

A Review of Floristic Diversity Inventory and Monitoring Methodology in India

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India abounds in a wealth of complex and diverse ecosystems exhibiting a great deal of variation. Documenting such a variation is essential for its proper management. The Convention on Biological Diversity (CBD) commits countries to prepare inventories of the bioresources for monitoring so as to check their possible degradation and erosion. India possesses a large base-line information on floristic diversity but partly unorganised and scattered. It is now time to collate this information for ready use in different inventorying and monitoring exercises. Effective inventorying and monitoring involve careful planning. The task is to look into the efforts already put in by various organisations and individuals. Some floras of the States, districts, and protected areas have been thoroughly documented. Programmes of monitoring can be initiated in such already documented areas. In inventorying, overlapping in our efforts is to be avoided and less explored areas are to be identified for prioritisation of survey. This is to be followed by developing plant lists for relocating and if required censusing in different regions basing on criteria such as endemic or endangered elements or species under commercial exploitation. Monitoring does not imply monitoring every inch of space for all the available species in the country. Neither does it mean having quantitative data for every species. Keeping track of population sizes of the species which are on the edge of elimination should be a priority activity of biodiversity monitoring. Our attempts to monitor the bioresources become less tedious and inexpensive if schemes are drawn using the existing information.

The paper reviews existing information and the options available for building up an inventory base for the monitoring schemes. Some suggestions having a direct or indirect bearing on monitoring schemes are included.

Key Words: Floristic diversity, Inventorying, Monitoring and Conservation

Introduction

Major achievements of Earth Summit, 1992 include the 'Rio declaration' on Environment and Development (a series of principles defining the rights and responsibilities of States in this area); a set of principles to support the sustainable management of forests worldwide; two legally binding conventions aiming to prevent global climate change and the conservation of biological diversity.

Convention on Biological Diversity (CBD) has a rather idealistic objective of preserving the existing biodiversity and its ecological and socio-

economic functions in its totality. This paper attempts to analyse on-going efforts on inventorying and monitoring exercises.

India's Biological Resources

India with its vast geographical area of about 329 m ha, ranks seventh largest in the world. Its coast line of about 7,500 km extends over 200 nautical miles offshore forming an exclusive economic zone (EEZ) of two million sq. km. The diverse physical features and tropical monsoon climate support rich biological diversity in different ecological habitats. India represents one of the 12 mega diversity centres in the world (table 1). The main natural

Table 1 Some species diverse countries in the World for Higher plants

Country	No. of flowering plant Species
Brazil	55,000
Columbia	35,000
China	30,000
Mexico	25,000
South Africa	23,000
Former Soviet Union	22,000
Indonesia	20,000
Venezuela	20,000
United States	18,000
Australia	15,000
*India	15,000

Source: Groombridge (1992) and Bibby et al.(1992).

*The figure for India is now considered as 17,000 instead of 15,000.

habitats in India are mountains, forests, grasslands, plains, rivers, wetlands, coastal and marsh areas and islands.

Species Diversity

India's location is at a junction of three biogeographic realms namely Afro-tropical, Indo-Malayan and Paleo-arctic. India harbours about 9% of the total species of the world. India, having 2.4% of global area, exhibits 12.51% of floral diversity and 6.67% of faunal diversity. India has about 48000 species of plants representing about 10% of the world's flora (Hajra & Mudgal 1997).

Significant diversity exists in Pteridophytes and Fungi. Different families in Angiosperms such as Poaceae, Orchidaceae, Balsaminaceae exhibit enormous diversity. Recorded number of species under different taxonomic categories are given in table 2.

Endemism is a significant factor in diversity assessment and conservation. About 4,900 species of flowering plants (33% of total recorded species) are endemic to the country (141 genera distributed over 47 families). Families like Poaceae, Acanthaceae, Rubiaceae, Orchidaceae and Fabaceae

had a higher representation of endemic taxa (Nayar 1997). Some important groups with percentage endemism are given in table 3. These taxa are concentrated in floristically rich areas of the North east India, the Western Ghats and the North West Himalaya. The Western ghats and Eastern Himalayas are reported to possess 1600 and 3500 endemic species of flowering plants respectively and are listed in 18 biodiversity hot spots of the world. Around 220 species of flowering plants are endemic

Table 2 Number of species(Group-wise) in India.

Taxon	No .of Species	Percentage
Bacteria	850	0.67
Algae	2,500	2.00
Fungi	23,000	18.23
Lichens	1,600	1.30
Bryophyta	2,700	2.14
Pteridophyta	1,022	0.80
Gymnosperms	64	0.05
Angiosperms	17,000	13.50
Protozoa	2,577	2.04
Mollusca	5,042	4.00
Crustacea	2,970	2.35
Insecta	5,077	40.00
Other invertebrates incl. Hemichordata	11,252	9.00
Protochordata	116	0.10
Pisces	2,546	2.02
Amphibia	204	0.16
Reptilia	428	0.34
Aves	1,228	1.00
Mammalia	372	0.30
Total	1,26,188	100.00

Source: Khoshoo (1995)

Table 3 Percentage endemism in various groups

Taxon	No. of species	%endemism
Bryophyta	2700	29.0
Pteridophyta	1022	24.5
Gymnosperms	64	12.4
Angiosperms	17000	33.5

Source: Mudgal and Hajra (1997)

to Andaman and Nicobar Islands (Jain 1983). These are two of the twenty five micro endemic centres of plants identified in the country. There is considerable endemism in other plant groups also.

India is the homeland of 167 important cultivated plant species. 320 species of wild relatives of domesticated crops originated in the Indian Sub-continent (Arora & Nayar 1984).

Articles of CBD relating to inventorying, monitoring and organising database

Article 7 of the CBD states that each contracting party shall, as far as possible and as appropriate, in particular for the purposes of Articles 8 to 10 (Articles 8 to 10 relate to *in situ* and *ex situ* conservation and sustainable use of components of biological diversity):

- (a) identify components of biological diversity important for its conservation and sustainable use having regard to the indicative list of categories set down in Annex I;
- (b) monitor through sampling and other techniques, the components of biological diversity identified pursuant to subparagraph a) above, paying particular attention to those requiring urgent conservation measures and those which offer the greatest potential for sustainable use;
- (c) identify processes and categories of activities which have/are likely to have significant adverse impacts on the conservation and sustainable use of biological diversity and monitor their efforts through sampling and other techniques; and
- (d) maintain and organise, by any mechanism data derived from identification and monitoring activities pursuant to subparagraph (a), (b) and (c) above.

State of Surveys

The main mandate of the Botanical Survey of India (BSI) and Zoological Survey of India (ZSI) concerns to articles 7, 8 and 9 of the CBD. Both the Surveys produced good amount of information connected to inventorying. To date,

the BSI has completed 60% of total geographical area for exploration as far as plant survey is concerned and ZSI about 70% area in case of survey of fauna. Surveys conducted so far resulted in inventorying over 45,000 species of plants and over 81,000 species of animals. The lists are not complete and constantly updated with more explorations and discovery of new species.

Available Information

Valuable information is in floras, checklists and in some revisionary studies. These are reports of descriptions, relatedness and occurrence of various species in different areas. Hooker's flora of British India (1872-1897) served as a standard reference till recently. A new Flora of India was conceived in early seventies. The BSI produced 5 volumes of the revised National flora in early 90s. This revisionary work was felt necessary as the area covered by the Hooker's work had undergone political transformation with the end of British rule. This revised flora incorporated various name changes, new taxa described and also changes in circumscription of many taxa due to monographic works. As for the regional floras, Flora of upper Gangetic plains (Duthie 1903-1922), Flora of Assam (Kanjalal 1934-1940), Flora of Madras Presidency (Gamble & Fischer 1957), Flora of Bombay (Cooke 1901-1908), Bengal Plants (Prain 1903), Bihar and Orissa (Haines 1921-1925), Rajasthan (Puri et al. 1964) are notable. Among the recent state floras, Karnataka (Sharma et al. 1984, Saldanha 1984), Himachal Pradesh (Chowdhery & Wadhwa 1984) Goa, Diu, Daman, Dadra and Nagarhaveli (Rao 1985-1986), Rajasthan (Shetty & Singh 1987), Madhya Pradesh (Verma et al., 1994) Arunachal Pradesh (Hajra et al. 1996) Andhra Pradesh (Pullaiah & Chinnaiah 1997), Tamil Nadu (Henry et al. 1989) and Tripura and Manipur (Deb 1961, 1981). Checklists were prepared for Sikkim. Flora of Andaman and Nicobar islands is in press.

The BSI has published floras of selected districts and ecosystems. The district floras include all species of angiosperms occurring in these areas with generic and specific keys, short descriptions,

distribution, localities and taxonomic citations. The older district floras include Allahabad (Srivastava, 1938), Ranchi (Bressers 1951), Delhi (Maheswari, 1963), Saurashtra (Santapau 1962), Hasan district (Saldanha & Nicolson 1976), Dehradun (Babu 1979) and Howrah (Bennet 1979). In the year 1984, sixty districts in 18 states were attempted under district flora scheme for detailed surveys. In total, 32 district floras appeared either in print or remained as Ph. D. thesis. The recent district floras include, Jowai (Balakrishnan 1981-1983), Tonk (Shetty & Pandey 1983), Banswara (Singh 1983), Panchmari and Bori reserves (Mukherjee 1984), Chamoli (Naithani 1984-1985), Raipur, Durg and Rajnandgaon (Verma et al. 1985) Akola (Kamble & Pradhan 1988), Cannanore (Ramachandran & Nair 1988) Sindhudurg, (Kulkarni 1988), Bilaspur (Panigrahi & Murthy 1989), Palghat (Vajravelu 1990) Mahabaleswar (Sandhya et al. 1993) Nasik (Lakshminarasimhan & Sharma 1991) Agra (Sharma & Dhakre 1995), Raigad (Kothari & Moorthy 1993), Yavatmal (Karthikeyan & Anandkumar 1993), Krishna (Lakshminarayana et al. 1997), Calicut (Manilal & Sivarajan 1982), Nizamabad (Pullaiah & Rao 1995) and Thiruvananthapuram (Mohanani & Henry 1994).

Protected Areas

India has a long history of conservation. During the first half of this century, there was a rapid decline in wildlife populations and the conservationists called for a national wildlife protection programme in the early 1970s. The thrust was towards protecting endangered species by giving legal protection to their habitats. The Project Tiger was launched in 1973 and 16 tiger reserves were declared. Later, another 7 were added to the list. To name a few, Bandipur, Corbett, Kanha, Manas, Melghat, Palamu, Ranthambore, Simlipal (now elevated to Biosphere reserve), Sunderbans, Periyar, Sariska, Buxa, Indiravathi, Nagarjuna Sagar, Namdapha Dudhwa, Kalakad, Mundanthurai, Valmiki, Pench, Dampa, Panna, Bandhwagarh and Taroba. Besides, working on individual tiger reserves (Malhotra & Moorthy 1992, Banerjee 1993) the Botanical Survey produced a book consolidating the general vegetational accounts in many of

the above tiger reserves (Jain & Sastry 1983). This book is now under revision by the Survey. The Indian Wildlife Act was promulgated in 1972 and this followed by declaration of national parks and sanctuaries. Some of these protected areas were surveyed thoroughly for flora. These include Manas wild life sanctuary, Corbett National Park, Mudumalai, Nandadevi and Dudhwa National Parks. In the year 1971, the International Coordinating Council for the MAB programme decided to have a coordinated world-wide network of protected areas in cooperation with the intergovernmental and non-governmental organisations to select, set aside and manage the areas needed for the long term conservation. These areas were designated as biosphere reserves. The Govt. of India in 1979 constituted a core advisory group of experts which identified and prepared a preliminary inventory of potential areas for recognition of biosphere reserves. In this exercise, BSI prepared project documents on plant diversity on the proposed biosphere reserves. Besides this, specific surveys were conducted in many protected areas and the results were published. Notable among them are Uttarkhand Biosphere Reserve (Valley of flowers) (Rau 1961, 1964, Wadhwa et al. 1987), Rann of Kutch (Jain 1968, Jain & Despande 1960, Jain & Kanodia 1960, Sabnis & Rao 1983); Thar desert Biosphere Reserve (Unpublished report of Arid Zone circle BSI 1983, Pandey 1981, Pandey et al. 1982, Shetty & Pandey 1977, Singh & Shetty 1977, 1983), Namdapha Biosphere Reserve (Joseph 1982), Nandadevi Biosphere Reserve (Hajra & Balodi 1995), Gulf of Mannar (Rao et al. 1963, Daniel, 1996), Nilgiri Biosphere Reserve (Joseph 1987, Sharma et al. 1977); Great Nicobar (Technical report of Ethnobiology Project 1991, Thothathri et al. 1976, Balakrishnan & Nair 1979, Balakrishnan & Nair 1980, Bhargava 1981), Nokrek Biosphere Reserve (Ghosh et al. 1978), Manas Biosphere Reserve (Hajra & Jain 1995), Kanha (Maheswari 1963), Sunderbans (Chandra 1977) and North Andamans (Balakrishnan 1989, Ellis 1989). A good number of sanctuaries and national parks are part of the Biosphere reserves.

The need for wetland protection was given serious consideration at the global level in the early 1960s. The International Biological Programme (IBP) and the International Union for conservation of Nature and Natural Resources (IUCN) provided the initial impetus that culminated into Convention on Wetlands, better known as the Ramsar Convention. India acceded to the convention in the year 1981. It is estimated that India has about 4.1 m ha of wetlands (excluding paddy fields and mangroves) of which 1.5 m ha are natural and 2.6 m. ha are manmade (Kaul 1995). Six internationally significant wetlands of India were designated as Ramsar sites and about 17 as wetlands of national importance. Wetlands namely Chilka, Harike, Keoladeo Ghana, Lokthak, Sambhar, Wular, Ashtamudi, Bhoj, Kabar, Kanjli, Kolleru, Nalsarovar, Pichola, Renuka, Sasthamkhotta, Sukhana and Ujni are some of the important Indian wetlands (WWF India 1992). Floristic Surveys in many of the above wetlands were completed. Siltation, reclamation, pollution, eutrophication and encroachment are some of the major identified ecological issues in these water bodies. As per one estimate (Naskar 1990) there are ca. 270 species of aquatic angiosperms representing 76 families in the lower gangetic delta alone. Rao (1994) listed ca. 300 aquatic plant species belonging to 69 families. 42 of these are designated as endemic plants. There are numerous reviews and project reports on many important wetland habitats (Billore & Vyas 1982, Gopal 1990, Kaul 1977, Mishra, 1992, Mukherjee 1975, Naskar 1990, Prakasam, 1991 and Gopal & Krishnamoorthy 1993).

The Botanical Survey of India made important contributions on endemic, rare and endangered plants. Red Data books, produced in three volumes (Nayar & Sastry 1987-1990) enlist around 600 species of rare and endangered species elaborating the present distribution, identified threats, conservation measures taken or recommended. Equally important is the contribution of this Survey on the endemic plants of India. Survey had envisaged this work in two volumes. Volume 1 on endemic plants of Peninsular India while the two

on the rest of the country. Besides, Nayar's recent publication on endemic plants of India and its neighbouring countries is comprehensive on the subject (Ahmedullah & Nayar 1987, Nayar 1997). In most of the above investigations, plant lists were brought out highlighting endemic and threatened elements. Such information bases are important for selection of species for monitoring.

Monitoring Methodology

Recently, a workshop was organised by Prof. Madhav Gadgil in Indian Institute of Science, Bangalore to discuss a methodology involved in monitoring (16-17 Sept., 1997). While envisaging a monitoring programme for Eastern and Western Ghats, the scheme called for monitoring the abundances of entire spectrum of organisms in the whole landscape and waterscape regions. India with an area of 320 million ha of landmass is known to possess 1,25,000 described and 4,00,000 undescribed species. The Eastern and Western Ghats consisting 10% of country's land area are expected to harbour about 55% of (ca. 65,000 species) India's terrestrial and fresh water diversity. Thus, the total task was defined as determining a matrix of (0.65×10^5) species for (3×10^7) locales, with each element in the matrix being the abundance of a given species in a particular hectare at some specified time. Here, the size of the monitoring unit was taken as 1 ha. while the total number of species to be monitored are 55% of the total identified species from the country. Monitoring would involve assessing changes in this matrix over time. This projection has its problems in implementation. Hence a subset of species in some selected localities were thought of for monitoring. This subset includes species from the entire range of plants and animals and in the proportion of their total abundance. Criteria such as evolutionary lineages, endemic plants, plants of human significance etc. are taken into consideration. While in case of localities, the choice was guided by many parameters such as sources of variation in the abundances/occurrences of species in different parts, differences in various biogeographic subprovinces, bioclimatic

conditions, etc. (Gadgil 1997). This monitoring scheme essentially draws methodology from CENPLANK Programme conducted by Centre for Plankton Collection, Sorting and Identification by Morski Institute and Sea Fisheries Institute, Poland (Ejsymont & Dunkiewicz 1994). This International Project is focussed on monitoring long-term changes in the coastal marine ecosystems using plankton. Here the plankton samples collected from Gulf of Alaska, East Bering Sea, California Current, Gulf of Mexico, Southern US Coast are analysed for species composition and their quantitative estimates. These data are stored under extensive database. Seasonal rhythms are recognised in many planktonic groups. Their abundance is essentially for a short period of time in the annual cycle and they repeat this appearance with definite rhythm in every year. Monitoring schemes of this nature (CENPLANK) are suited to document seasonal disturbances, if any, in different planktonic groups. However, monitoring of terrestrial systems is to be based essentially on relocation of species considered as endangered and their subsequent population monitoring. In fact monitoring programmes should be undertaken more objectively. Monitoring does not literally mean monitoring every inch of space for all the species. Monitoring exercises should encompass the following themes in their execution.

- (i) Monitoring guidelines should be site specific and are to be formulated based on experience drawn from surveys involved in inventorying.
- (ii) Monitoring can be initiated groupwise depending on the level of understanding and the inventory base in different situations.
- (iii) Monitoring is a continuous process and evolves with inventorying exercises
- (iv) Once inventorying is complete in a given area, suitable time-frames can be drawn depending on the information on inventory base
- (v) Monitoring should be essentially a qualitative one for common species as long as there are no perceivable changes in their abundances. However, species identified as endemics, threatened or under human exploitation may be taken up for population census. Relocation of certain

species is necessary in certain situations and this may be included in monitoring exercises.

- (vi) Other criteria such as representatives of evolutionary lineages, species of human significance such as pollinators, medicinal plants, keystone species may be applied for selection of species for monitoring.
- (vii) Monitoring areas are to be prioritised in the lines of areas prioritised for inventorying.

Another proposal in the above scheme is monitoring through college and post graduate students with the premise that such decentralised exercises help us in completion of resource surveys faster. While proposing this, the skills involved in the identification of species and further monitoring were not given due consideration. The tasks involved in inventorying and monitoring are technical. Both the exercises should come under the ambit of Surveys and these are possible only through experienced taxonomists and not by others. In the year 1980, an ambitious programme was taken up by the Botanical survey to mop up surveys at district level taking the help of teachers connected to universities and other institutions. In this scheme, jobs assigned to some colleges and universities could not be executed with the needed seriousness due to lack of field experience, involvement in the subject, expertise and other situational problems.

Variations in nature are sometimes discreet and sometimes continuous. Only a competent taxonomist and field botanist can understand these variations and suitably evaluate them. Even a trained taxonomist, sometimes faces difficulty in these judgements. Literature is replete with misidentifications and consequent confusions in many groups. Much synonymy and frequent name changes of many taxa are partially a reflection on lack of total understanding. According to Aristotele, each species or form has an essence, certain intrinsic features which make it what it is, that is universal for the species. The essence may be deducted by intuition by observing a number of individuals and abstracting what is universal in them. Individuals in turn have two sets of properties, namely the essential ones which are invariable and form

the defining characters of the species and the accidental ones which are quite variable among the members of this group. The latter are not related to the essence of species and are discorded as 'sports of nature' (Sivarajan 1991). Understanding this ground plan of each species with fluctuations in other characters is the job of experienced taxonomist alone.

Taking these arguments into consideration, monitoring schemes should be evolved by strengthening the existing schemes on conservation, intensifying inventorying and by developing site specific 'species lists' for monitoring.

Some Points in Conservation and Monitoring

Expansion of protected area network: The main strategy for conservation of species is the protection of viable habitats in representative ecosystems. At present the protected area network does not cover all the biogeographical units nor the protected areas distributed equally within states or biogeographic regions. The existing protected area network consists of 8 biosphere reserves, 21 wetlands, 15 mangroves and 4 coral reefs, 85 National Parks and 448 sanctuaries. This covers about 4.2% of the total geographical area. In order to reduce the gaps in the coverage of various biogeographic units and biomes and to ensure representation of maximum wildlife habitats, the Wildlife Institute of India has highlighted the need to increase the protected area network in different parts of the country. The proposal is to increase the existing network coverage to 147 National Parks and 519 Wildlife sanctuaries thereby raising the coverage to 5% of the total geographical area (Arora et al. 1996).

Ordering information: State and district floras help us to develop tentative inventory in various geographical areas which can form a sound basis to select localities for monitoring. There is a greater need to assess the literature available with us in various groups as stated in article 7(d) to identify gaps. The Botanical Survey also produced information exclusively with regard to endangered and endemic plants. This information can get into

monitoring exercise. Keyworks produced by the Survey (Nayar 1984-86, 1988) help us to some extent in summing up this information.

Localised monitoring programme: While addressing the problems of monitoring, two issues are relevant for clarification. First, it concerns the baseline information available in the geographical area to be taken into consideration for monitoring. The second issue relates to selection of species for both qualitative and quantitative monitoring. As for the first issue is concerned, monitoring is to be based on local inventories and not by the database at country level. Target species for monitoring are to be identified basing on threatened or endemic elements or both. Flora of national level has limited use in planning such decentralised monitoring schemes.

Stress to documentation: As estimated, out of six lakh plant and animal species existed in the country, only a fraction say, 1,25,000 were documented in terms of their identity and taxonomy. More stress to documentation is primarily the first step towards understading diversity which can be used in followup monitoring. A conference on 'Capacity building in Taxonomy' held in Jaipur (1997) stressed the need to develop required taxonomic expertise to handle the inventorying exercises in various groups separately. Significant inventory bases were prepared by some universities in lower groups, particularly algae and fungi. A well coordinated effort between the Botanical Survey and other research institutions can avoid duplication of documentation in various groups and also in different situations.

Monitoring units: The size of monitoring units in biodiversity conservation may vary but preferably not larger than the size of a sanctuary or a national park or a tiger reserve. Smaller areas make the monitoring exercise easy and monitoring schemes can be integrated in annual action plans of these protected areas.

Endemic elements: Through years of survey and inventorying, a good number of species were recorded as endemics. However, many of the species were not understood for the niche requirements as the studies of this nature could

form an effective feed back in developing species specific management plans. Also the monitoring areas can be identified with reference to such specific groups. For example, out of 18 genera and 130 species so far known in bamboos in India, 15 genera and 63 species are represented in Northeastern India (Rao 1997). The locations of many of these species can be known only by noting type localities and these areas may be carefully tracked for monitoring. The larger endemic genera occurring in India are *Pterocanthus* (20 species) and *Nilgirianthus* (20 spp.) of the family Acanthaceae. The family Podostemaceae which represents

exclusively aquatic plants, has good number (24 species) of endemic plants in India (Nagendran & Arekal 1981). Like-wise the family Poaceae is one of the largest families with over 370 endemic taxa (Jain, 1986). Such specific endemic taxa may be prioritised for monitoring by knowing their localities. Such taxa oriented monitoring schemes can take care of good number of species for conservation.

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