordulidae) are very narrowly distributed within the Western Ghats. The destruction of riverine habitats by hydro-electric and irrigation projects threatens the survival of these odonates, which depend on fast flowing torrential streams or stream associated habitats such as Myristica swamps. Destruction or alteration of a small catchment means likely extinction of these species. The protection of key habitats (fast flowing streams) for these species is an immediate priority. This is particularly urgent for species such as *Disparoneura apicalis*, *Calocypha laidlawi* and *Melanoneura bilineata*.

Long term conservation of the odonate fauna of the region depends upon: (1) conservation of riparian forest cover, (2) prevention of flow modifications in streams and rivers, (3)

Industrial pollution, Kalinadi River, Dandeli, Karnataka. © K.A. Subramanian

conservation of Myristica swamps and high altitude peat bogs, and (4) prevention of use of pesticides and other agrochemicals in upper catchments of rivers.

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Cauvery River at the Gaganachukki waterfalls in Kollegal. © Sanjay Molur

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

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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

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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.

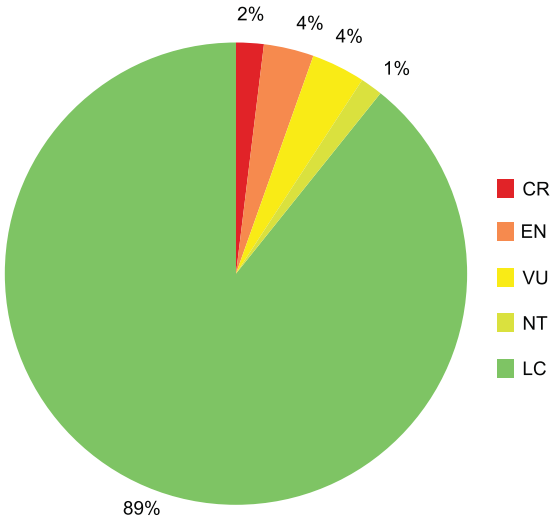

Figure 6.1 Percentage of aquatic plant species in each Red List category in the Western Ghats assessment. region. (IUCN Red List Category: CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, LC – Least Concern)

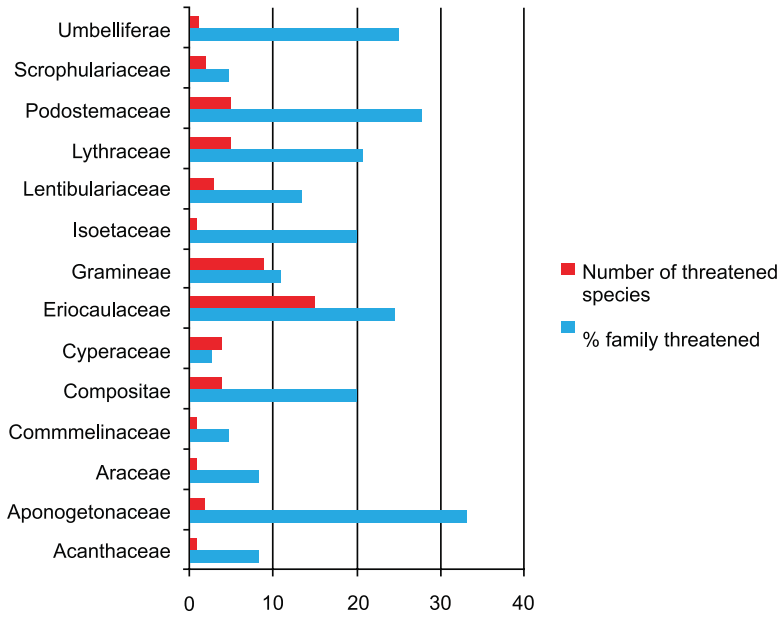

Figure 6.2 Number and proportion of threatened species in the selected aquatic plant families.

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

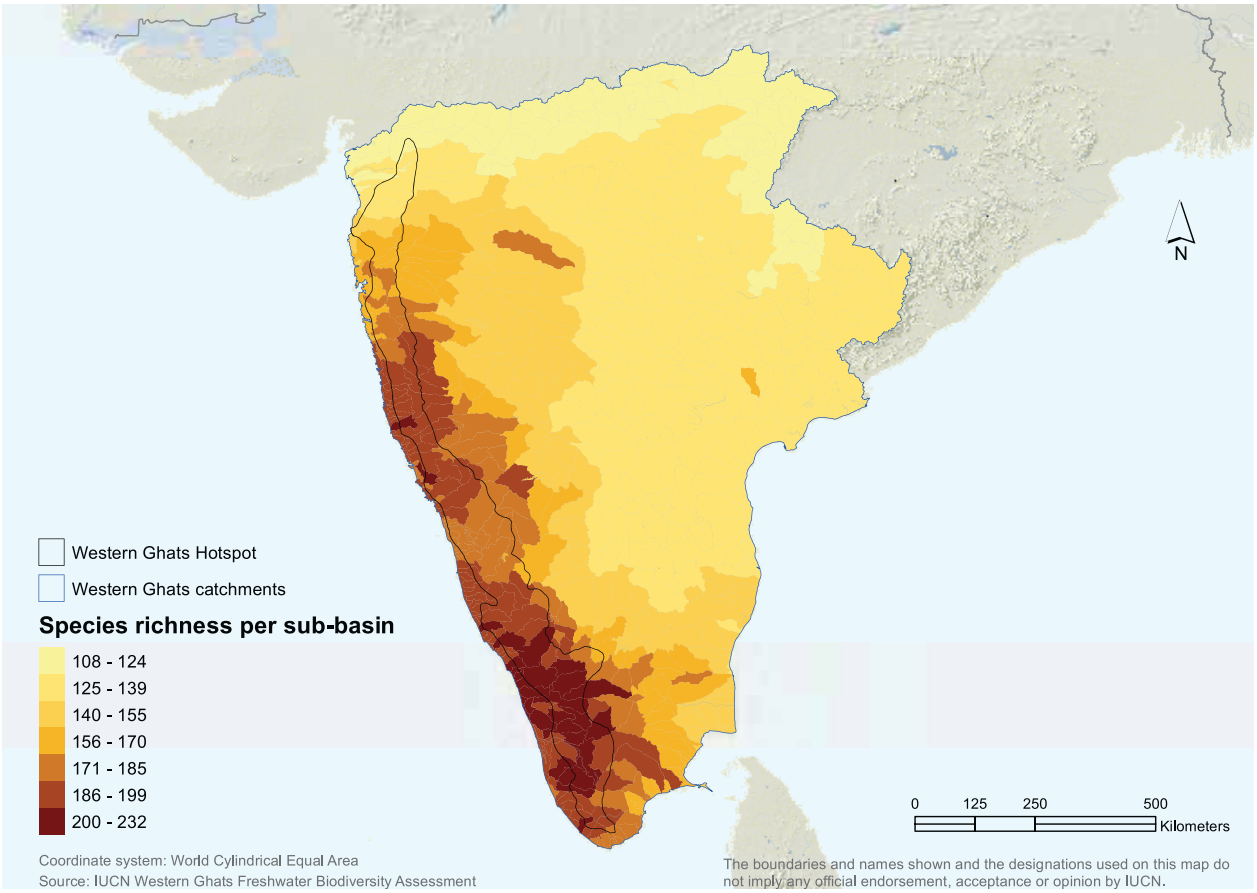

Figure 6.3 Species richness of aquatic plants species in the Western Ghats assessment region.

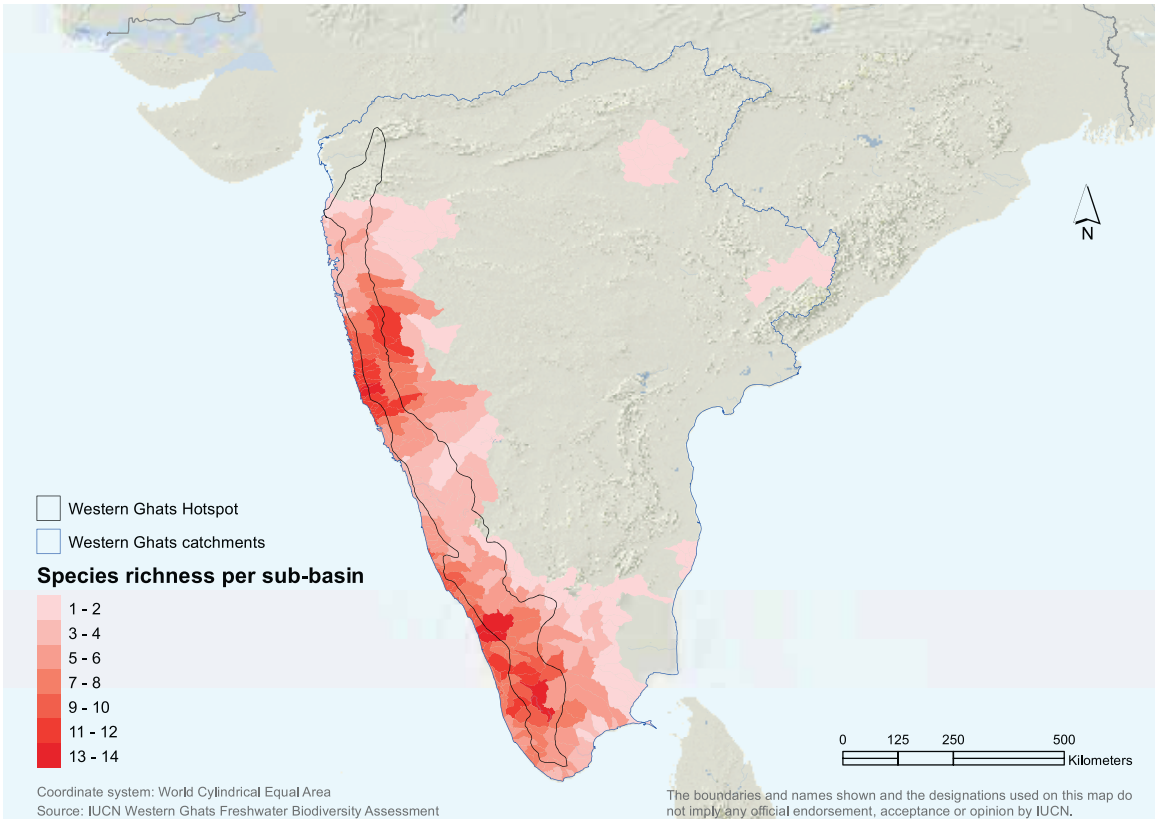

Figure 6.4 Species richness of threatened aquatic plants species in the Western Ghats assessment region.

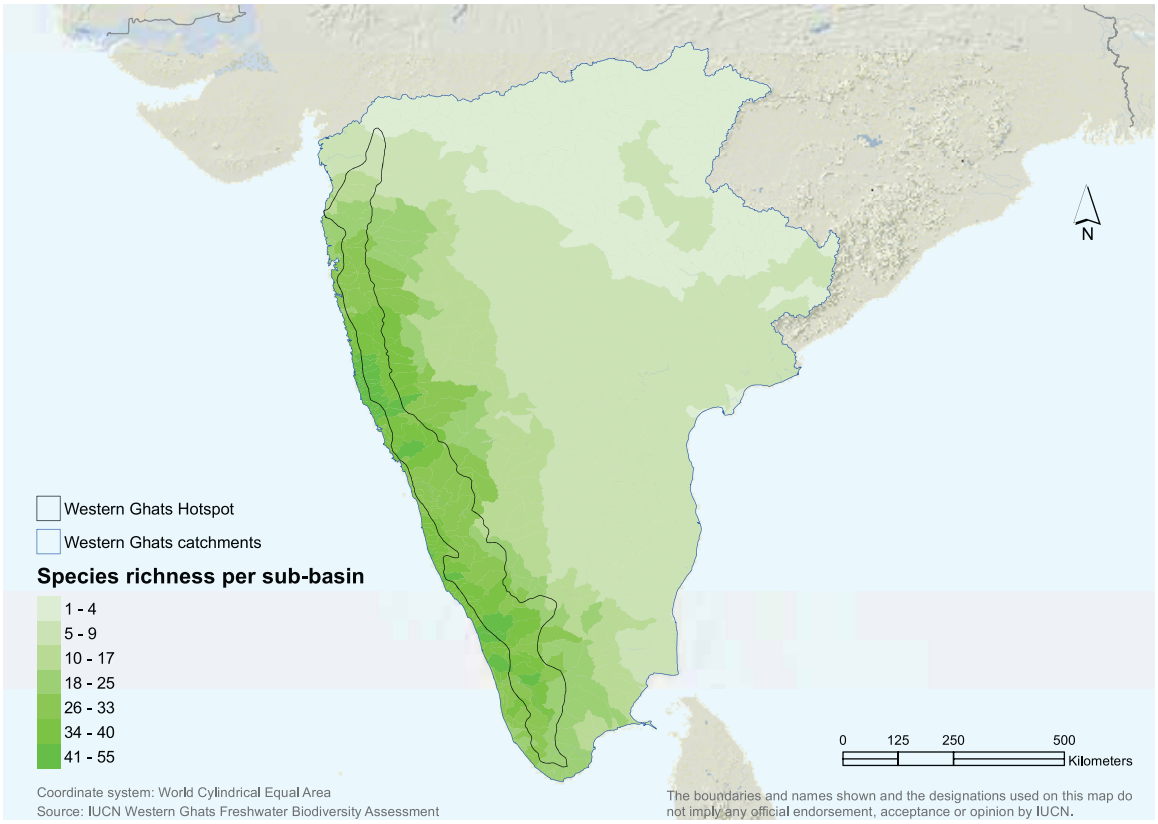

Figure 6.5 Species richness of aquatic plants species endemic to the Western Ghats assessment region.

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.

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Cauvery River at Ranganathittu Bird Sanctuary. © Sanjay Molur

Stream vegetation on Chaliyar River. © Sanjay Molur

Chapter 7. Synthesis for all taxa

Kevin Smith[1], Rajeev Raghavan[2], Neelesh Dahanukar[3], Sanjay Molur[4], Robert Holland[1], Adrian Hughes[1] and David Allen[1]

7.1 Introduction

In this synthesis chapter we combine all the data sets from Chapters 3 to 6 (freshwater fishes, molluscs, odonates and aquatic plants) and consider the status and distribution (overall species richness, endemic, Data Deficient and threatened species richness) of freshwater biodiversity across the Western Ghats region. The factors driving threats to the freshwater biodiversity conservation, are quantified and discussed and potentially important sites for freshwater species, known as Key Biodiversity Areas identified. The objective of this analysis (and the accompanying data) is to provide outputs to inform conservation and development planning for wetland ecosystems and species at the national, state, catchment and site scales.

7.2 Red List status

Whilst the Western Ghats region covers less than one percent of the Earth's land surface (excluding Antarctica) it supports a significant proportion of species dependent upon freshwater habitats (Table 7.1). The region contains nearly 2% of the world's freshwater fishes, 3% of the odonates and amphibians and just over 4% of the world's freshwater dependant mammals. The plants have the highest representation within the region with over 25%, however this may partly reflect that the definition of an aquatic plant used by Balian *et al.* (2008) is stricter than the one used by this project.

Of the 1,146 species within the projects' focus groups (fishes, molluscs, dragonflies and damselflies, and aquatic plants)

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Table 7.1 Estimated numbers of extant inland water-dependent species by major taxonomic groups.

Taxon	Global number of described species	Number of species in Western Ghats assessment region	% of species found in Western Ghats assessment region
Fish	>15,000[1]	290[3]	1.9%
Molluscs	>5,000[1]	77[3]	1.5%
Odonates	5,680[1]	1,713	3.0%
Plants	21,411*	541[3#]	2.5%
Amphibians	4,221[2]	137[4]	3.2%
Mammals	145[2]	6[4]	4.1%

Data sources: [1]Balien *et al.* 2008; [2]2010.4 IUCN Red List - filtered by 'system = freshwater'; [3]species lists generated by experts for this project; [4] Based on GIS analysis using the Red List species distributions; [*]Total species for the families listed by Balian *et al.* (2008) that are comprehensively assessed through this project; [#]Not all families comprehensively assessed by this project are listed in Balian *et al.* (2008), therefore this is the total number of species identified by this project that are in the families that are listed by Balian *et al.* (2008).

Table 7.2 Summary of Red List Category classifications at the global scale by taxonomic group.

Category	Fish	Molluscs	Odonata	Plants	Overall
EX	0	0	0	0	0
EW	0	0	0	0	0
CR	12	0	0	12	24
EN	54	4	0	21	79
VU	31	3	4	21	59
NT	6	0	6	8	20
LC	161	51	115	517	844
DD	26	19	46	29	120
% Threatened	36.7	12.1	3.2	9.3	15.8
Total	290	77	171	608	1146

IUCN Red List Categories: EX – Extinct, EW – Extinct in the Wild, CR – Critically Endangered, EN – Endangered, VU – Vulnerable, NT – Near Threatened, LC – Least Concern, DD – Data Deficient . The highlighted rows (CR, EN and VU) are the 'threatened' categories.

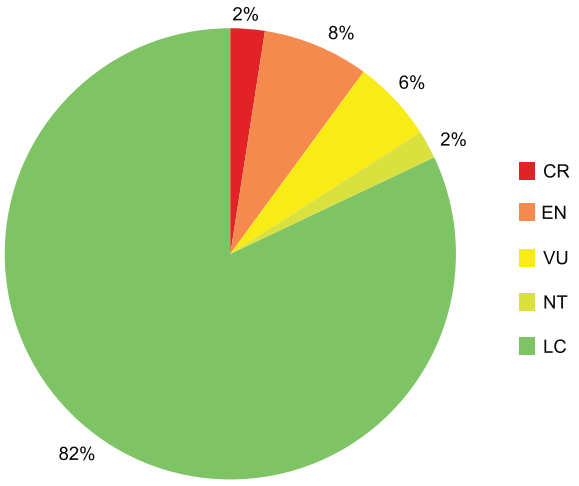


Figure 7.1 The proportion (%) of extant species for which sufficient data are available withing each global Red List Category. Note that an additional 120 species are assessed as Data Deficient and do not have sufficient information to be able to identify their risk of extinction.

currently known to be present within the Western Ghats Biodiversity Hotspot, 15.8% (162 species) of extant species for which sufficient data are available are threatened (Table 7.2; Figure 7.1). None are considered to have become Extinct (EX) or Extinct in the Wild (EW), although five species of fishes and five species of plants are assessed as Critically Endangered (Possibly Extinct), which means that urgent surveys are required to confirm whether the species are still extant or have become extinct. When compared with the level of global threat for selected taxonomic groups that have been comprehensively (i.e. all known species) assessed (e.g. amphibians 40.7% threatened; mammals 24.7% threatened; birds 12.6% threatened) (IUCN 2010), this figure is relatively low, being just greater than birds. However, when compared to a similar study of the Eastern Himalaya Hotspot (Allen *et al.* 2010), where 10.4% of extant species for which sufficient data are available are threatened, the level of threat in the Western Ghats is higher. However, the level of Data Deficient freshwater species in the Western Ghats is also relatively low (10.4%) when compared with amphibians (25.3% DD), mammals (15.2% DD), and the Eastern Himalaya project freshwater species (31.3% DD), but is much greater than birds (0.6% DD) (IUCN 2010).

7.3 Patterns of species richness

Species richness is presented as the number of species contained within river sub-basin, derived from HydroSHEDS hydrographic data (Lehner *et al.* 2008) and has been mapped to include the four species groups included in this. As not all plant species have been mapped to river sub-basin but rather to countries (see Chapter 6), we have not included the plants in the multi-taxa analyses presented here.

As with many species richness maps, they have the potential to be biased by sampling intensity and mapping methodology. Some parts of the region may have benefited from more intensive survey effort and taxonomic study either historically (i.e. the colonial era) or by more recent workers, or because they happen to be close to research centres. Conversely, some areas are likely to have higher species richness than is shown in this report as they have been historically under-surveyed, often because of political instability or actual difficulty of access. We have attempted to overcome these potential biases by asking participating experts to infer species distributions based on their knowledge of each species ecological requirements.

7.3.1 Centres of species richness

The highest levels of species richness (between 260-312 species per sub-basin) are almost all within the southern part of the Western Ghats Hotspot (Figure 7.2). These high richness catchments include the western flowing rivers (moving south to north); Pamba, Meenachil, Muvattupuzha, Periyar, Karuvannur, Bharatapuzha, Chaliyar, Kuttyadi, and Valappattanam in Kerala, the Netravati in southern Karnataka, and the eastern flowing rivers: (moving north to south) upper Vaipar, the Amaravati, Bhavani and Moyar (all upper Cauvery catchment) in Tamil Nadu and the upper Kabini and Cauvery in southern Karnataka. Species richness then decreases northwards through the Western Ghats Hotspot and then east towards Andhra Pradesh.

These highly species-rich catchments drain the Sivagiri, Nilgiri, Kodagu, Attapadi and parts of Anamalai hills (in the Periyar-Agasthyamalai, Mysore-Nilgiri and some parts of Anamalai corridors (CEPF 2011) where they flow through southern Western Ghats montane rain forests, southern Western Ghats moist deciduous forests and the Malabar Coast moist forests (around the lowland rivers). Many protected areas (including the Periyar National Park, the Aralam Wildlife Sanctuary, the Wyanad Wildlife Sanctuary, the Silent Valley National Park and the Mudumalai Wildlife Sanctuary) as well as reserved forests such as New Amarambalam and Siruvani are located within or near to these catchments.

The decrease in species richness northwards through the Western Ghats Hotspot is thought to be primarily a consequence of a lack of data on fish fauna in most of these rivers. West flowing rivers of the central and northern Western Ghats (Dahanukar *et al.* 2004), and tributaries of east flowing rivers like Krishna and Godavari (Jadhav *et al.* 2011) remain poorly explored or in some cases have not been explored at all.

7.3.2 Distribution of threatened species

The greatest numbers of threatened species (between 40 and 48 species within a sub-basin) are found almost entirely within the southern tip of the Western Ghats Hotspot in Kerala and Tamil Nadu. These include the western-flowing rivers (from south to north): the Pamba, Manimala, Meenachil, Muvattupuzha and Periyar which all flow into Vembanad Lake, and the Bharatapuzha River; and the eastern flowing the upper Vaipar and Amaravati (part of the Cauvery catchment) (Figure 7.3).

The catchments that contain relatively high numbers of threatened species (31-39 species) are again, almost entirely within the southern part of the Western Ghats Hotspot (Figure 7.3); these rivers include the Kallada and Achankovil in southern Kerala, the upper Chittar and Vaigai in southern

The Bharatapuzha River in Silent Valley is one of the species rich sub-basins in the southern Western Ghats. © Rajeev Raghavan

Tamil Nadu, the Bharatapuzha, the Chaliyar and upper Cauvery (the Bhavani and Moyar) which all drain from the Nilgiris Mountains in Tamil Nadu and Kerala, the upper Kabini (Bilgiri Rangan Hills) on the Karnataka–Kerala border, and the upper Tungabhadra (in the Kappat Hills) in Karnataka.

Richness of threatened species then decreases northwards through the Western Ghats Hotspot and then east towards Andhra Pradesh.

Catchments with the highest numbers of threatened species drain the Sivagiri, Nilgiris, Attapadi, Anamalai and the Agasthyamalai hills (in the Periyar-Agasthyamalai, Mysore-Nilgiri and Anamalai corridors (CEPF 2011)) where they flow through southern Western Ghats montane rain forests, southern Western Ghats moist deciduous forests, northern Western Ghats moist deciduous forest as well as the Southern Deccan Plateau dry deciduous forests. Many protected areas are located in these catchments including the Biligiri Ranganatha Swamy Temple Sanctuary, Bhadra Wildlife Sanctuary, Shendurney Wildlife Sanctuary, Kalakkad-Mundathurai Tiger Reserve, Silent Valley National Park, Mudumalai Wildlife Sanctuary, Periyar Tiger Reserve, Chinnar Wildlife Sanctuary apart from the reserved forests of Achankovil, New Amarambalam, Attapadi and Siruvani.

Lowland areas within most of the above catchments are subjected to sand mining, pollution from industrial sources and domestic sewage, whilst the upper catchments of the Periyar and the Bharatapuzha have been dammed extensively. These upper reaches are also subjected to pollution from plantations of tea, coffee, and cardamom. In addition, there is also an ongoing threat from increased tourism in the middle and upper reaches of these catchments.

7.3.3 Distribution of Data Deficient species

The map of Data Deficient species highlights those areas where more research is needed. However, it should be noted that not all Data Deficient species can be mapped as their distributions may remain unknown or too uncertain to be suitable for mapping. In some cases species are only known from their type locality, which itself is uncertain.

Sub-basin with the highest numbers of Data Deficient species are all within the southern part of the Western Ghats Hotspot from the western flowing (south to north) Bharatapuzha, Chaliyar, Kuttyadi and the Valappattanam of Kerala and the upper Netravati of southern Karnataka; and from the eastern flowing upper Cauvery catchment in the Bhavani and Moyar in the Nilgiris Mountains, Tamil Nadu, and the Kabini and upper Cauvery in southern Karnataka. Richness of Data Deficient species then decreases travelling south and north through the Western Ghats hotspot and then eastwards to Andhra Pradesh (Figure 7.4).

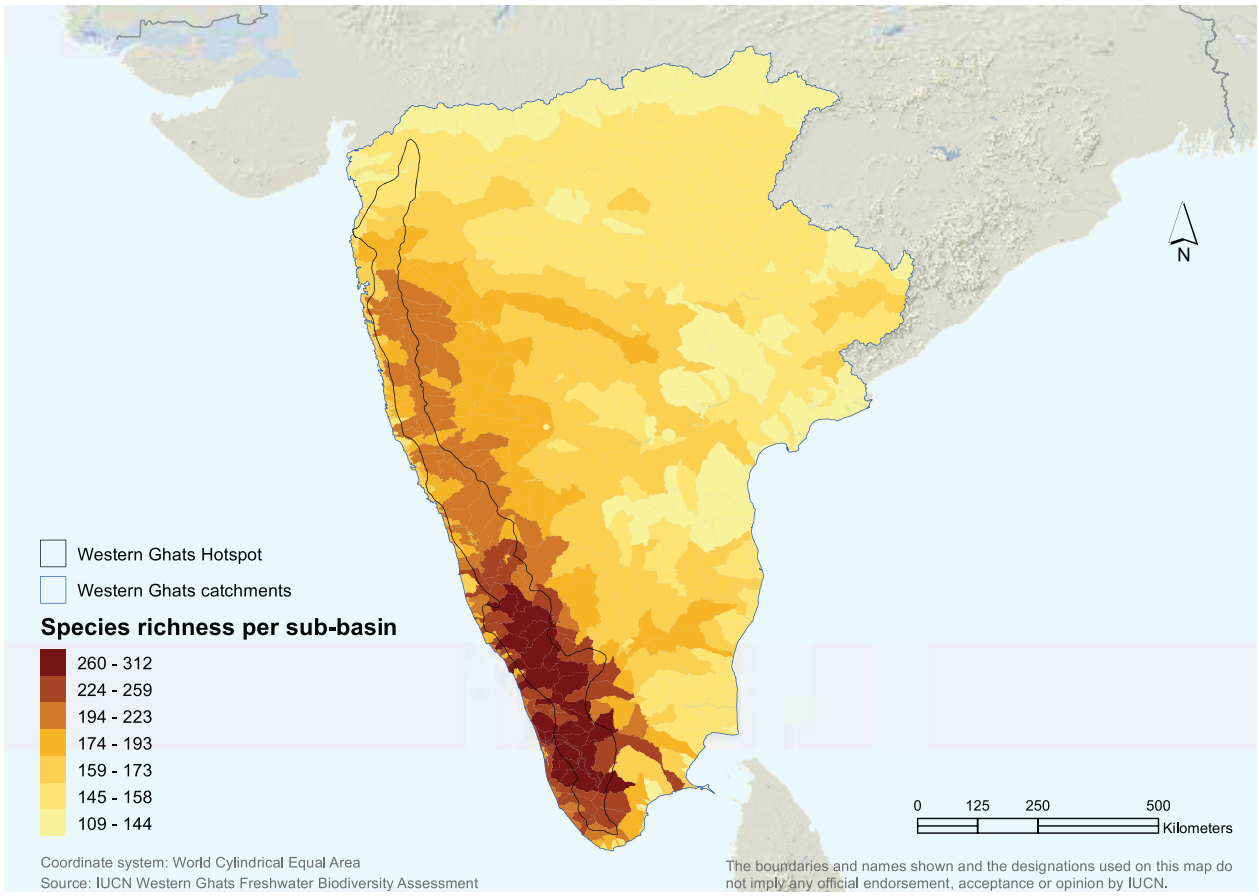


Figure 7.2 Distribution of all species of fishes, molluscs and odonates in the Western Ghats project area.

Sub-basin with the highest numbers of Data Deficient species drain the Nilgiris, Attapadi hills and parts of Anamalai hills (Mysore-Nilgiri and Anamalai corridors of the CEPF Investment) where they flow through southern Western Ghats Montane rain forests, southern Western Ghats moist deciduous forests, southern Deccan plateau dry deciduous forests and parts of Malabar Coast moist forests. Protected areas in this catchment include the Aralam Wildlife Sanctuary, Mudumalai Wildlife Sanctuary as well as the Silent Valley National Park and also the reserved forests of New Amarambalam, Attapadi and Siruvani.

7.3.4 Distribution of endemic species

Areas of high endemic species richness (between 103 and 129 species per sub-basin) are found within the southern Western Ghats Hotspot (Figure 7.5). The west flowing catchments that contain these high levels of endemism are (from south to north) Pamba, Manimala, Meenachil, Muvvatupuzha, Periyar, Bharatapuzha, Chaliyar, Kuttyadi and the Valappattanam all in Kerala (with small overlap into Tamil Nadu and Karnataka); the east flowing rivers are all parts of the upper Cauvery catchment and include (from south to north) the upper Amaravati, Bhavani and Moyar in Tamil Nadu and Kerala, and the Kabini and upper Cauvery in southern Karnataka. Richness of endemic species then decreases northwards through the Western Ghats Hotspot and east towards Andhra Pradesh.

Catchments with the highest number of endemic species drain the Sivagiri, Nilgiris, Attapadi and parts of Anamalai hills (Mysore-Nilgiri, Malnadu-Kodagu as well as parts of Anamalai corridors of the CEPF Investment) where they flow through the southern Western Ghats montane rain forests, southern Western Ghats moist deciduous forests and northern Western Ghats moist deciduous forests. Protected areas in this catchment include the Periyar National Park, Idukki Wildlife Sanctuary, Aralam Wildlife Sanctuary, Malabar Wildlife Sanctuary, Silent Valley National Park, Chinnar Wildlife Sanctuary, Mudumalai Wildlife Sanctuary, Wyanad Wildlife Sanctuary, Cauvery Wildlife Sanctuary, Brahmagiri Wildlife Sanctuary, Pushpagiri Wildlife Sanctuary and Talakaveri Wildlife Sanctuary, and the reserved forests of New Amarambalam, Attapadi and Siruvani.

7.3.5 Freshwater mammals, birds and amphibians

As all birds, amphibians and mammals have been globally assessed on the IUCN Red List, the freshwater/wetland species from these groups can be included in the analysis. The number of species and their Red List categories are shown in Table 7.3. It shows that, even though there are only eight freshwater-dependent mammals, six of these (75%) are globally threatened including the Asian buffalo (*Bubalus arnee*) and Fishing cat (*Prionailurus viverrinus*), both of which are Endangered, and the Asian small-clawed otter (*Aonyx cinerea*) and the Smooth coated otter (*Lutrogale perspicillata*)

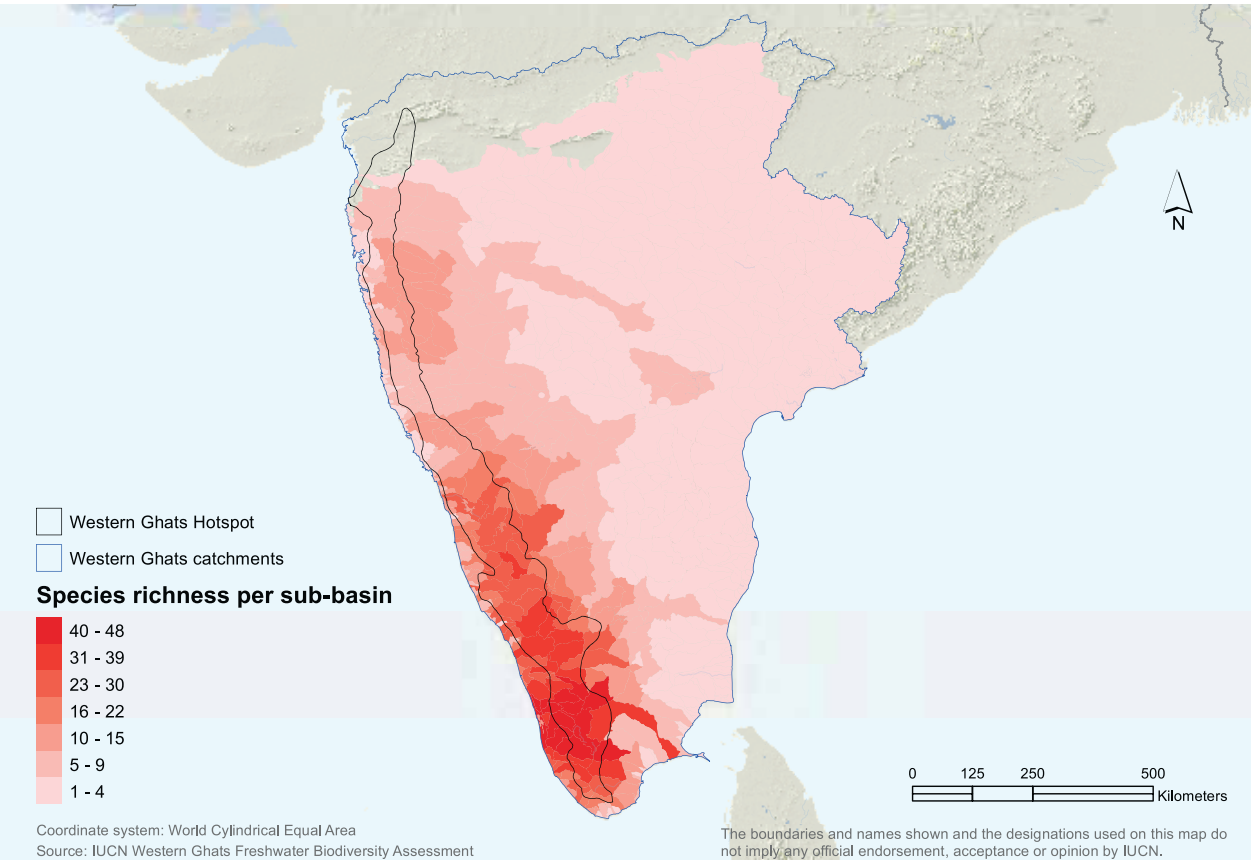


Figure 7.3 Distribution of all threatened species (listed as CR, EN or VU) of fishes, molluscs and odonates in the Western Ghats project area.

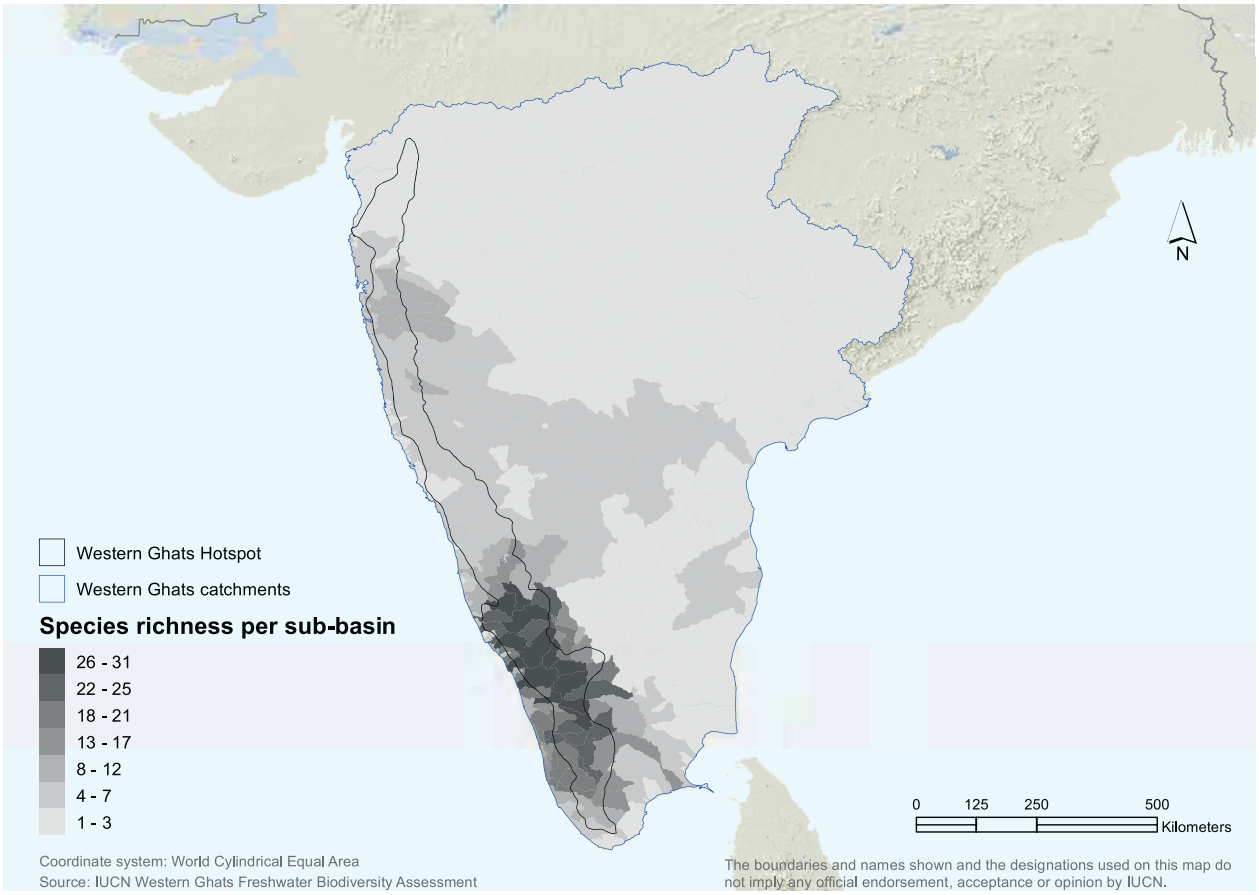


Figure 7.4 Distribution of all Data Deficient (DD) species of fishes, molluscs and odonates in the Western Ghats project area.

Table 7.3 Summary of Red List Category classifications at the global scale for freshwater mammals, birds, and amphibians of the Western Ghats region.

Category	Mammals	Birds	Amphibians
EX	0	0	0
EW	0	0	0
CR	0	0	5
EN	2	0	21
VU	4	3	9
NT	2	6	5
LC	0	41	32
DD	0	0	29
% Threatened	75	6	35
Total	**8**	**50**	**101**

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

both of which are assessed as Vulnerable. The wetland birds in the Western Ghats region are less threatened than the mammals with only three of the 50 species (6%) assessed as threatened. The threatened water birds are the Sarus crane (*Grus antigone*), Pallas's fishing eagle (*Haliaeetus leucoryphus*) and the Indian skimmer (*Rynchops albicollis*) all of which are Vulnerable and occur in the very north of the assessment region. One-hundred-and-one amphibian species are found within the western Ghats assessment region, 35 of these (35%) are threatened, including *Indirana gundia*, *Fejervarya murthii*, *Indirana phrynoderma*, *Micrixalus kottigeharensis* and *Rhacophorus pseudomalabaricus* all of which are Critically Endangered and found only within the Western Ghats Hotspot.

By including distributions of these additional groups with those of the fishes, molluscs and odonates, a more comprehensive picture of the geographic patterns of freshwater species richness and areas of threatened freshwater species can be produced. The combined map for all freshwater species (Figure 7.6) shows a very similar pattern to that of just the fishes, molluscs and odonata with the only notable difference being an increase in richness for most sub-basin. Sub-basin containing the highest species richness (between 337 and 404 species) are still within the southern Western Ghats Hotspot, from the upper Cauvery in southern Karnataka, through some of the coastal rivers of Kerala and the Moyar and Bhavani of northern Tamil Nadu. Species richness then decreases northwards through the hotspot and then eastwards to Andhra Pradesh.

The richness of threatened species for all groups combined (Figure 7.7), again reflects that shown by just the fishes,

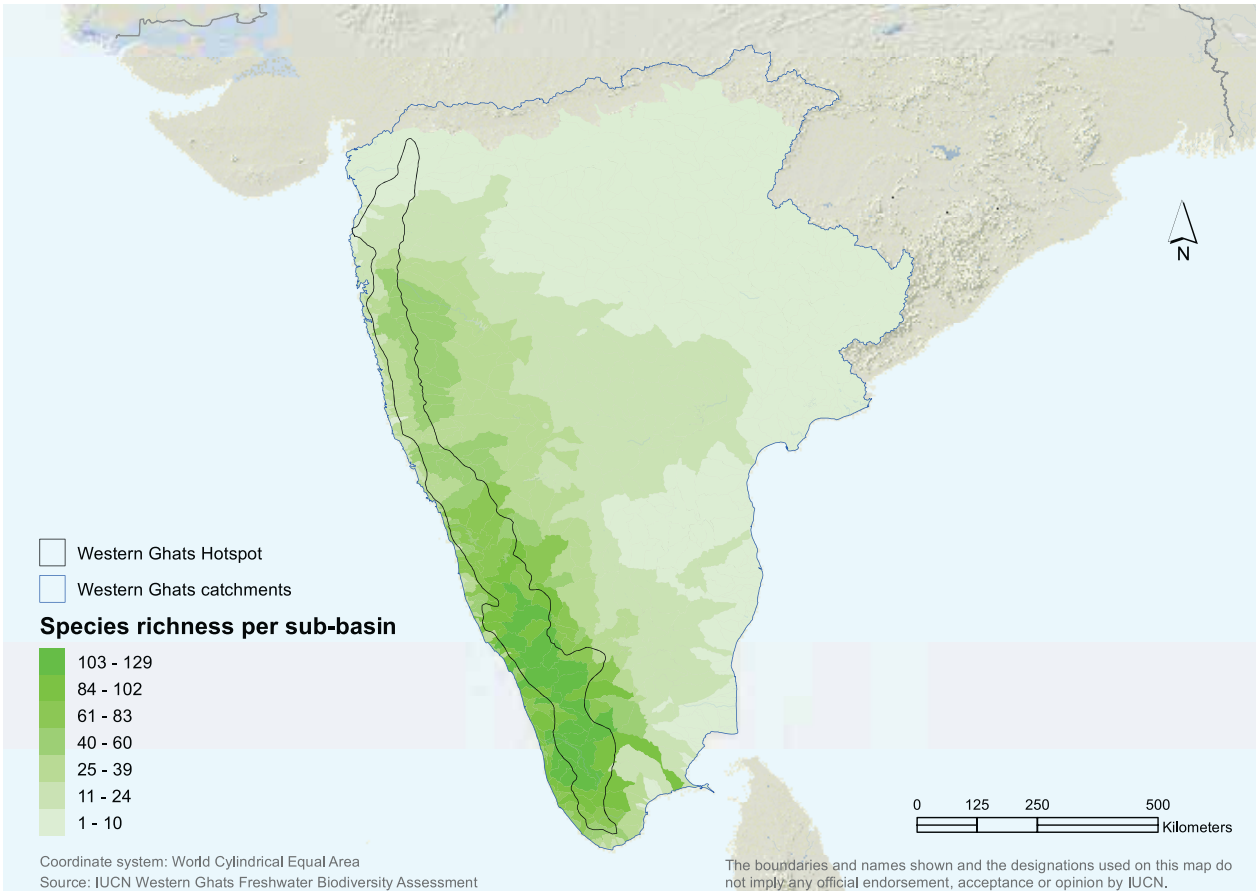


Figure 7.5 Distribution of all species of fishes, molluscs and odonates endemic to the Western Ghats project area.

molluscs and odonates. The areas of greatest richness of threatened species (52-62 species) are within the southern tip of the Western Ghats Hotspot, in the Chaliyar, Periyar, and Pamba rivers of Kerala and the upper Amaravati (upper Cauvery) in Tamil Nadu. Again, threatened species richness declines northwards through the hotspot and then eastwards to Andhra Pradesh.

7.4 Threats to freshwater biodiversity in the Western Ghats

7.4.1 Ongoing threats to Western Ghats freshwater biodiversity

An analysis of the threats identified for each species assessed (Figure 7.8) identifies pollution as the greatest threat to all the animal groups impacting nearly half (49.7%) of all fish species (and 70% of all threatened fishes), 20% of all mollusc species (and 57% of all threatened molluscs) and 21% of odonate species (and 50% of all threatened odonates). Figure 7.9 breaks down the pollution threat in Figure 7.8 into its differing sources, identifying domestic and urban pollution as the greatest threat to fishes, impacting nearly a third of all fish species, followed by agricultural pollution which affects 25% of fishes. For molluscs, odonates and plants, the greatest source of pollution is from agriculture impacting 15%, 20% and 2% of all species respectively followed by domestic and urban sources of pollution. Industrial and military sources of pollution are ranked third for all taxonomic groups.

Biological resource use (fishing, harvesting and logging) is also identified as a major threat to freshwater biodiversity in the region as it is the second greatest threat for the fishes and molluscs (Figure 7.8) affecting 38% of fishes (53% threatened fish), 17% of molluscs (14% threatened molluscs). It also impacts 7% of odonates, but none of these species are threatened species.

Residential and commercial development (not including pollution) is the greatest ongoing threat to the regions' aquatic plants, impacting 11% of species (69% of threatened plants). This threat also affects 14% of fishes (22% of threatened species), 11% of odonates (25% of threatened odonates) and 8% of molluscs (14% of threatened species).

Dams (Natural systems modifications) are identified as a major ongoing threat to all the groups, impacting 13% of fishes (19% of threatened fishes), 8% of molluscs (71% of threatened molluscs), 4% of odonates (25% of threatned odonates) and 3% of plants (22% of threatened plants).

Invasive species are only identified as a major threat to fishes, impacting 22% of all species (34% of threatened fishes).

Agriculture and aquaculture (not including pollution) are only a major threat to plants impacting 4% of species (19% of threatened plants). Seven percent of odonates are also impacted, but none are threatened species.

Energy production and mining are identified as major ongoing threats to fishes with 6% of species (9% of threatened species) impacted, molluscs with 5% of species (43% of threatened molluscs) impacted, and plants with 4% of species (13% of threatened species) impacted.

7.4.2 Participative threat mapping

At the Red List training workshop experts from within the region undertook a participative threat mapping exercise prior to data compilation and the subsequent assessments of species conservation status. The maps assisted experts to be consistent in their assessments of species conservation status by providing a standard baseline reference map of threats across the region. Each expert drew, on paper maps, known threats within their geographic area of knowledge. While this exercise did not identify all the threats to freshwater within the region, it did reveal widespread impacts of industrial, mining and agricultural development and pollution, and also the number of catchments impacted by dams (Figures 7.10 and 7.11).

7.4.3 Discussion of the major threats

The Western Ghats are being rapidly degraded as a result of land use change that has occurred in the recent past. Apart from impacts from traditional farming, grazing and fire practices, emerging threats include deforestation due to mining, roads, dams, urbanization and industrialization have resulted in biodiversity loss. Conversion of existing wilderness areas into intensive agriculture, urbanization and industries in the northern part of Western Ghats has altered the natural ecological attributes in recent decades (BVIEER 2010).

Industrial expansion due to globalization during the late nineties led to rural industrialization in peninsular India which has been strongly supported by state Industrial Development Corporations. River valley projects that have been developed for over a century are now operating in nearly all suitable major valleys in the Western Ghats leaving very few intact (BVIEER 2010). There are also extensive networks of roads throughout the region (Ramakrishna *et al.* 2001).

Tourism in the Western Ghats began with pilgrimages and social forms of tourism, and this continues to represent a significant component of tourism in the region. However, small scale unregulated and unplanned tourism development

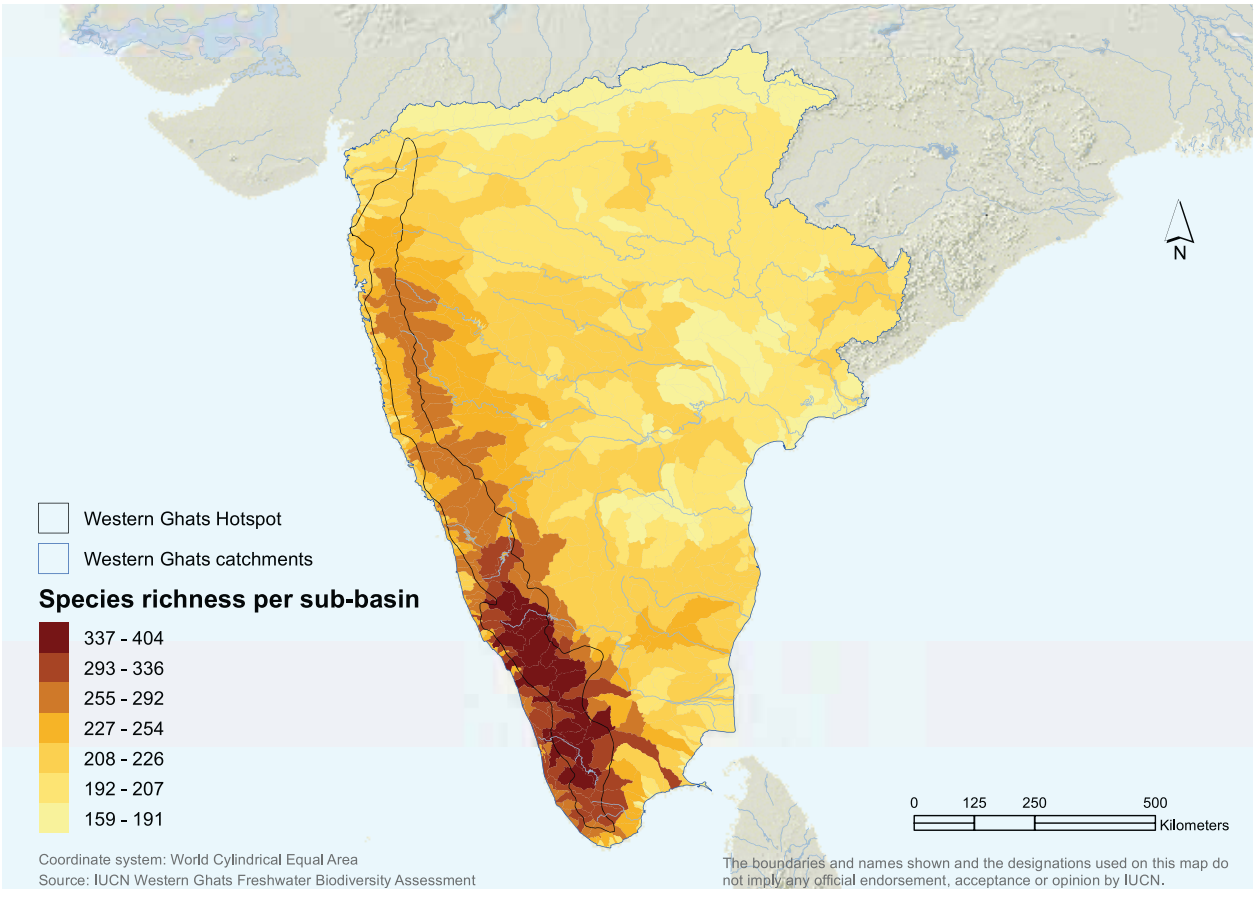


Figure 7.6 Distribution of all species of fishes, molluscs, odonates, and freshwater mammals, birds and amphibians in the Western Ghats project area. Bird distribution data provided by Birdlife International and Natureserve (2011).

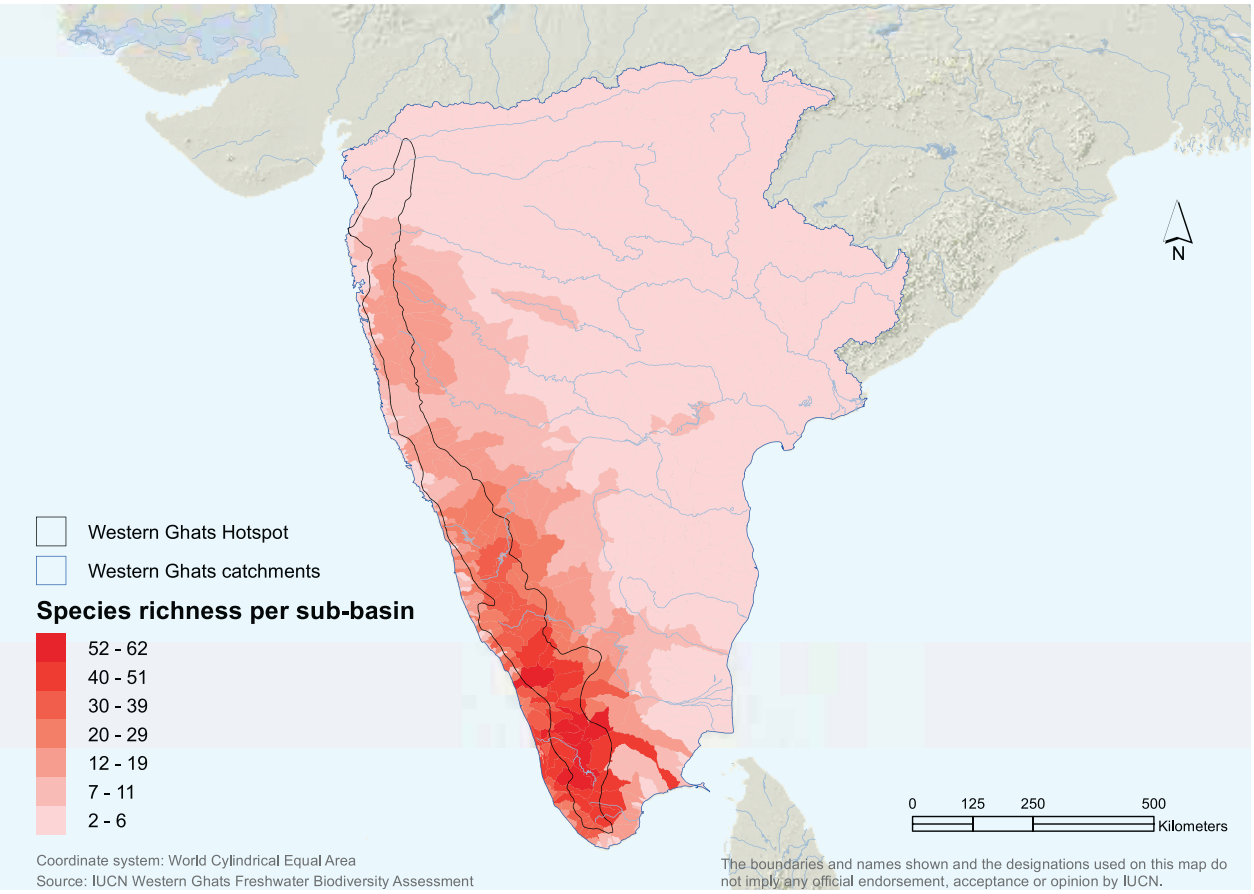


Figure 7.7 Distribution of all threatened species of fishes, molluscs, odonates, and freshwater mammals, birds and amphibians in the Western Ghats project area.

Threat mapping exercise during the training workshop.
© Kevin Smith

as well as large scale commercial tourist developments (such as the Aamby Valley and Lavasa City (a 25,000 acre hill station city (Equations 2011)) now represent a major cause of habitat loss.

High human population density (Cincotta *et al.* 2000) and human population pressure (Shi *et al.* 2005) in the Western Ghats will no doubt lead to increased anthropogenic impacts on freshwater ecosystems in the coming decades. Eighty-one million people living within Western Ghats are predicted to have insufficient water by the year 2050 (McDonald *et al.* 2011). Immediate protection of the freshwater ecosystems of the Western Ghats region is a priority.

7.4.3.1 Pollution

Pollution is one of the major threats to the freshwater biodiversity of the Western Ghats impacting almost 50% of all fish, 20% of molluscs and 21% of odonate species. The Western Ghats is one of the most densely populated hotspots in the world (Cincotta *et al.* 2000). There are very few drainages and catchments in the region that are free from pollution. The middle and downstream stretches of many rivers such as the Chaliyar, Bhadra, Bhavani, Pamba and Narmada have been subjected to high levels of pollution from domestic and urban waste water as well as industrial effluents, while upstream catchments of the major rivers of the region are affected by

Figure 7.8 Major ongoing threats to freshwater species in the Western Ghats region.

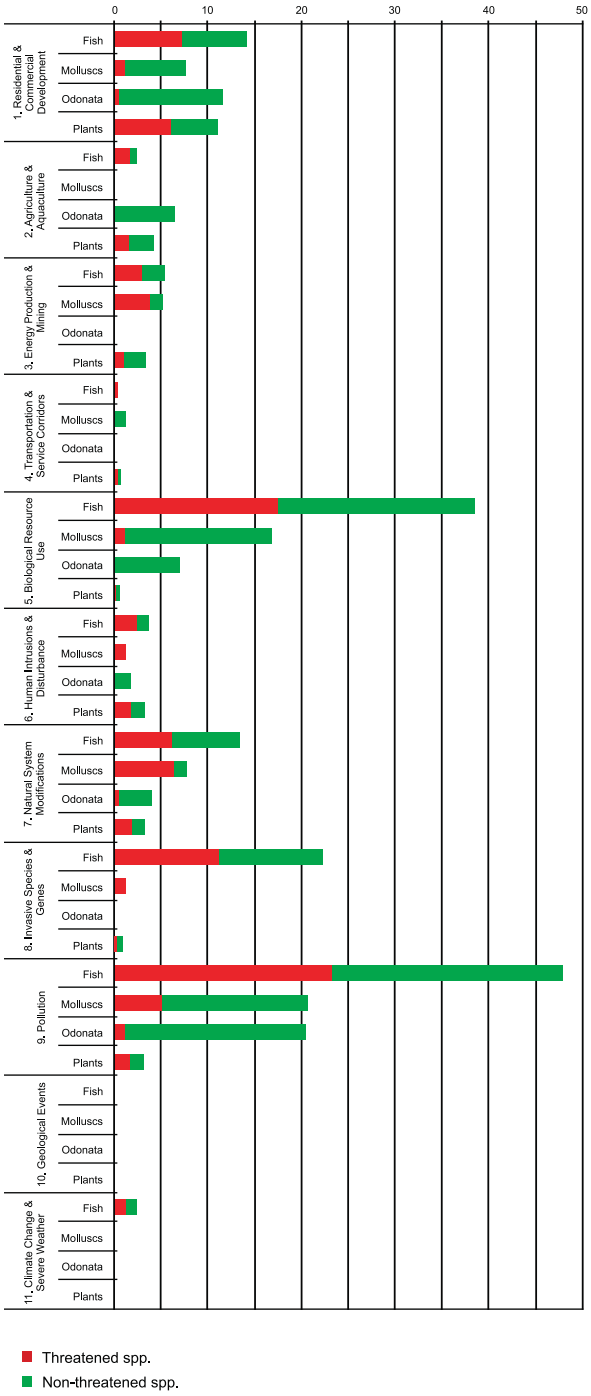
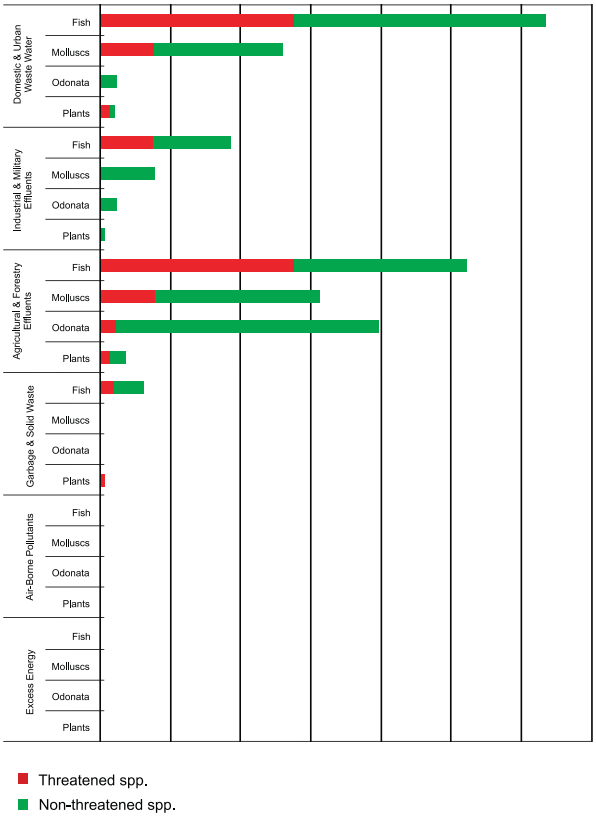


Figure 7.9 Detailed breakdown of pollution sources as a threat to freshwater species in the Western Ghats region.



Dams across rivers are major threat to freshwater fish diversity.
© Rajeev Raghavan

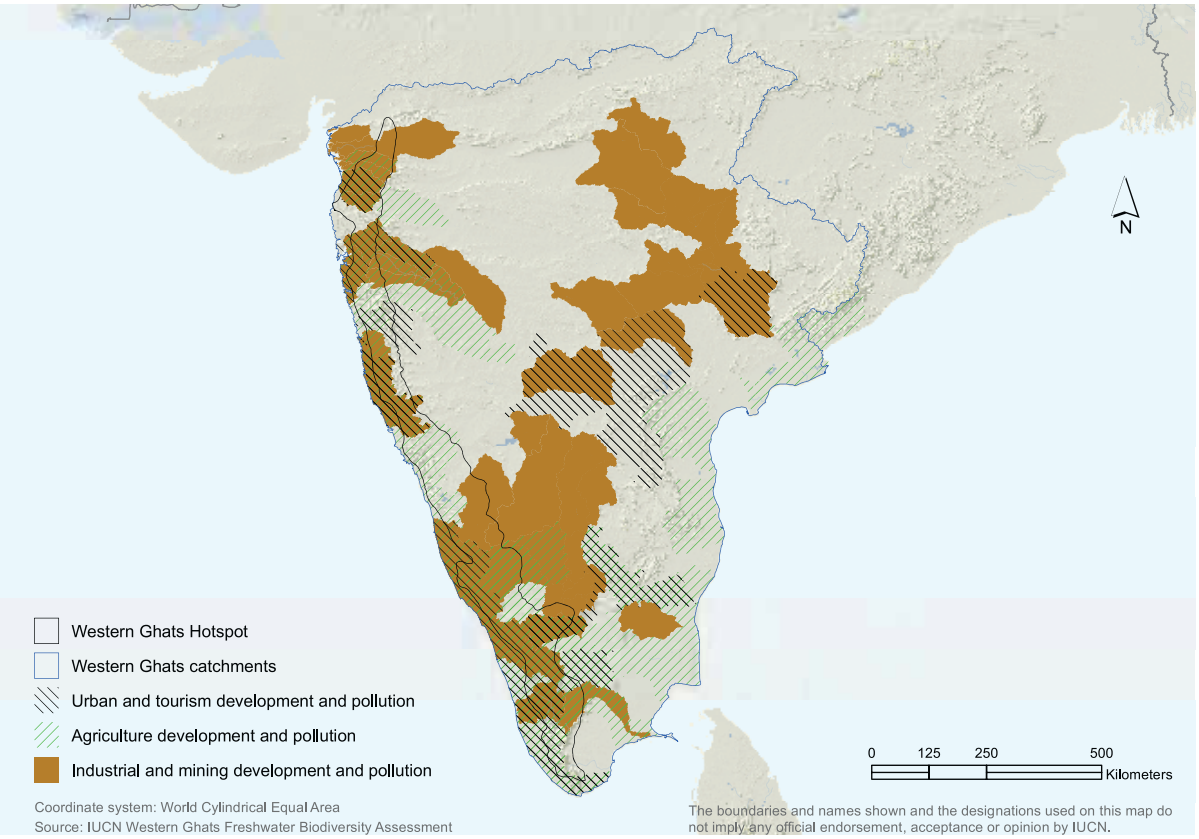


Figure 7.10 Distribution of urban, agricultural and industrial development and pollution across the Western Ghats region.

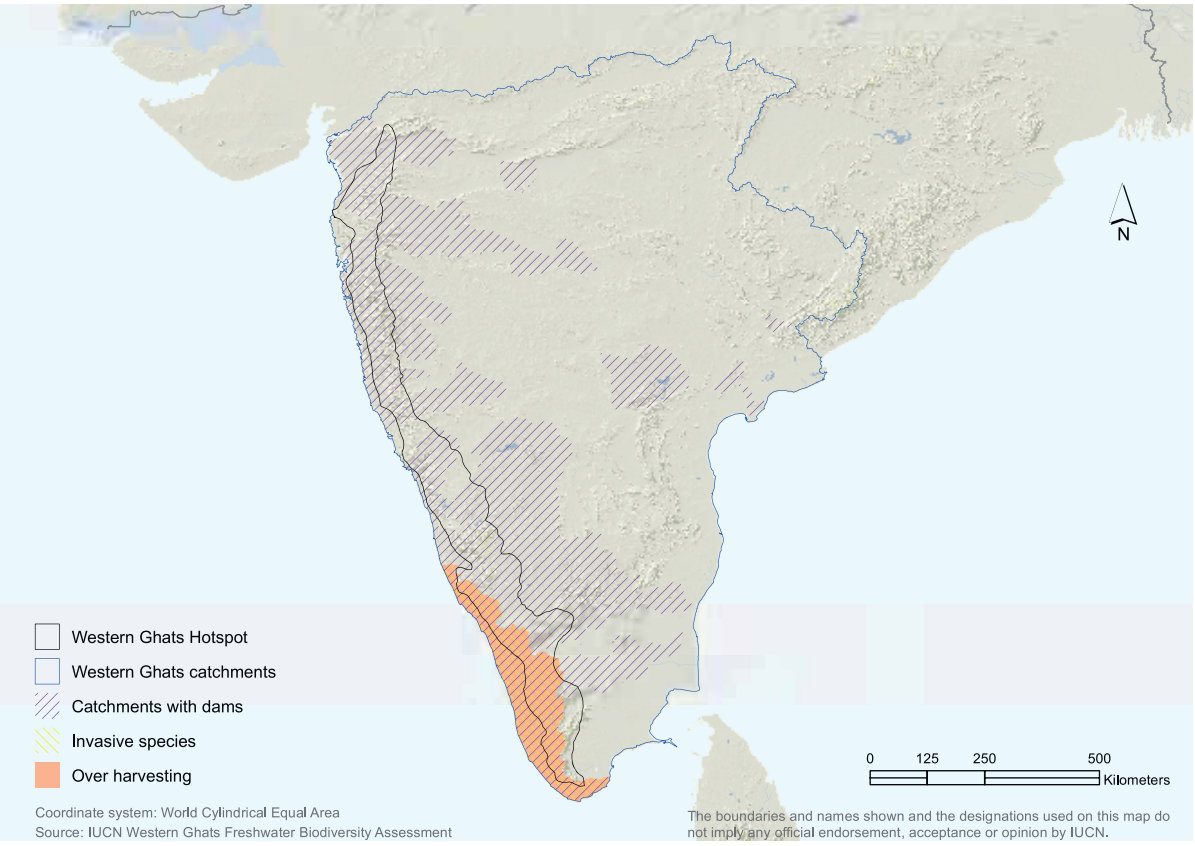


Figure 7.11 Distribution of dams, invasive species and overharvesting across the Western Ghats region.

pollution from pesticide and chemical runoff from the large number of tea, coffee, cardamom and rubber plantations. Upper reaches of some of the rivers flowing through the Nilgiri Biosphere Reserve, including the Pykara, Moyar and Bhavani, receive chemical and industrial effluents as high as 4,300 kiloliters/day (Koshy 2007). Decades of industrial pollution have affected rivers such as the Tungabhadra where fish kills have been often reported. Endemic and threatened aquatic plants of the Western Ghats have been impacted by pesticide (as in the case of *Podostemum munnarense* (EN) in the upstreams of River Periyar) and herbicide pollution (as in the case of *Rotala malabarica* (CR)). Pollution from urban sources is specifically threatening the aquatic plants associated with the marshy grasslands of Karnataka and Maharashtra (see Chapter 6). Similarly, odonates are known to be impacted by pesticides and studies have revealed a total absence of endemic species in plantation streams (see Subramanian *et al.* Chapter 5). Runoff of chemicals from agricultural sources are almost certain to increase in the coming years as the Western Ghats is predicted to receive increased rainfall as a result of climate change (Kumar *et al.* 2011).

7.4.3.2 Biological resource use

Unsustainable harvest and use of species affects nearly 38% of fish and 17% of molluscs in the Western Ghats. Much of this harvest takes place in the rivers of the southern Western Ghats in the state of Kerala, and in some parts of Tamil Nadu and Karnataka. Fisheries for large cyprinids, catfish and snakeheads are common in the reservoirs and rivers, and many species such as *Tor khudree* (EN) and *Horabagrus brachysoma* (VU) are being harvested at unsustainable levels (Raghavan *et al.* 2011, Ali *et al.* 2007). At least six species of molluscs are known to be threatened by exploitation for food while indiscriminate collection for the aquarium pet trade is known to be a possible threat for 32 species of fish found in the Western Ghats.

Teak plantation as seen as a carpet of inflorescence on the canopy at Parambikulam. © Werhitsu

Dynamite fishing has been documented in parts of Western Ghats since the early 1940s (Jones 1946) and continues to be one of the most widely used destructive fishing techniques practiced in the region (Raghavan *et al.* 2011). Although dynamite fishing has been banned through the Travancore Cochin Fisheries Act of 1950 (Government of Kerala, India) there is little or no enforcement, and the practice continues even inside protected areas across the region (Abraham *et al.* 2010). Destruction of fish species using dynamite is also known to cause population reduction in endemic and threatened molluscs such as *Pseudomulleria dalyi* (EN) (which uses freshwater fish as a host).

Extensive harvest of the black clam (*Villorita cyprinoides* (LC)) from areas such as Vembanad Lake in Kerala, may be a future threat to the species if management interventions are not put in place (see Chapter 4).

7.4.3.3 Urban and agricultural development (as habitat loss)

In the mountainous regions of Western Ghats, the human population density varies between 100 and 300 habitants per square kilometre and only at a few places is it lower than 100 (Pascal 1988). Between the 1920s and 1980s, conversion of forest into agricultural land or open areas accounted for 40% of deforestation in the Western Ghats (Menon and Bawa 1997). In the 1950s and 1960s, expanding populations and the famine-driven 'Grow More Food campaign' led to state supported clearing of forests for agriculture (Bawa *et al.* 2007). High elevation areas of the Western Ghats are now dominated by tea, coffee, rubber, cardamom and monoculture of oil palm.

In the northern part of the Hotspot, more than half (58%) of the montane rainforests have now been cleared, with habitat loss and fragmentation especially heavy close to the large cities of Mumbai and Pune (WWF 2011), while more than 75% of the moist deciduous forests have been cleared (Anon. 2001a). Similarly, in the southern Western Ghats three-quarters of the natural vegetation of the moist deciduous forests (Anon. 2001b), and two-thirds of the montane rain forests have now been cleared (Anon. 2001c).

Urbanization and agricultural development is the greatest ongoing threat to aquatic plants of the Western Ghats, impacting 11% of species. Habitats of *Lindernia minima*, an Endangered plant endemic to Chengalpattu and Tirunelveli in Tamil Nadu are threatened by massive urbanization, including the development of Information Technology Parks and Special Economic Zones (SEZ). Habitats of many pteridophytes such as *Bolbitis appendiculata* (LC) are threatened due to conversion of forests to tea and rubber plantations in Kanyakumari and Tirunelveli districts of Tamil Nadu (see Chapter 6).

7.4.3.4 Invasive species

The threat from invasive aquatic species is the highest in the southern Western Ghats in the states of Kerala, Tamil Nadu and Karnataka, and affects mainly freshwater fish species. At least 13 species of exotic fish currently occur in the southern Western Ghats. Species such as the African Catfish, *Clarias gariepinus* are spreading rapidly across the various drainages of Western Ghats causing wide spread damage to endemic and threatened species (Dahanukar *et al.* 2011, Krishnakumar *et al.* 2011).

7.4.3.5 Dams

Drainages of the Western Ghats have been significantly impacted by the construction of dams and other barrages. Dams have been built across all major river systems of the Western Ghats from Maharashtra to Tamil Nadu. Rivers such as the Periyar which harbours several endemic and threatened freshwater fishes has 16 dams throughout its course (Mathew 2011). New proposals for large and small dams are being continuously submitted by state governments and have met with mass protest by environmentalists in the region. The Karnataka High Court recently restrained all power companies from developing new mini-hydro projects in the Western Ghats region within the state until further orders. Projects on which work has begun will also be subject to further evaluation (The Hindu 2011)

Although there have been no rigorous scientific studies on the impacts of dams on the freshwater biodiversity of the Western Ghats, case studies from elsewhere in tropical Asia on the upstream and downstream impacts of river regulation and dams indicate a cause for concern.

7.4.3.6 Mining

Open-cast mining is widely acknowledged to have devastating effects on downstream ecosystems, and the impacts in humid tropical areas are particularly severe (Bird *et al.* 1984). One of the problems associated with mining operations is release of pollutants to both surface water and groundwater. Many activities and sources associated with a mine dump can contribute toxic and non-toxic materials to waters. As the Western Ghats receives high levels of rainfall the mobility of pollutants is relatively extensive as they can quickly leach into freshwater systems (Lad and Samant *unpub.*).

Mining is a particular threat to the aquatic ecosystems in the northern Western Ghats in the states of Karnataka, Maharashtra and Goa. For example in the state of Goa alone, there are around 100 open-cast mines tapping iron ore, bauxite and manganese (Outlook India 2011). The iron ore mining industry in Kudremukh, Karnataka caused wide spread damage to the downstream ecosystems of the Bhadra River during the 1980s and 1990s until it was stopped through the efforts of conservationists. Lateritic mining in Kerala is threatening Critically Endangered plant species such as *Fimbristylis hirsutifolia* which is known only from a single location.

7.5 Identification of potential freshwater Key Biodiversity Areas (KBAs)

7.5.1 Key Biodiversity Areas methodology

Criteria developed by IUCN for the identification of freshwater Key Biodiversity Areas (Holland *et al.* in review) were applied to datasets for the Western Ghats fishes, molluscs and odonates. Plants were excluded from this analysis as they fall under a different set of criteria developed and applied by Plantlife called Important Plant Areas (see Anderson 2002, Plantlife International 2010), and in addition were often mapped at the country level as detailed distribution data are lacking. Key Biodiversity Areas or KBAs are defined as sites containing species of global conservation significance, identified by applying criteria relating to vulnerability and irreplaceability where vulnerability is defined as the likelihood that a species will be lost over time, and irreplaceability refers to the spatial options for conservation of the species. Langhammer *et al.* (2007) provide a detailed discussion and examples of the application of KBA methodologies for various taxonomic groups.

Three criteria were applied to identify sites that qualify as potential KBAs.

1. A site is known or thought to hold a significant number of one or more globally threatened species or other species a of conservation concern. Here the presence of species assessed as Vulnerable, Endangered or Critically Endangered triggered qualification of the sub-basin.
2. A site is known or thought to hold non-trivial numbers of one or more species (or infraspecific taxa as appropriate) of restricted range. Threshold values of 20,000 km^2 were applied to fish and molluscs and 50,000 km^2 to odonates for the species to qualify as restricted range.
3. A site is known or thought to hold a significant component of the group of species that are confined to an appropriate biogeographic unit or units. Here the WWF freshwater ecoregions of the world were used as the biogeographic unit, and qualification was triggered where more than 25% of the species within any sub-basin were restricted to the ecoregion.

The aim of the freshwater KBA methodology is to identify all sites that meet the site selection criteria, these are termed 'potential KBAs'. This exercise represents only the first step in the formal identification, recognition, and designation of KBAs. This is, as such, a preliminary exercise designed to provide an initial output that might then be taken forward through a series of stakeholder workshops to determine the suitability of each potential site for designation as a formal KBA. Final designation of sites as formal KBAs should consider each site within the context of other pre-existing and overlapping managed sites and with consideration of all other relevant administrative, economic and social issues. The resulting KBA may include the entire sub-basin or sites within that catchment depending upon the nature of the species within it and the type of management required. In the current

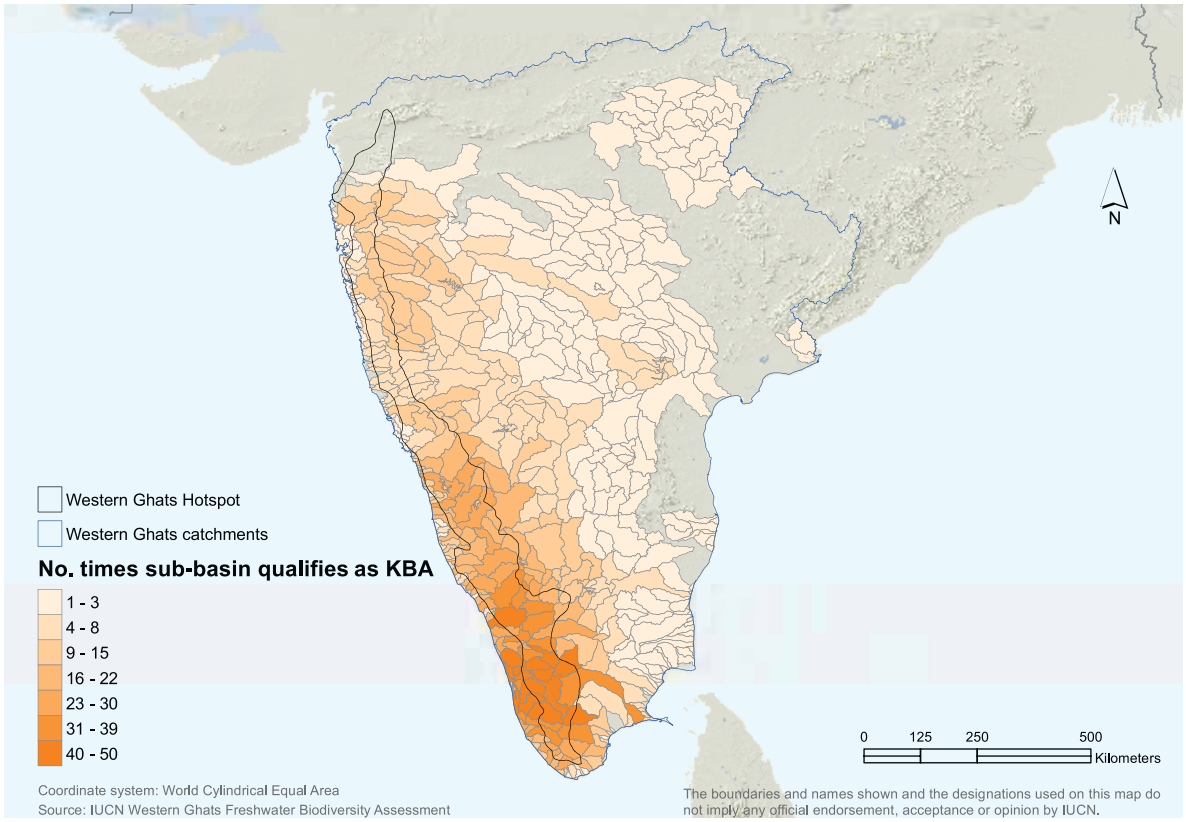


Figure 7.12 Sub-basin qualifying as potential freshwater Key Biodiversity Areas for fishes. Sub-basin in darker orange indicate presence of higher numbers of species meeting the KBA criteria.

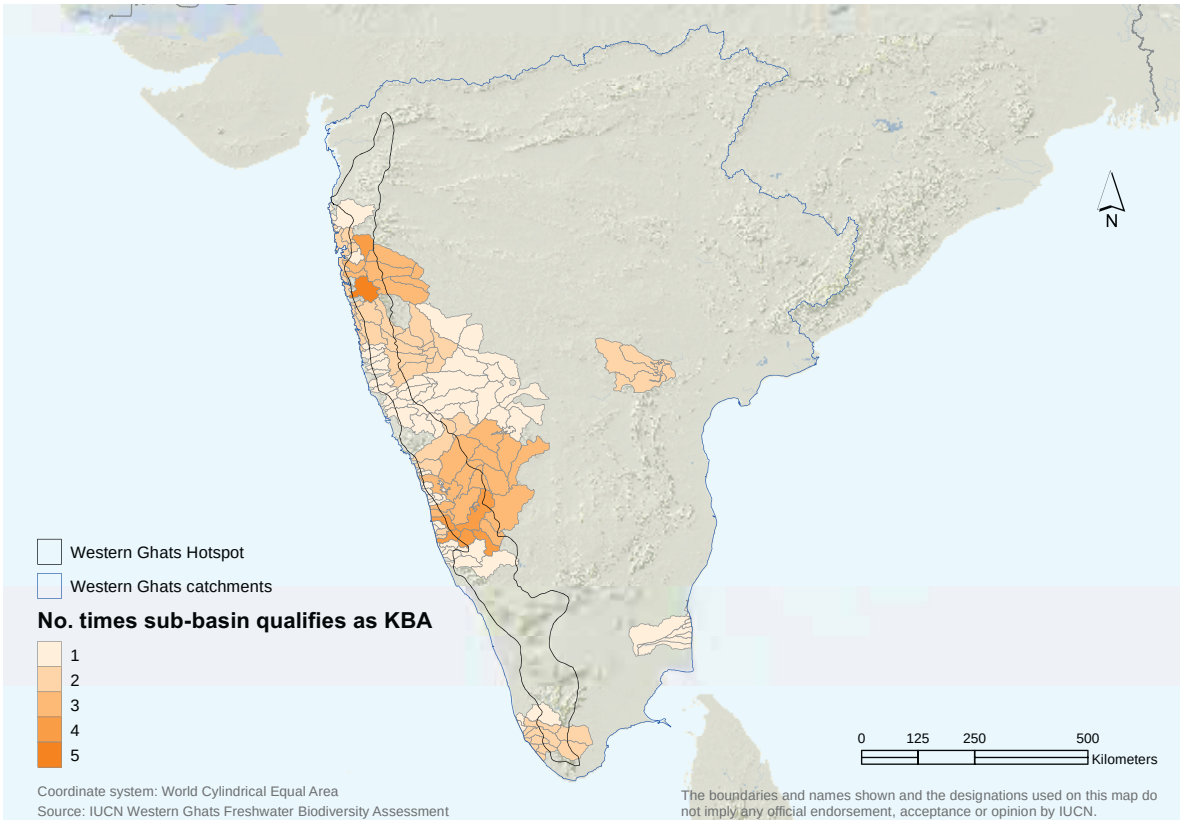


Figure 7.13 Sub-basin qualifying as potential freshwater Key Biodiversity Areas for molluscs. Sub-basin in darker orange indicate presence of higher numbers of species meeting the KBA criteria.

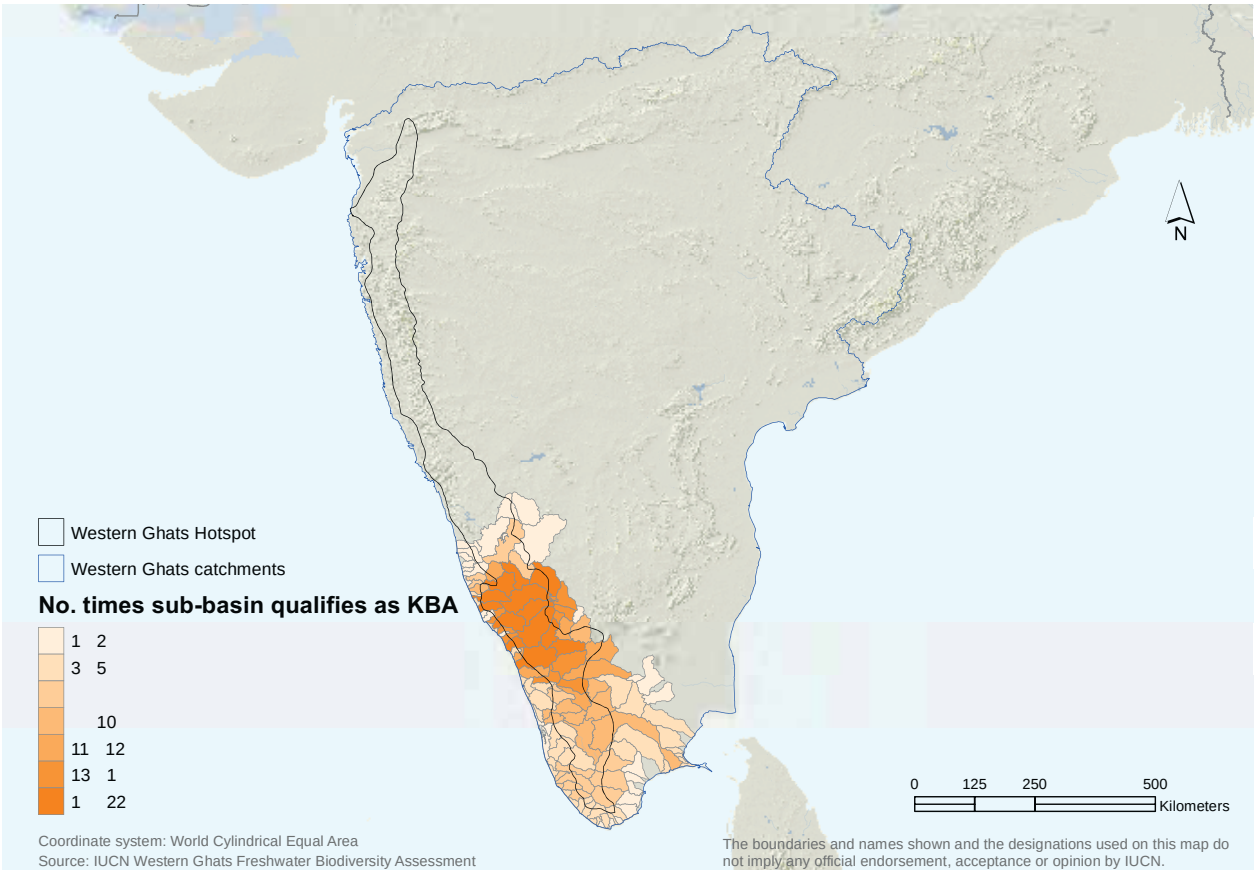


Figure 7.14 Sub-basin qualifying as potential freshwater Key Biodiversity Areas for odonates. Sub-basin in darker orange indicate presence of higher numbers of species meeting the KBA criteria.

study we present maps showing the number of times each sub-basin qualifies as a KBA (in terms of the number of species or species assemblages within it that meet any of the three the KBA criteria), however, no effort is made to prioritise amongst sites. The prioritisation of potential KBAs, through such approaches as Systematic Conservation Planning, represents a priority for future work.

7.5.2 Potential freshwater Key Biodiversity Areas.

Following application of the KBA selection criteria, 479 sub-basin (out of a total of 723 sub-basin in the Western Ghats Hotspot assessment region) qualify as potential KBAs. Table 7.4 summarises the results, and shows that fish trigger the greatest number of sub-basin, followed by molluscs and then odonates. For the fishes, Criterion 1 (threatened species) triggers the greatest number of sub-basin by a significant number with 337 more sub-basin triggered than by Criterion 2 (restricted range species). For molluscs Criterion 1 triggers 25 more sub-basin than Criterion 2, whereas for the odonates Criterion 2 triggers the greatest number of sub-basin with 35 more than Criterion 1. No sub-basin were triggered under Criterion 3 (species restricted to a biogeographic unit).

Figures 7.12–7.14 show sub-basin triggered by fishes, molluscs and odonata species, respectively. For fishes (Figure 7.12) the southern part of the Western Ghats Hotspot contains the

Table 7.4. Number of sub-basin meeting each of the Key Biodiversity Area criteria for each taxonomic group.

	Fish	Molluscs	Odonates	All taxa
Criterion 1	479	97	83	479
Criterion 2	142	72	118	215
Criterion 3	0	0	0	0
Total	479	133	118	479

catchments with the greatest number of species triggering a KBA. Catchments with the highest numbers of species meeting the KBA criteria (40-50) are the east flowing upper Vaipar and Amaravati (Cauvery catchment) in western Tamil Nadu and the west flowing Pamba, Manimala, Meenachil, Thodupuzha, Periyar, Muppili Puzha/Manali, Bharatapuzha and Chaliyar in Kerala. The areas of greatest richness for molluscs (4-5 qualifying species per catchment) are in the northern and central parts of the Western Ghats Hotspot in the Savitri and Ulhas rivers in coastal Maharashtra, and the upper Netravati and upper Tunga in Karnataka (Figure 7.13). For the odonates (Figure 7.14), the highest richness (19-22) is found in the central southern section of the Western Ghats Hotspot in the westerly flowing Chaliyar, Kuttyadi, Valappattanam, Chandragiri/Payaswini (mostly in Kerala and a small part in Karnataka) and the upper Netravati in Karnataka, also the easterly flowing Moyar in Tamil Nadu, and upper Kabini and Cauvery in Karnataka and Kerala.

When the taxa are combined (Figure 7.15), the areas of highest richness (52-64 qualifying species per catchment) almost exactly match the results for the fishes, but excludes the Vaipar and Amaravati in Tamil Nadu and the Meenachil, Thodupuzha and Muppili Puzha/Manali. In addition, the Upper Bhavani and Moyar in Tamil Nadu and upper Kabini in Karnataka/ Kerala are included in the highest richness category. Figure 7.12 also shows how little of these areas is currently protected by the existing protected area network.

Only 58 Protected Areas (PAs) (14 National Parks (IUCN Category II) and 44 Wildlife Sanctuaries (WS) (IUCN Category IV) covering an area of 13,595 km^2 (9.1% of the Western Ghats Hotspot area)) fall within the boundaries of the Western Ghats Hotspot (Bawa *et al.* 2007). Areas above 2,500 m elevation are best represented and areas below 500 m are the least represented within the current protected areas (PA) network in the Western Ghats (Bawa *et al.* 2007). With regard to freshwater biodiversity of the Western Ghats, hill streams are mostly within the PA network, while the larger stream orders on the plains are largely unprotected, open access areas (Abraham *et al.* 2010). Positive results have been obtained through the Western Ghats PA network for the conservation of charismatic species of mammals and birds (Bawa *et al.* 2007) but the benefits are less apparent for freshwater taxa such as amphibians (Vasudevan *et al.* 2006). PAs in the Western Ghats are not sufficient for conserving lowland freshwater taxa and show only partial benefits for freshwater biodiversity conservation (Abraham *et al.* 2010).

7.5.3 Next steps: Formal designation of KBAs and gap analysis

As mentioned above (Section 7.5.1), application of the KBA criteria to identify potential KBAs represents only the first step in the process for the formal designation of KBAs. Following this initial analysis expert knowledge and conservation planning tools (see Margules and Pressey 2000, Turak and Linke 2011) can be used to identify a network of priority sub-basin given that is unlikely to be practical to designate for protection all those sites meeting the basic criteria. Systematic Conservation Planning approaches might be used to design such a network of priority sites.

Systematic Conservation Planning principles are often referred to as CARE as they i) aim to prevent bias by including the full range of species, processes and ecosystems (Comprehensiveness); ii) ensure that the design of the conservation network is suitable for their persistence (Adequacy); iii) ensure that the network of sites captures all aspects of biodiversity (Representativeness) and; iv) aims to minimise the costs and impacts on stakeholders (Efficiency) (Linke *et al.* 2011). Recent years have seen the development of a range of software tools to guide this process. However engagement with stakeholders on the ground is clearly key to this process (Barmuta *et al.* 2011) as to be effective the final network of sites must take into consideration not only biodiversity targets but the full range of social, economic and political factors.

Once these processes have been undertaken the prioritised network can be proposed to the relevant national and international bodies for formal recognition. These additional steps in the process for the formal identification of KBAs are yet to be undertaken for the Western Ghats freshwater species.

7.5.4. Overlap with existing Key Biodiversity Areas

By overlaying the existing Key Biodiversity Areas and Critical Link sites (corridors) defined by CEPF, the Wildlife Conservation Society (WCS), and the Ashoka Trust for Research in Ecology and the Environment (ATREE) for globally threatened flora and fauna (mammals, birds, reptiles and amphibians) in the Western Ghats, with those sub-basin identified above as meeting the criteria for Potential Freshwater KBAs, areas of overlap can be identified. Before these areas of overlap are discussed, it should be stressed that a high degree of overlap between an existing (terrestrial) KBA and a potential freshwater KBA does not automatically represent a high degree of protection for the freshwater area of concern. Threats to freshwater species will often have their origins some distance from the site holding a species of conservation concern and may be beyond the boundaries of any existing KBA or protected area even if it overlaps the sub-basin where the species is found. It is also the case that management objectives and actions within existing terrestrial KBAs may not be effective for conservation of freshwater species, even where those species are fully enclosed within the KBA – this is largely a product of the high connectivity within freshwater ecosystems. For many freshwater species the type of protection required may not be site-based as defined by KBAs, and integrated catchment management may be required, possibly in conjunction with site based actions.

A high degree of overlap is evident between those sub-basin containing the highest number of species triggering potential freshwater KBA status (52-64) and the existing KBAs. For example the Rajiv Gandhi NP, Wyanad WS and Kalpetta forest-coffee complex all cover parts of the upper Kabini catchment in southern Karnataka and northern Kerala, the Moyar River (upper Cauvery) and the Chaliyar River in north-western Tamil Nadu and northern Kerala significantly overlap the Talaimalai RF, Mudumalai WS, Nilgiris North FD, Nilambur FD and Murkurthi NP KBAs. To the south along the Kerala–Tamil Nadu border the Muppili Puzha (upper Karuvannur) and Periyar are also well covered by KBAs including the Malayattur FD, Parambikulam and the Cardamom Hills RF. However, there are gaps in those sub-basin with the highest numbers of species meeting the freshwater KBA criteria including the Bhavani catchment (upper Cauvery) in north-western Tamil Nadu which only marginally overlaps the Attapadi and Kundah RF KBAs, and to the west the Pulantod catchment in Kerala receives minimal cover by the Silent Valley NP.

There is much less overlap between sub-basin containing a high number of species triggering freshwater KBA criteria (42-51) and existing KBAs, as some catchments including the Meenachil, upper Muvvatupuzha and Kuttyadi receive no coverage from KBAs at all. Also many sub-basin have

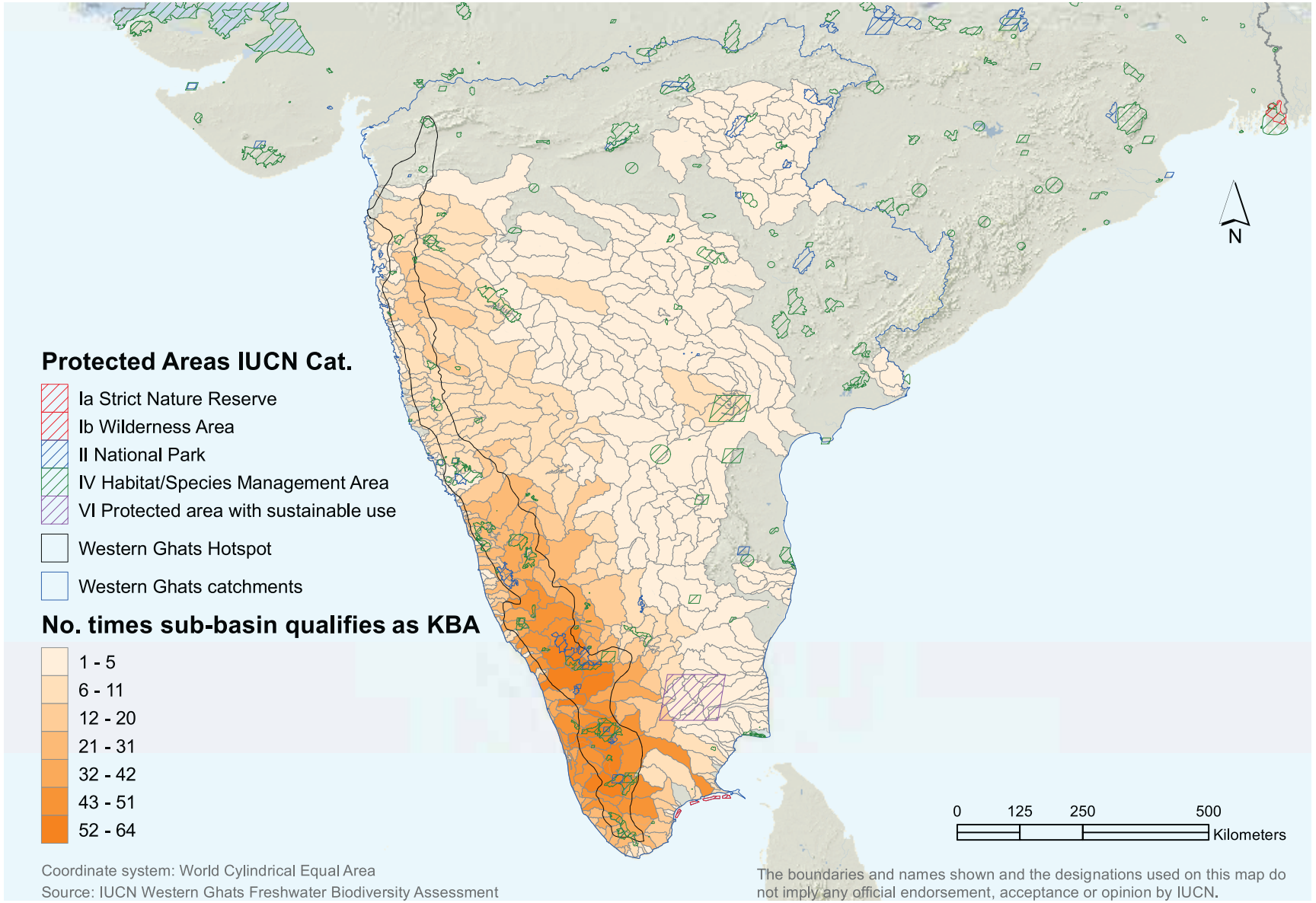


Figure 7.15 Sub-basin qualifying as potential freshwater Key Biodiversity Areas for all taxa (fishes, molluscs and odonates). Sub-basin in darker orange indicate presence of higher numbers of species meeting the KBA criteria.

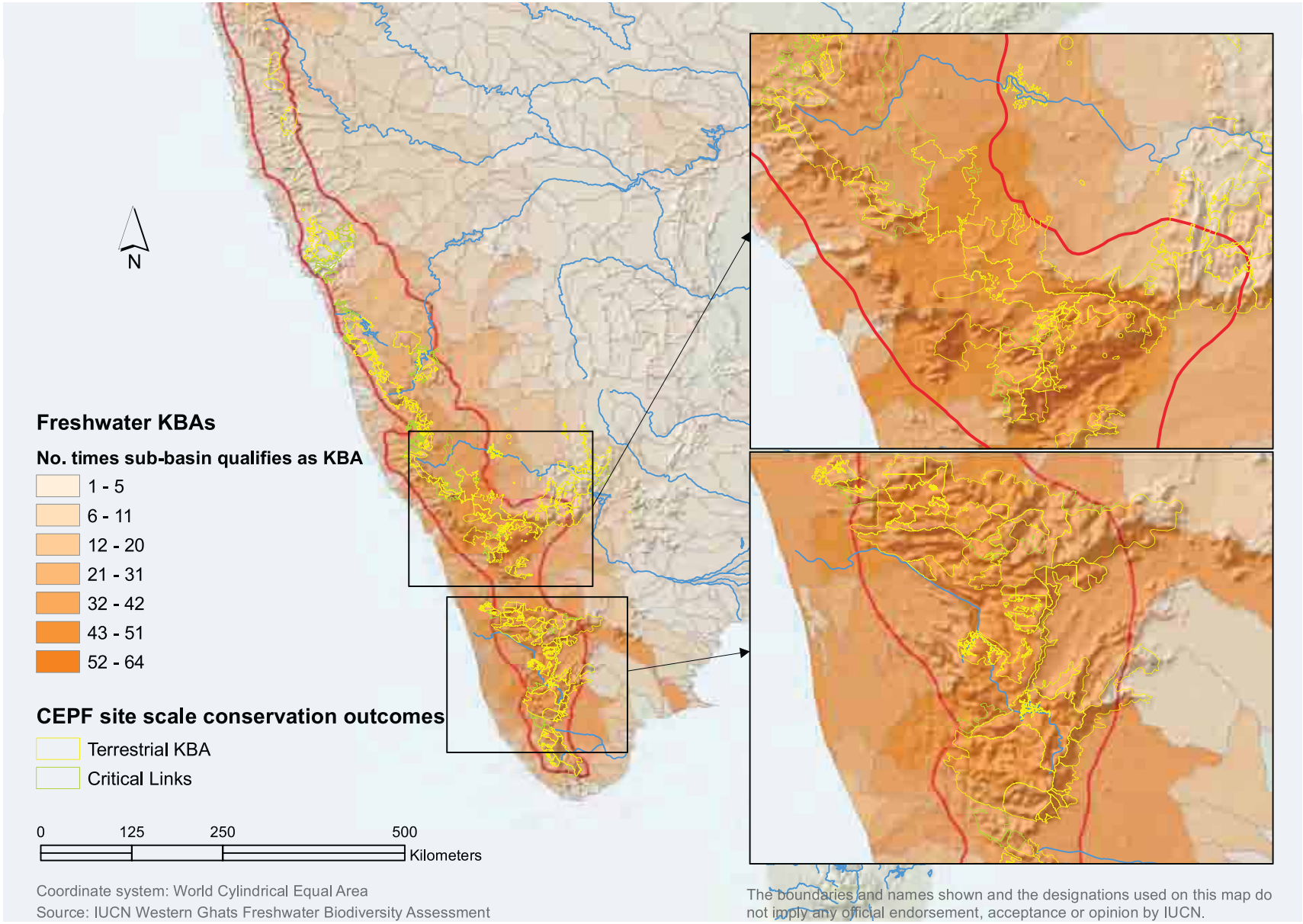


Figure 7.16 Overlay of potential freshwater KBAs and CEPF conservation outcome terrestrial KBAs. Conservation outcome data provided by CEPF.

Table 7.5 Number of species of fishes, plants and molluscs utilised for different purposes, with the number of species possibly threatened by the harvesting for that purpose (these data excludes those species that are sourced from captive breeding or horticulture).

	Fishes		Molluscs		Plants	
Purpose	All	Poss. Threat	All	Poss. Threat	All	Poss. Threat
Food - human	162	45	14	6	83	1
Food - animal	3	-	2	-	80	-
Medicine - human and veterinary	4	1	3	1	175	-
Poisons	-	-	-	-	2	-
Manufacturing chemicals	-	-	-	-	3	-
Other chemicals	-	-	-	-	14	-
Fuel	-	-	-	-	6	-
Fibre	-	-	-	-	9	-
Construction/structural materials	-	-	-	-	9	-
Wearing apparel, accessories	-	-	-	-	3	-
Other household goods	-	-	-	-	12	-
Handicrafts, jewellery, decorations, curios, etc.	-	-	2	2	16	1
Pets/display animals, horticulture	108	32	1	-	37	-
Research	-	-	-	-	7	1
Sport hunting/specimen collecting	5	1	-	-	3	1
Other	-	-	-	-	11	-

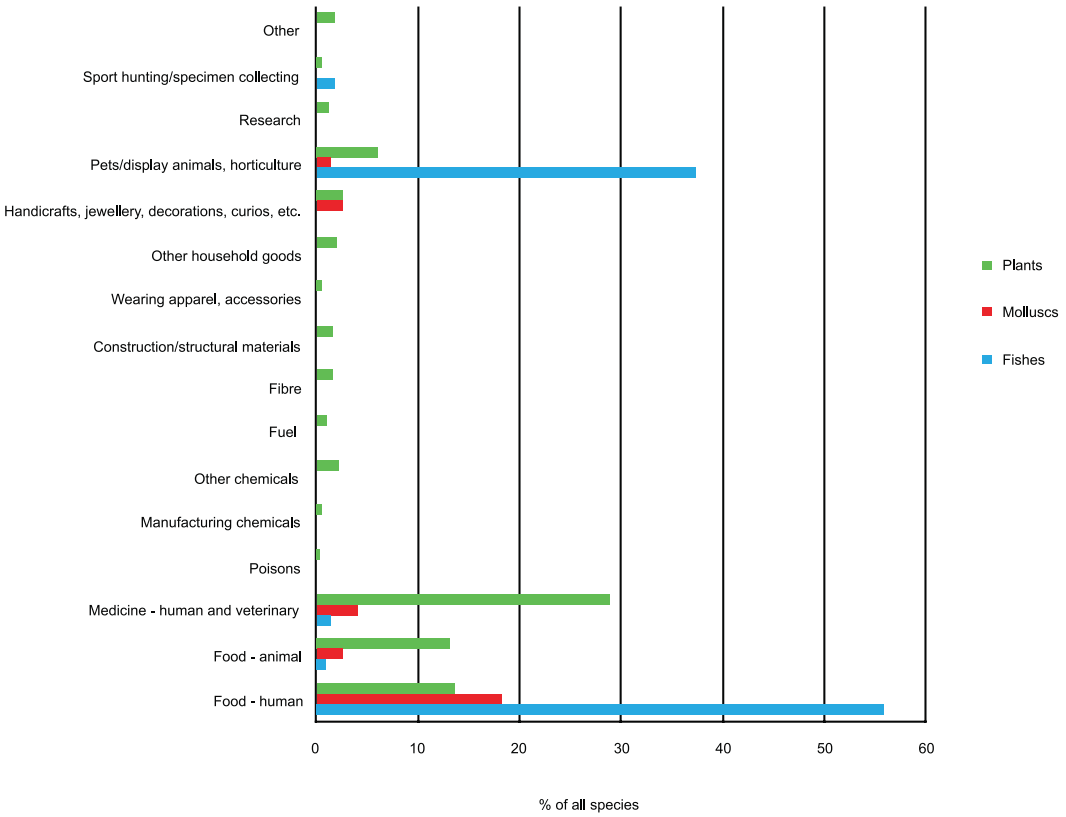


Figure 7.17 Proportion of all fishes, plants and molluscs utilised for each purpose in the Western Ghats

very minimal overlap, often only in the very upper parts of the catchment for example with the upper Vaigai, Vaipar and Chittar rivers.

7.6 Provisioning ecosystem services and freshwater biodiversity of the Western Ghats

In India, millions of people rely on products from natural ecosystems to sustain their livelihoods (Shanker *et al.* 2005). This includes those provided by freshwater systems such as fish as source of protein or plants for medicinal use. India has the third largest inland capture fisheries (not including aquaculture) in the world, landing 953,103 tonnes in 2008 (FAO 2010). Based on the information collated through the species assessments those freshwater species found in these Western Ghats that directly contribute to provisioning ecosystem services (e.g. food, medicine, fodder etc) can be identified. Where harvesting a species for a particular purpose is thought to represent a possible threat, this has been recorded. However, this is not based on quantitative analysis of sustainable harvest levels (which would be a recommendation), and it does not imply that the species is assessed as threatened under the IUCN Red List Categories.

Results show that plants have by far the most diverse range of uses, with species being utilised in every category, though they are predominantly used as medicine and food for both humans and animals (Table 7.5). Over a quarter of all aquatic plants (28%, 175 species) are harvested for medicinal use, with 14% (83 species) and 13% (80 species) being used for food for humans and animals respectively (Figure 7.17). Very few plant species are thought to be threatened by overharvesting for these uses. *Lagenandra toxicaria* (LC) an endemic species to the south-western part of India, often abundant in marshes and streams, has a number of medicinal used including: the treatment of kidney disorders, heart diseases and swellings, use as an insecticide (Pullaiah 2006), an infusion of tuberous rootstock is used to treat tuberculosis, and a decoction of tuberous root is used to check the growth of tumours (Swarnkar and Katewa 2008). The plant also contains an acrid juice is used in ointments to soothe itching (Rehel and Kumar 2010).

Fishes have a more restricted set of purposes than plants with most species utilised for food (for humans) and as pets/display animals (aquarium trade) (Table 7.4). Figure 7.17 shows that over half (56%, 162 species) of fish species are harvested for use as human food, and that 37% (108 species) are harvested for the aquarium trade. Harvest for these purposes is categorised as being a 'possible threat' to some species, with 45 species (28% of all species used for this purpose) possibly threatened by harvesting for food (for humans), and 32 species (30% of the species used for this purpose) through collection for the aquarium trade (pets/display) (Table 7.4). For example, *Labeo potail* is an Endangered species of carp endemic to the Western Ghats where it is harvested for food and sold in local markets. The level of harvest is thought to be contributing to the species decline (Kharat *et al.* 2000, 2003), as in Kerala alone the species has undergone a population reduction of 99% over the past two decades (Kurup *et al.* 2003) and it is also impacted by pollution and introduced non-native carp species (Dahanukar 2011). *Puntius tambraparniei* (EN), which is only found in flowing streams of the upper and middle reaches of the Tambraparni River basin southern Tamil Nadu is harvested for the aquarium trade, where it is known as the Arulius barb. This species is currently threatened by loss of riparian cover, sand mining and pollution. Collection for the aquarium trade is also a potential threat (Dahanukar 2010).

Molluscs are also largely harvested for human consumption and have a relatively restricted set of other uses (Table 7.5). Fourteen species, 18% of all freshwater molluscs in the region are utilised as food for people, six of which (33%) are possibly threatened by this harvest. *Villorita cornucopia* (LC), is a species of clam found in the backwaters and estuaries of Kerala, is harvested for food in large quantities and is one of the major clam species of commercial importance. Extensive wild harvest of this species in the future could represent a potential threat (Madhyastha 2010).

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Nadugani, Nilgiris, Tamil Nadu. © Keystone Foundation

Appendix 1. Example species summary and distribution map: *Puntius denisonii* (Day, 1865)

ANIMALIA - CHORDATA - ACTINOPTERYGII - CYPRINIFORMES - CYPRINIDAE - Puntius - denisonii

Common Names: Chorakaniyan (Malayalam), Tulijuovabarbi (Finnish), Red Line Torpedo Barb (English), Denison Barb (English), Chenkaniyan (Malayalam), Denisonbarbe (German), Parmička Denisonova (Czech), Miss Kerala (English), Rotstrich-algenfresser (German)

Synonyms: Labeo denisonii Day, 1865;
Taxonomic Note: *Puntius denisonii* was described by Day (1865) from Mundakkayam, Kerala, southern India.

Red List Assessment

Red List Status
EN - Endangered, A2acde+3cde;B2ab(iii) (IUCN version 3.1)

Assessment Information

Reviewed?	Date of Evaluation:	Status:	Reasons for Rejection:	Improvements Needed:
True	2010-10-10	Passed	-	-

Assessor(s): Dahanukar, N., Ali, A. & Raghavan, R.
Reviewer(s): Krishna , K.K., Johnson, J.A., Rahul, K., Molur, S., Gopalakrishnan, A., Arunachalam, M., Shaji, C.P., Vidyadhar, A. & Rema Devi, K.R.
Contributor(s): Bogutskaya, N., Molur, S. & Rema Devi, K.R.

Assessment Rationale
Puntius denisonii has been assessed as Endangered as populations have declined by more than 50% in the recent past due to indiscriminate exploitation for the international aquarium pet trade. These declines are expected to continue in the foreseeable future unless local management plans, as well as national and international legislations are created and implemented. The species also has a restricted range with an area of occupancy of less than 300 km² with continuing decline in quality of key habitats.

Distribution

Geographic Range
Puntius denisonii is endemic to the Western Ghats where it occurs as fragemented populations in the states of Kerala and Karnataka (Raghavan *et al*. 2010, Prasad *et al*. 2008). Known from the rivers Chandragiri (Biju 2005, Kurup *et al*. 2004), Valapatanam (Biju 2005), Karyangod (Kurup and Radhakrishnan 2006), Chaliyar (Shaji *et al*. 2000), Kuttiyadi (R. Raghavan and A. Ali pers.obs.), Bharatapuzha (Kurup *et al*. 2004), Sullya (R. Raghavan and A. Ali pers.comm), Kuppam, Iritti, Anjarakandipuzha and Bhavani River in Chavadiar (Mercy 2010; A. Gopalakrishnan pers. comm.).

Populations have also been reported from Chalakudi (Radhakrishnan and Kurup 2006), Periyar (Thomas 2004), Manimala (Thomas 2004), Achenkovil (Kurup *et al*. 2004), and Pampa (Thomas 2004). These localities however represent *P. chalakkudiensis* (A. Gopalakrishnan pers. comm.).

Biogeographic Realms
Biogeographic Realm: Indomalayan

Occurrence

Countries of Occurrence

Country	Presence	Origin	Formerly Bred	Seasonality
India	Extant	Native	-	Resident
India -> Karnataka	Extant	Native	-	Resident
India -> Kerala	Extant	Native	-	Resident

Population
The total population of *P. denisonii* is unknown. However the species is considered to be rare (Radhakrishnan and Kurup 2006, Kurup and Radhakrishnan 2006). Studies conducted at Cochin University of Science and Technology have indicated that populations of *P. denisonii* has declined at a rate of 70% at key collection sites (Kurup and Radhakrishnan 2006). A recent ongoing study by the Conservation Research Group, St. Albert's College, Kochi has observed that the species is overfished in Valapatanam River (exploitation rate E = 0.596) in Kerala (Raghavan 2010). In another completed study by MPEDA, based on the secondary data collected from the collectors, the catch by the collectors increased from 2003 to 2007 in Valapattanam, Kuttiyadi, Chalayar and Chandragiri rivers (Mercy and Malika 2010).

Habitats and Ecology
P. denisonii is a stream dwelling fish with an affinity towards rocky pools, edges with thick overhanging vegetation along its banks (Radhakrishnan 2006; Raghavan *et al*. 2009). However they have also been observed from a wide variety of riverine habitats including run, glide and riffles with sand, gravel, cobbles and boulders as substrates (Biju 2005). They are gregarious and often appear in shoals. The species is known to spawn during the North East Monsoon in the months of November-January (Manoj *et al*. 2010; R. Raghavan and A. Ali pers. obs.).

IUCN Habitats Classification Scheme

Habitat	Suitability	Major Importance?
Wetlands (inland) -> Wetlands (inland) - Permanent Rivers/Streams/Creeks (includes waterfalls)	Suitable	Yes

Life History

Size at Maturity (in cms): Female
100.5 +/- 9.71mm (Rajeev Raghavan and Anvar Ali Per. Observ.).

Size at Maturity (in cms): Male
91.5 +/- 12.39mm (Rajeev Raghavan and Anvar Ali Per Observ.).

Maximum Size (in cms)
180mm (males) and 163 mm (females) (Rajeev Raghavan and Anvar Ali Per. Observ.).

Natural Mortality
0.23 to 1.34 per year (Rajeev Raghavan, Neelesh Dahanukar and Anvar Ali Per. Observ.).

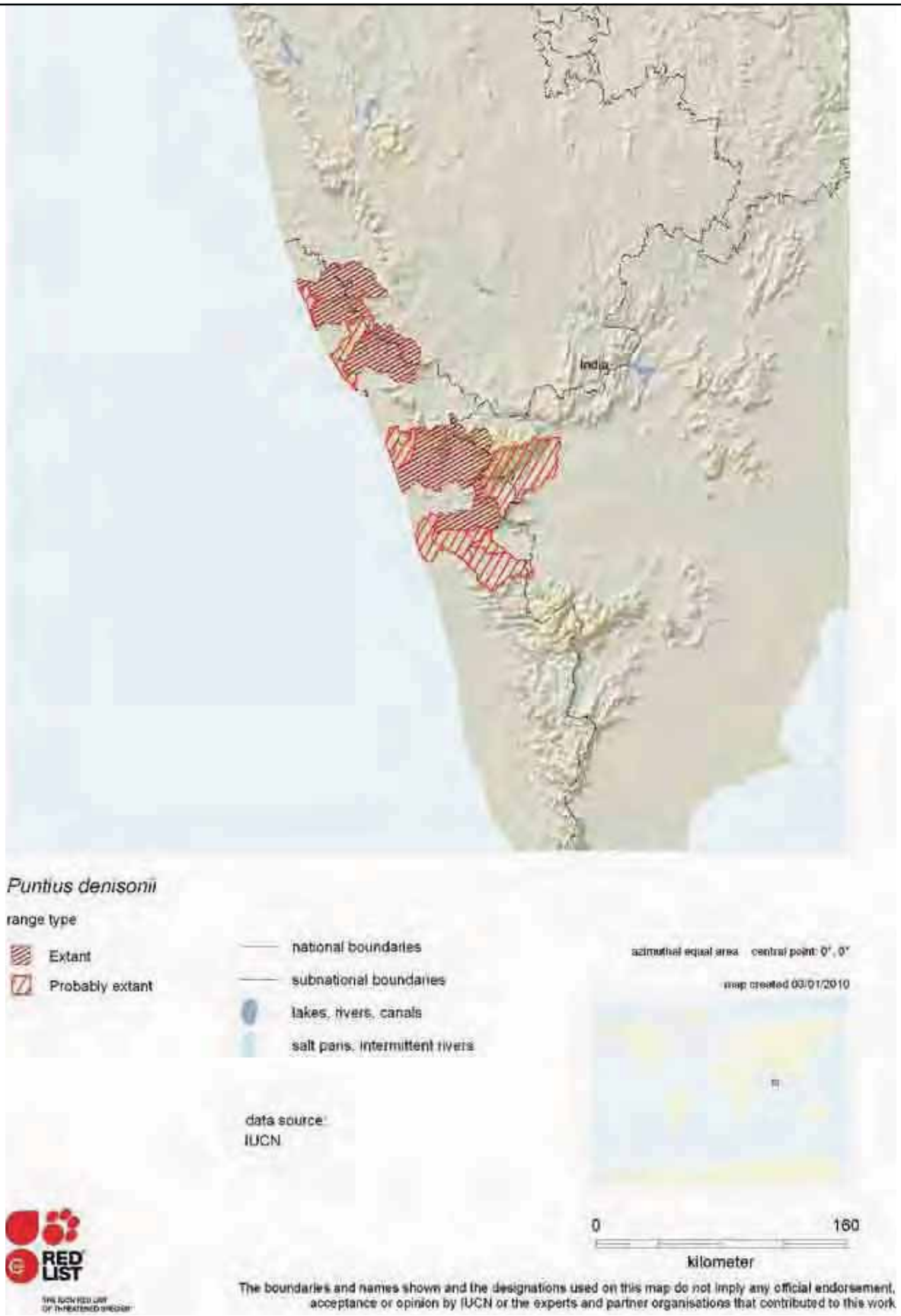
Systems
System: Freshwater

Use and Trade
General Use and Trade Information
P. denisonii is the most popular and highly priced freshwater ornamental fish of the Western Ghats. Of India's total live ornamental fish exports to the tune of 1.54 million US$ during 2007-2008, *P. denisonii* accounted for almost 60-65% (Mittal 2009). This colorful barb is so popular in the hobby that it has been requested in majority of the trade enquiries and exported regularly from India (Sekharan and Ramachandran 2006). The larger individuals of *P. denisonii* are also used as food fish by the local communities and tribes in the forest areas of Kerala (A. Ali and R. Raghavan pers. obs.). Captive bred *P. denisonii* are being exported from Indonesia and Singapore (Mittal 2009).

Threats
Collection for the international aquarium pet trade is the single major threat to *P. denisonii* (Mittal 2009, Prasad *et al*. 2007). Harvest of 'yet to be mature' juveniles as well as brooders is a major concern as the fishery is unregulated and 'open access'. In addition, there is an on-going decline in habitat quality at prime habitats of *P. denisonii* due to pollution from plantations as well as domestic sources. Destructive fishing for larger food fish using dynamites and plant poisons also affect *P. denisonii* as they share habitats with the larger cyprinids.

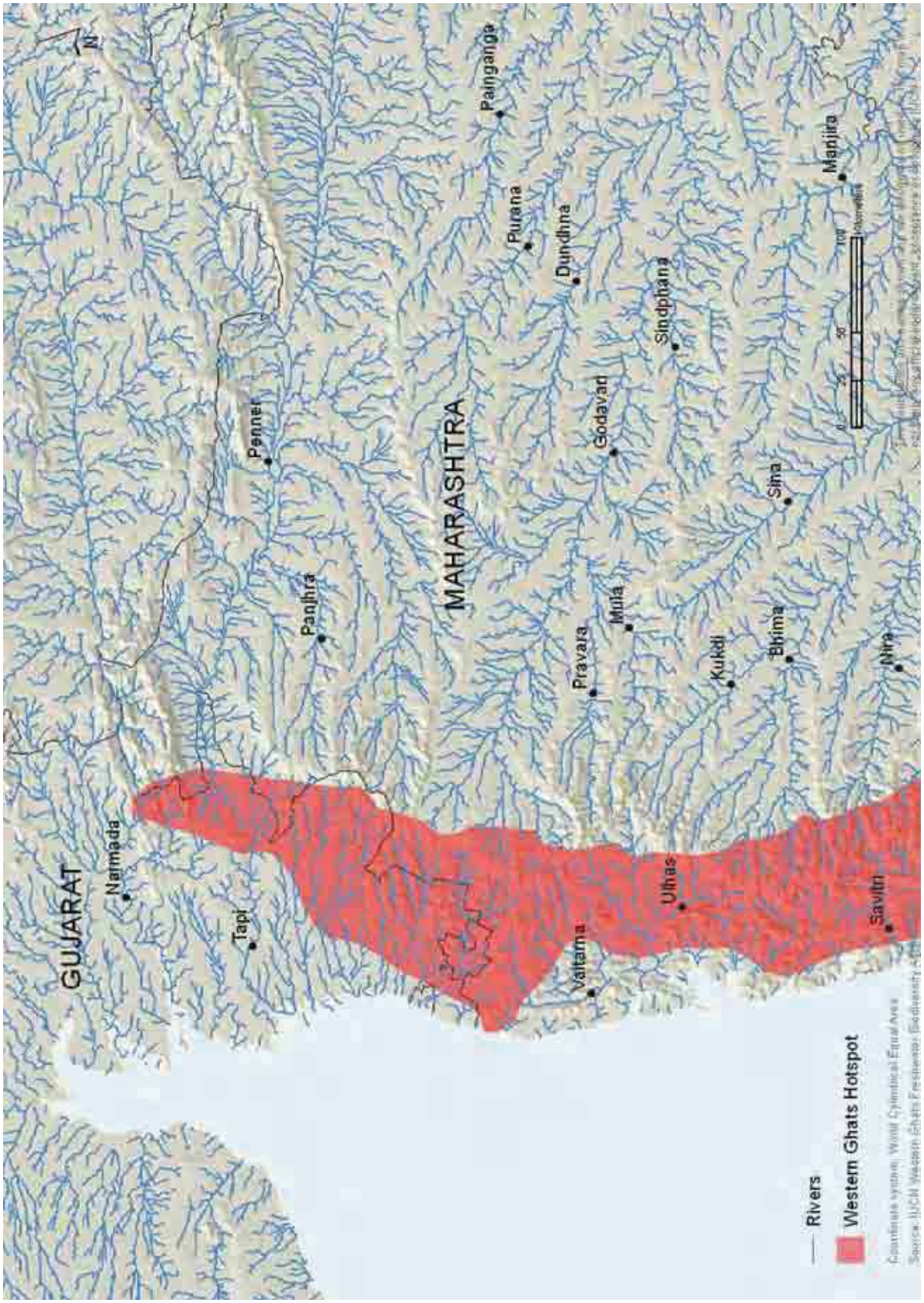
Conservation
To regulate the harvest and trade of this cyprinid, the Government of Kerala (India) has initiated management plans including fixing total allowable catch (TAC), restrictions on gear size, closed seasons. There are also plans to demarcate certain key *P. denisonii* habitats as sanctuaries and no take zones (Mittal 2009). Although the captive breeding technology for this species has been developed by both researchers and hobbyists (Manoj et al. 2010; Mathew 2008; Mercy et al. 2010), commercial scale operations have not started. There are reports that *P. denisonii i*s being captive bred in Indonesia and Singapore and exported (Mittal 2009), but the impacts of such operations on the collection and exports from India is yet to be understood.

Life history studies on the species have been conducted by Radhakrishnan and Kurup (2008) and Harikrishnan et al. (2008) studied the population dynamics in \the rivers of Kerala. Distinct genetic stocks identified in Chandragiri, Valapattanam and Chaliyar rivers (Lijo unpublished PhD thesis, NBFGR). A species specific conservation plan requires urgent attention.



Western Ghats Assessment

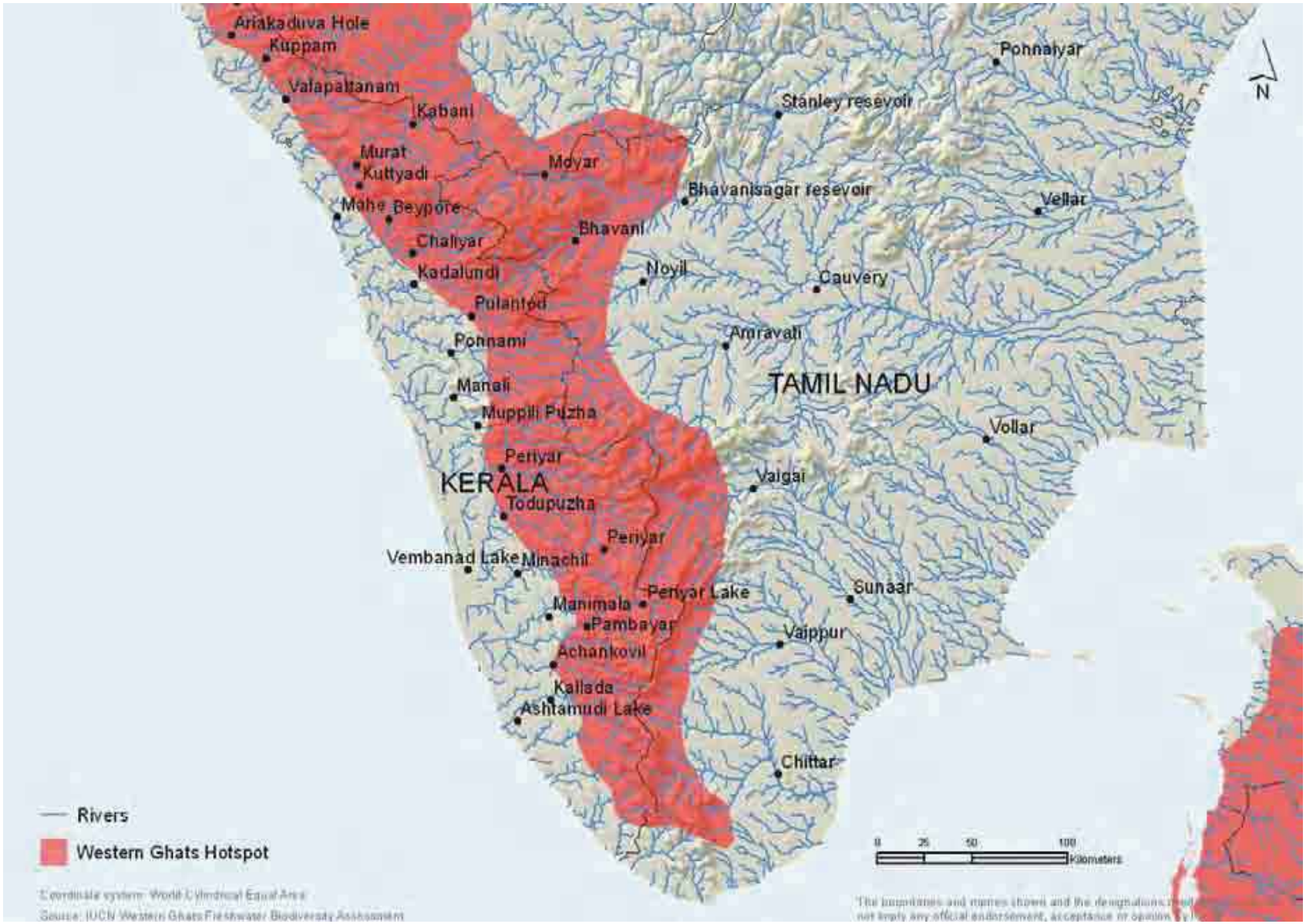
Appendix 2. River maps of the Hotspot



River map hotspot upper

River map hotspot middle upper

River map hotspot middle lower



River map hotspot lower

Appendix 3. Data CD

(i) Executive Summary
(ii) Western Ghats Assessment Report PDF
(iii) Species Summaries
(iv) Species Maps
(v) Species Shapefiles
(vi) Species Lists

IUCN Red List of Threatened Species™ – Regional Assessments

Freshwater Africa
The Status and Distribution of Freshwater Biodiversity in Eastern Africa. Compiled by William R.T. Darwall, Kevin G. Smith, Tomas Lowe, Jean-Christophe Vié, 2005.
The Status and Distribution of Freshwater Biodiversity in Southern Africa. Compiled by William R.T. Darwall, Kevin G. Smith, Denis Tweddle and Paul Skelton, 2009.
The Status and Distribution of Freshwater Biodiversity in Western Africa. Compiled by Smith, K.G., Diop, M.D., Niane, M. and Darwall, W.R.T., 2009.
The Status and Distribution of Freshwater Biodiversity in Northern Africa. Compiled by N. Garcia, A Cuttelod, and D. Abdul Malak. 2010.
The Status and Distribution of Freshwater Biodiversity in Central Africa. Compiled by Brooks, E.G.E., Allen, D.J. and Darwall, W.R.T. 2011.
The Diversity of Life in African Freshwaters: Under Water, Under Treat. An analysis of the status and distribution of freshwater species throughout mainland Africa. Darwall, W.R.T., Smith, K.G., Allen, D.J., Holland, R.A, Harrison, I.J., and Brooks, E.G.E. (eds.). 2011.

Freshwater Asia
The Status and Distribution of Freshwater Biodiversity in the Eastern Himalaya. Compiled by Allen, D.J., Molur, S., and Daniel, B.A. 2010.

Mediterranean
The Status and Distribution of Freshwater Fish Endemic to the Mediterranean Basin. Compiled by Kevin G. Smith and William R.T. Darwall, 2006.
The Status and Distribution of Reptiles and Amphibians of the Mediterranean Basin. Compiled by Neil Cox, Janice Chanson and Simon Stuart, 2006.
Overview of the Cartilaginous Fishes (Chondrichthyans) in the Mediterranean Sea. Compiled by Rachel D. Cavanagh and Claudine Gibson, 2007.
The Status and Distribution of Dragonfies of the Mediterranean Basin. Compiled by Elisa Riservato, Jean-Pierre Boudot, Sonia Ferreira, Milos Jovic, Vincent J. Kalkman, Wolfgang Schneider and Boudjéma Samraoui, 2009.
The Status and Distribution of Mediterranean Mammals. Compiled by Helen J, Temple and Annabelle Cuttelod, 2009.

Europe
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European Red List of Amphibians. Compiled by Helen J. Temple and Neil Cox, 2009.
European Red List of Reptiles. Compiled by Neil Cox and Helen J. Temple, 2009.
European Red List of Saproxylic Beetles. Compiled by Ana Nieto and Keith N.A. Alexander, 2010.
European Red List of Butterfies. Compiled by Chris van Swaay, Annabelle Cuttelod, Sue Collins, Dirk Maes, Miguel López Munguira, Martina Šašić, Josef Settele, Rudi Verovnik, Teo Verstrael, Martin Warren, Martin Wiemers and Irma Wynhof, 2010.
European Red List of Dragonfies. Compiled by Vincent J. Kalkman, Jean-Pierre Boudot, Rafał Bernard, Klaus-Jürgen Conze, Geert De Knijf, Elena Dyatlova, Sónia Ferreira, Miloš Jović, Jürgen Ott, Elisa Riservato and Göran Sahlén, 2010.

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