SAHYADRI : WESTERN GHATS BIODIVERSITY INFORMATION SYSTEM

http://ces.iisc.ernet.in/biodiversity

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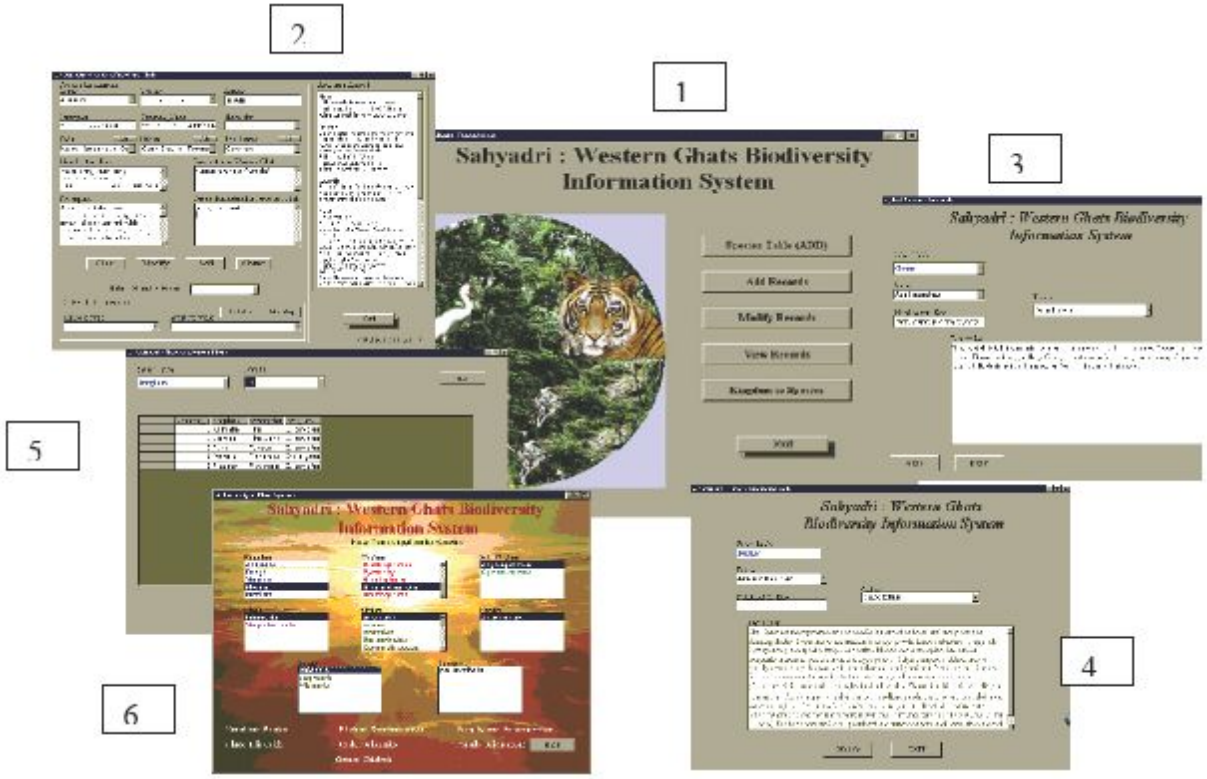

Abstract : **The Western Ghats is a mega biodiversity region, with varied flora, fauna and landscapes. The distribution and magnitude of the biodiversity that exists today is a product of over 3.5 billion years of evolution, involving speciation, migration, extinction and more recently, human influence. This is emphasized on the diversity of plant life as an essential underpinning of most of the tropical ecosystem. The adverse effects of human impacts on environment are increasing dramatically and threatening the very foundation of sustainable development. Unless actions are taken to protect biodiversity, the opportunity of reaping its full potential benefit to mankind will be lost forever. This necessitates a balanced exploitation and conservation of the nation's wealth, especially plant and animal wealth. It has become imperative to explore for obtaining an inventory of floristic elements and to identify plants that have potential ecosystem importance. The data and information about these resources is scattered and staggered. This enormous amount of data available in different sources when organised can turn out to be valuable information for future. There is a need to design an information system that would help in the conservation and management of these resources. This paper describes the design and implementation of the interoperable network of biodiversity databases and information systems. The Sahyadri: Western Ghats Biodiversity Information System acts as a decision support system with the vast quantity of biodiversity information. It is designed and implemented to promote analysis on Western Ghats biodiversity resources (e.g., flora and fauna) based on inventorying, monitoring and mapping. Thus the Sahyadri offers means for accessing, interpreting and querying of information for the purpose of conservation and sustainable management.**
Keywords: **Biodiversity, Western Ghats, Hot spots, Information System, Sahyadri**

INTRODUCTION

The earth is home to a rich and diverse kind of living organisms, whose genetic diversity and relationships with one another and with their physical environment constitute biodiversity. Biodiversity or biological diversity generally refers to the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems. Thus, biodiversity is the totality of genetic, species, ecosystem and habitat diversity in a region that has evolved through millions of years of evolutionary history. It changes across environmental gradients like, latitude, altitude, depth, aridity, etc. Inventorying and monitoring of biodiversity is done at different organisational levels from genes to ecological systems (landscapes), and at different spatial scales from a few square meters to continents. Hence, the recognition and characterisation of biodiversity depends critically on taxonomy, genetics and ecology. Taxonomy provides the reference system and depicts the pattern or tree of diversity for all organisms. Genetics gives a direct knowledge of the gene variations found within and between species. Ecology provides knowledge of the varied ecological systems in which taxonomic and genetic diversity is located, and of which it provides the functional components.

The origin of life is a consequence of pre-biotic evolution of organic material to cellular forms. The present complexity that life has developed by successive evolutionary optimization took 3.5 to 4.0 billion years (earliest fossil record of life on earth is 3.6 billion years ago). An estimated 1.7 million species have been described to date, and conservative estimates suggest that around 12.5 million species must be existing on earth. This rich diversity is facing various threats for its very survival. Even before we fully describe the species richness, we are losing many species, due to the alarming rate of extinction. It is hard to develop a measure of extinction rates of the entire flora and fauna due to the scant knowledge of the species pool before the impact. Even though, speciation and extinction processes (as many as 12 mass extinctions have taken place so far naturally) are part of the evolutionary process, extinction is overtaking speciation. Humankind has to realise that *what is lost is lost for ever*, and cannot be brought back. Human development should be without interfering with natural ecosystems that exist, rather should be in harmony with nature, conserving it for the future generations.

The loss of biodiversity could be attributed to: the expanding human population activity by way of habitat destruction through fragmentation and degradation, overexploitation of species for human use, introduction of exotic species, increased spread of disease, predators and many other complex unexplored factors. The habitat changes (physical, chemical and biological) have altered inextricably interwoven complex relationship between species and habitat, resulting in species extinction (an irreversible process). The natural disturbances (in small amounts) in ecosystems dominated by late successional communities, like forests, will result in increased diversity. The healthier the ecosystem is, the more diversity it will contain, capable of finding an alternate pathway if one is destroyed and continue to provide ecosystem services.

The adverse effects of human impacts on environment are increasing dramatically and threatening the very foundation of sustainable development. Unless actions are taken to protect biodiversity, the opportunity of reaping its full potential benefit to mankind will be lost forever. This necessitates a balanced exploitation and conservation of the nation's wealth, especially plant and animal wealth. It has become imperative to explore for obtaining an inventory of floristic elements and to identify plants that have potential ecosystem importance. This biodiversity is the natural biological capital of the earth, and presents important opportunities for all nations, especially India.

India has a unique combination of living species, habitats and ecosystems, which together makes it a diversity rich country in the world. The Indian region with varied bio-climatic zones, altitudinal zones, edaphic condition and other accompanying micro-climatic conditions nurture rich and diverse flora which in turn have bestowed upon it the distinction of being the sixth among the 12-mega biodiversity zones of the world. India is recognized as a country rich in all aspects of biodiversity, ecosystem, species and genetics. India harbours two mega-biodiversity regions the North Eastern hill regions and the Western Ghats. India, while following the path of development, has been sensitive to the needs of conservation. India's strategies for conservation and sustainable utilization of biodiversity in the past have comprised of providing special status and protection to biodiversity rich areas by declaring them as national parks, biosphere reserves, sanctuaries, ecological fragile and sensitive areas. One such area is the Western Ghats, which runs parallel to the west coast of India.

The Western Ghats covers of six states namely Gujarat, Maharashtra, Karnataka, Kerala, Goa and Tamil Nadu. It has a wide range of vegetation and topographical features. Biogeographically, the hill chain of the Western Ghats constitutes the Malabar province of the Oriental realm, running parallel to the west coast of India from 8° N to 21° N latitudes, 73° E to 77° E longitudes for around 1600 km. Rising up from a relatively narrow strip of coast at its western border, the hills reach up to a height of 2800 m before they merge to the east with the Deccan plateau at an altitude of 500-600 m. The average width of this mountain range is about 100 km.

The Western Ghats (known as Sahyadri ranges in Sanskrit) has to its credit a wide range of species diversity, 4500 plant species out of which 35 percent are endemic. Levels of endemism in this area are high – nearly 2000 species of higher plants, 84 species of fishes, 87 species of amphibians, 89 species of reptiles, 15 species of birds and 12 species of mammals are endemic to the Western Ghats (Daniel, 1997). This bioregion is highly species rich and under constant threat due to human pressure and has within it many hotspot (region recognised to hold diverse life forms which requires conservation) regions like the forests of Mahabaleshwar, hills of Coimbatore, Pulneys, Tirunelveli, Nilgiris, places like Nagarahole, Silent Valley etc. These are some of the places that harbour rich diversity of endangered species both in the aquatic and terrestrial ecosystems. The plant and animal species known to be from the Western Ghats that are categorized by the IUCN (International Union for Conservation of Natural Resources) as endangered and vulnerable. Hence, there is an urgent need for the conservation of these species before they get vanished into the air.

Conservation can be achieved in big way by proper dissemination of information. The spread of information and the diversity of life on earth has always remained striking features. This diversity in life is popularly referred to as biodiversity, the information for which is scattered among different people, regions, books and traditions. Over the last few decades, computers are playing a very important role in the field of biology. The current decade faces the information revolution. Data from different sources when processed forms information. Computer assisted data management leads to the development of information system. Information System contains a discrete set of information organized for the collection, processing, maintenance, transmission, and dissemination, in accordance with defined procedures. A systematic recognition of data and its organization has become the requirement of the day. The information needs for biodiversity are many and varied, and the state of knowledge is all too unsatisfactory for proper evaluation to be made (Heywood 1997). Hence, the modern technology now makes it possible for the management of this kind of biodiversity data using computer technology. An information system that provides knowledge about the biodiversity of the region, the conservation and management practices needed to sustain these resources is referred to as the Biodiversity Information System. The Sahyadri: Western Ghats Biodiversity Information System is developed with the aim to aid decision makers in conservation endeavour with the organised spatial information.

Western Ghats Biodiversity Information System : Objectives

The Sahyadri is a web interfaced Western Ghats Biodiversity Information system for the Western Ghats. Objectives of Sahyadri are

1. To collect and supply information on "Western Ghats and Biological Diversity"
2. Identification of information/data gaps in the specified subject areas and action taken to fill these gaps.
3. Web based database creation on "Ecology, Environment, Western Ghats and Biological Diversity"
4. To establish linkages with information users, carriers and providers from among government academia, business and Non Governmental Organisations (NGO's) including that with ENVIS.
5. To help India in fulfilling the norms of the Convention on Biological Diversity.

Biological Diversity

The 1992 Convention on Biodiversity, signed by 175 countries reflects the global consensus on the importance of biodiversity in maintaining the planet's life-sustaining systems. As the majority of countries have now signed the convention, these countries are committed to this convention and so is India. The convention explicitly recognizes that the conservation of biological diversity requires the development and implementation of national strategies and action plans (Article 6). In turn, development of these strategies and action plans require the development of improved mechanisms for information collection and management (Article 7), since without adequate information; it is difficult to develop effective strategies and action plans. In order for a country to comply fully with this article, it is necessary to inventory the organisms present within the regions. An inventory is a prerequisite for assessments of conservation status and sustainable utilization, and for prescribing appropriate actions. No country has a comprehensive species list for any of the species rich groups. The essential first step would be inventorying the organisms that have been selected as priorities. Article 7 of the CBD commits each party 'as far as possible and as appropriate' to identify components of biological diversity important for its conservation and sustainable use (UNEP, 1992). Data sources available fall into five categories:

i. Nomenclatures, or catalogues covering the literature of organism names including countries of origin and updating issues
ii. Checklists and biotas, that is a complimentary tool that provides a basis for full account of species.
iii. Reference collection, which provides the only verifiable source of accuracy of reports of particular species.
iv. Unpublished reports, such as field notes and records, reports degree.
v. Indigenous knowledge on biota, which had hardly been tapped; indigenous people may have particular knowledge of endangered species within the region which can improve the level of awareness of conservation biologists.

Hotspots are recognised on the basis of the presence of greatest number of endemic or restricted range species. Since the endemic speciesare found in restricted areas, often requiring special niche for survival, many of them, especially those with very restricted distribution, are extinction-prone, particularly if their habitats are disturbed. Hence, at the global level, the hotspots are areas of high conservation priority, because if unique species are lost they can never be replaced.

Biodiversity Information

The data and information regarding the biotic resources is distributed among several organizations and individuals, which makes it difficult to access information about them easily and efficiently. Chavan. et al (2004) discusses the importance of developing electronic catalogues of known life and reviews the global and national scenario. Baseline information of more than 93% of the known faunal species in India is documented in IndFauna, which is accessible at http://www.ncbi.org.in. The electronic catalogues would be effective in overcoming the taxonomic impediments as well as better sustainable use and conservation of biotic resources. This can be efficiently attained by taking the geographic boundaries into consideration, hence the need for the geographic information system (GIS). Salem, (2003) discusses the need for spatial biodiversity database, the application of GIS and its efficiency in locating the population of endangered species. The steps to results of a complete spatial database are listed with importance to data from Egypt on the endangered plant species of that region.

The diversity of any life on earth is governed by the genetic sequencing of the particular organism be it flora or fauna along with its relation to the environment. A biodiversity database system, which can integrate the spatial, taxonomical and genetic aspect of the resources would help enhance the prospects of conservationists and researchers. The BODHI: Bio-diversity Object Database architecture system (Srikantha et. Al, 2003) has a taxonomy model, genome model and spatial model with an object oriented database system intended for use in biodiversity applications.

The vastness of the biodiversity data has probed the way for different organizations to start many information systems, which serve the purpose of its own. Electronic cataloguing is done for the purpose of retrieval, spatial analysis and for various ecological analysis of the data available. Some of the comprehensive information system existing are

Integrated Taxonomic Information System	http://www.itis.usda.gov/
Species 2000	http: //www.sp2000.org/
ETI World Biodiversity Databases	http://www.eti.uva.nl/
Amphibiaweb	http://www.amphibiaweb.org//
Fishbase	http://www.fishbase.org
IndFauna	http://www.ncbi.org.in/biota/fauna/
International Plant Name Index	http://www.ipni.org/
International Legume Database and Information Service	http://www.ildis.com

There are many other information systems which deals with micro-organisms like the Bacterial Insight Orienting system (BIOS), Index Fungorum, The Universal Virus Database etc., The notable among the information systems are the ITIS and Species 2000. The ITIS contains the taxonomic information of flora and fauna from both aquatic and terrestrial habitats. The Species 2000 integrates 19 distributed database, including IT IS to collate baseline information on 308,000 species and 33,000 intraspecific taxa of plants and animals (Chavan et al 2004). World's leading marine scientists initiated Census of Marine Life (CoML) with the goal of developing detailed series of online atlases. Ocean Biogeographic Information System consists of scientific names and species list, which is accessible through the web. The heterogeneity of the global database available and the incompatibility among the database, led to the formation of Global Biodiversity Information Facility (http://www.GBIF.org) to promote and enhance the networking and interoperability.

Apart from the global level, efforts are being carried out in India for the electronic documentation of the diversity of Eastern and Western Ghats and the Himalayas. Several organizations have worked to bring out documents in the form of CD-ROM, Information System. Some of them are Sasya Sahyadri released by ATREE, Bangalore which gives the baseline information of plants in the Western Ghats. FRLHT, Bangalore, developed a database on medicinal plants, SACON, Coimbatore has developed a database on the birds of India and many other database are developed by Wildlife Institute of India, Dehradun, SRISTI (Society for Research and Initiatives for Sustainable Technologies and Institutions), Ahmedabad, French Institute of Pondicherry. All these database cover a particular group of species with a few attribute information which support the group. Hence as a part of Environmental Information System (ENVIS) of the Ministry of Environment and Forests, Government of India, the task has been taken up to bring out a comprehensive database for a specific area covering the complete biotic resource available with all the possible attributes.

Also, at present there is no single repository to provide information such as scientific names, common names occurrence of organisms, their spatial and temporal distribution and the bibliography. The need for this basic information system on Western Ghats hotspot diversity is there for the conservationists, researchers and taxonomists. Hence an information system was designed and implemented to collate existing information, bring it out to the public and try to conserve the diverse wealth in every way possible. In this regard, WGBIS with flora and fauna database provide the best approach to achieve the objective of the information system catalogues.

Architecture of WGBIS (Database Section)

The complex and interlinked biodiversity data and their dynamic nature pose many challenges for data management and networking. The encoding of biodiversity data collected from disparate sources such as geography, taxonomical and economically useful data is one of the challenging steps in data management. Therefore, it is necessary to set up a unique cost effective and easy to use information system. In addition, precision and ease in data entry is required to deal with the rigorous task of entering data. An effective data entry technique and data analysis method forms the basis for a comprehensive information system. The architecture of WGBIS is as shown in Figure 1.

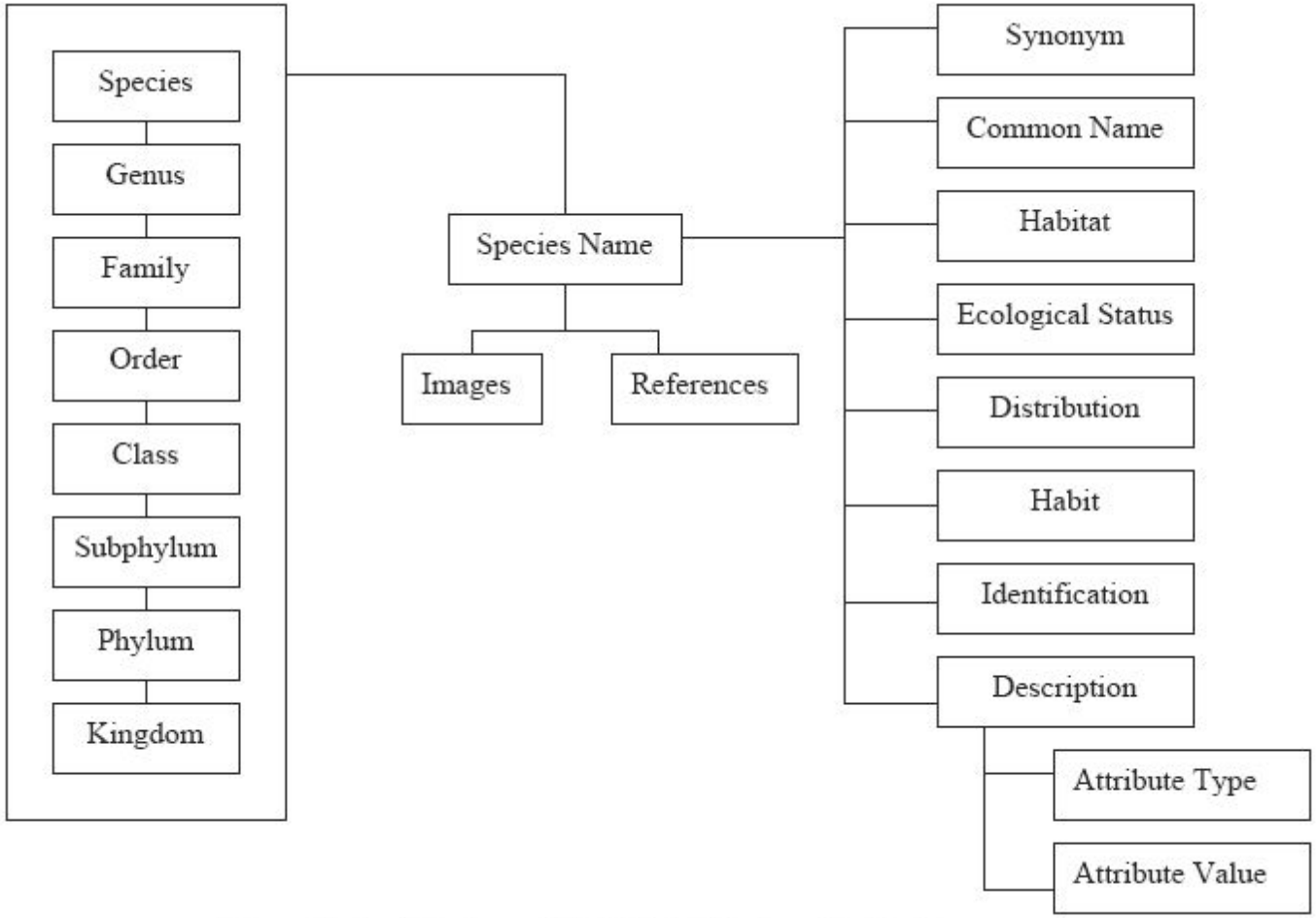

Figure 1: Architecture of WGBIS (Database Section)

Development of biodiversity database

The literature required for the creation of a database on flowering plants and fauna of Western Ghats is collected. The data collection forms the basis of the work. Data is compiled from the field studies and various secondary data sources like Books on Taxonomy, District Flora and Medicinal Plants. Publications of FRLHT (Foundation for Revitalization of Local Health Traditions, Bangalore), BSI (Botanical Survey of India, Coimbatore), IUCN (International Union for Conservation of Natural Resources), IFGTB (Institute of Forest Genetics and Tree Breeding), Coimbatore, KFRI (Kerala Forest Research Institute, Peechi). These ground truth verified data are organized to form a database on flowering plants.

The list of flowering plants in Western Ghats is collected from the publications of FRLHT. Another set of plant list is collected from IFGTB (from the list of folk medicines). Publications from KFRI provided a list of medicinal plants in Trissur District of Kerala.

IUCN publications provided information on the list of plants that are included in the Red Data Book. The IUCN categories for the ecological status of different plants are also noted. The books on taxonomy provided information on classification, description on each level of plant hierarchy. From the books on flora, information on the habitat, ecological status categorization according to the year of publication, the distribution of the plant, the description and habit of the plant, the synonyms and authorization were derived. The data on medicinal value, certain other uses of the plants and common names in different languages are got from various books, knowledge individuals and reports.

The data collected from each of these sources are compiled and a complete database, which could maintain and record the information, is designed.

The database is created in such a way that the data collected could be well organized. The database is designed keeping in mind all the possible information that can be got from various sources. The design is a comprehensive structure where data from the species hierarchy to its use has been compiled. The database is split up into number of normalized tables and normalization has been done up to the third normal form.

The relational database is created using the relational database management system. Assigning identification number for each record in the table gives the relationship. This number acts as the primary key of that particular table and forms the foreign key in the related table. In the same way relationship is identified between all the corresponding tables and the final species table is derived.

The data compiled from various sources and appended in the MySQL database in Linux platform with PHP interface GUI (Graphic User Interface). The decision support system on web server makes the database accessible to wider users across the globe (http://ces.iisc.ernet.in/biodiversity). Currently, the database consists of plant species, amphibians, butterflies, birds, etc.

The entity identification forms an important step in the creation of database. Based on the number of entities, the number of tables is decided and the relationships between the entities were derived. List of entities in the database :

Kingdom, Phylum, Sub-phylum, Class, Order, Family, Genus, Species

The taxonomy of plants forms a very important aspect, which has to be considered when the description or the identification of different plant species is taken into consideration. Botanists have grouped plants in number of ways and there are number of classification of plants in the present day taxonomy. The widely used classification is the Bentham and Hooker classification. But since many modifications and updating have been taking place in taxonomy level (order in modern classification is series in Bentham and Hooker classification), there are classifications, which are more specific and well organized. Keeping this in mind, the Modern Classification is followed for the flora database of Western Ghats.

The relationship of entities in the database is of the type 1: M (one-many relationship). That is one kingdom will have many phyla, one phylum will have many sub phyla and so on till species. The attributes for each entity are identified. After the identification of the entities, their relationships and the different attributes an entity relationship diagram (Fig. 2) can be obtained.

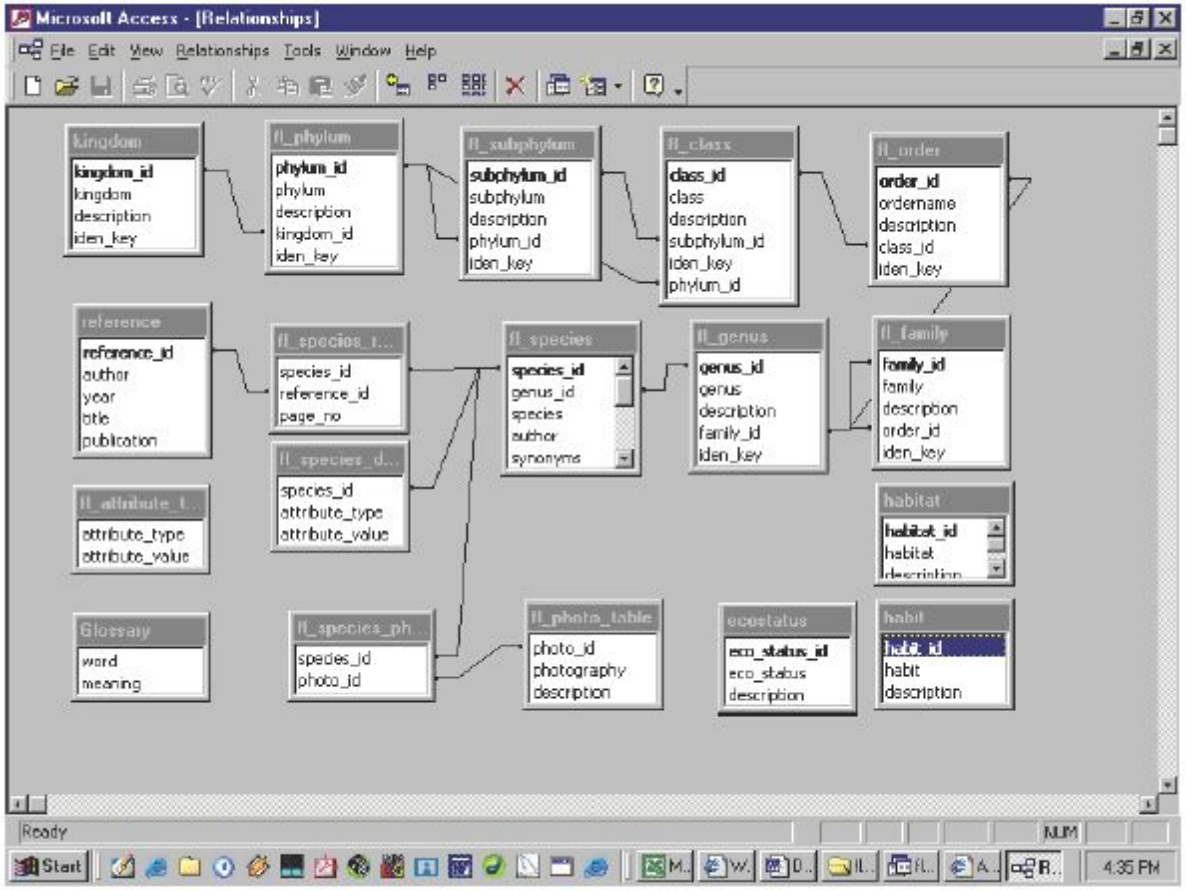

Figure 2: E-R Diagram of the entire database design

The information from different sources are compiled and sorted into the different relations. The data on different taxon, geographical and scientific information are fed to MySQL (My Structured Query Language) database and retrieval is done using PHP (Hypertext Preprocessor). Web page is developed using PHP. The web page consists of a species search and querying form, which answers to the query posted by the viewer with regard to the species description, taxonomy and spatial distribution and economic status. This page is accessible at
http://wgbis.ces.iisc.ernet.in/biodiversity/database/database.htm

Results

The different forms in the GUI (Graphic User Interface) are displayed below.

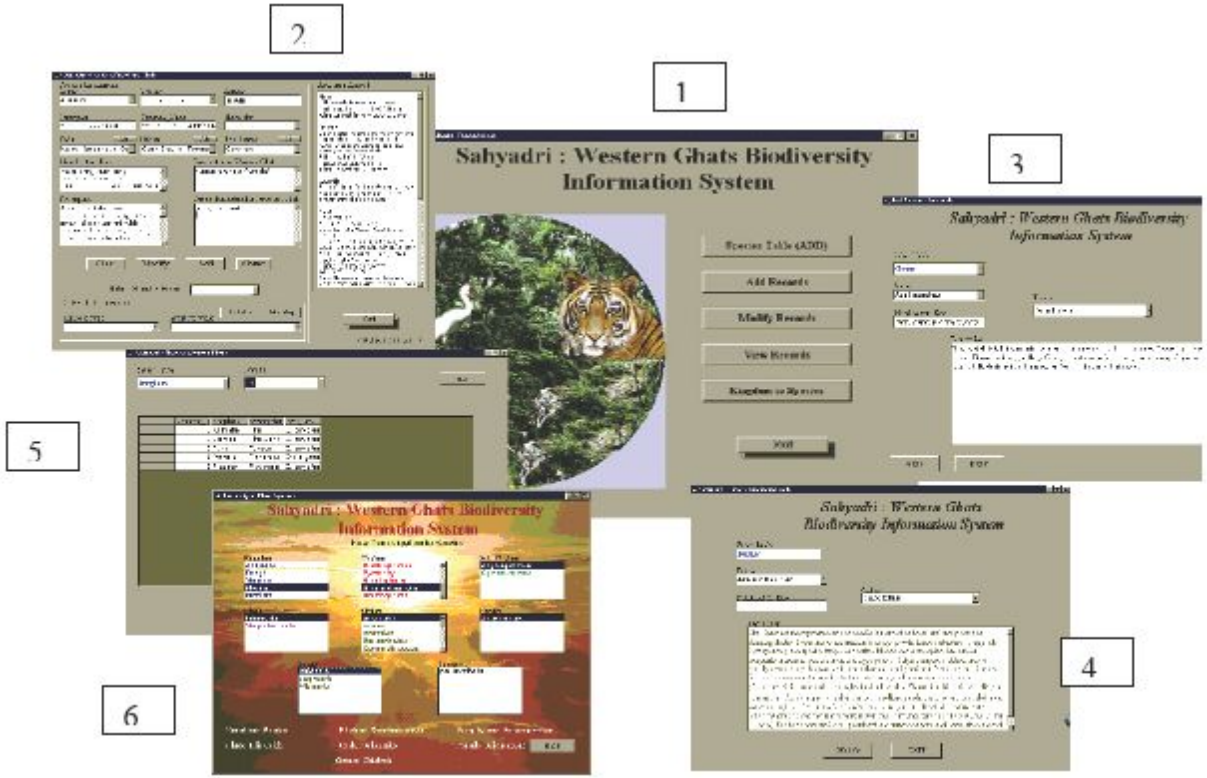

Figure 3: WGBIS Graphic User Interface

The screen 1 (Figure 3) is the main screen from which we can navigate through the entire front-end based on the purpose like add species or other records, view records, the hierarchy of the entire species, etc.

The screen 2 is used to add the species to the database. The attribute types and attribute values can be selected and then added to the database. The 'count' button gives the number of species added with all the attributes in the database.

The screen 3 is used to add the data into other tables in the database except the species table. The first name indicates the name of the taxon in the selected table, the second name gives the next higher taxon in the hierarchy.

The screen 4 is used to modify the data in the other tables except the species table. The data in the species table can be modified in the first form itself.

The screen 5 is used to browse the data present in the database.

The screen 6 is used to display the hierarchy from Kingdom to Species in a comprehensive manner.

The information in Sahyadri can be viewed by the user by navigating through the website
http://wgbis.ces.iisc.ernet.in/biodiversity/

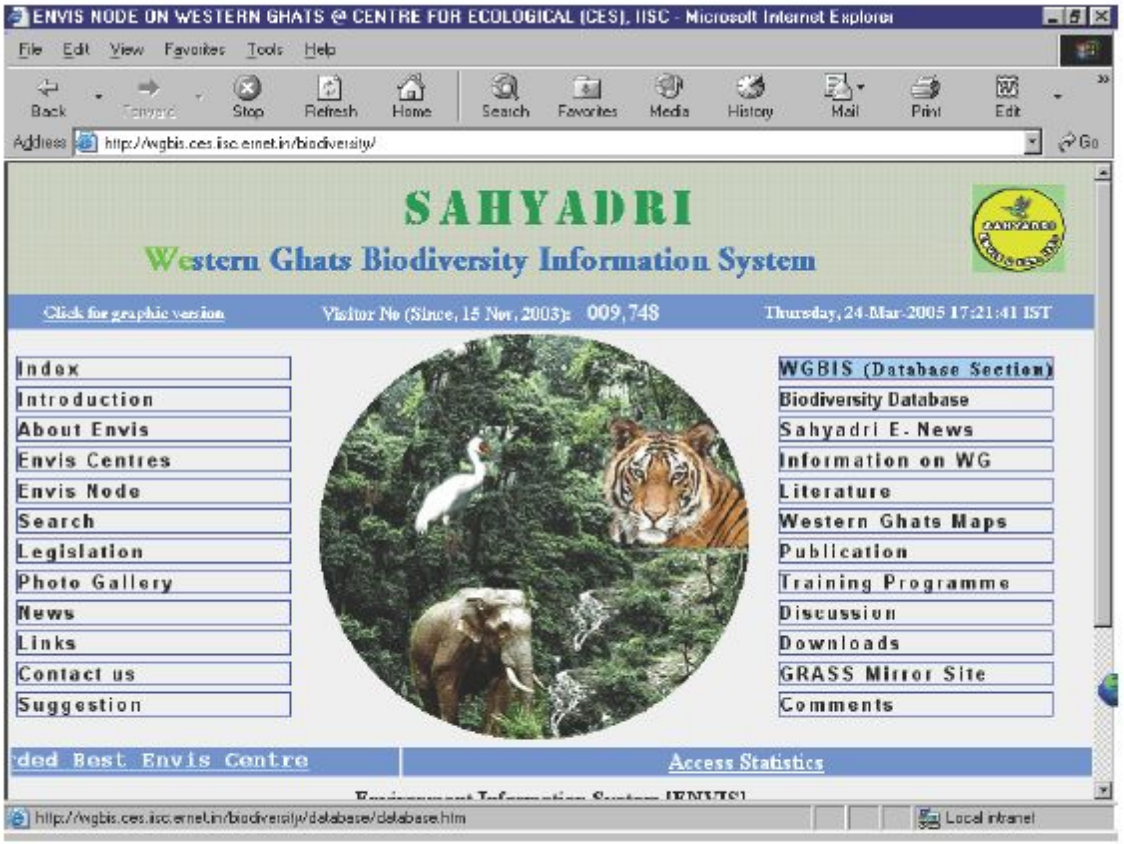

Figure 4: Sahyadri Web Page

Figure 4 is the Sahyadri web page, which helps the user to browse through the website. The important sections are the WGBIS – Database Section, Sahyadri E-news, Information on Western Ghats, Western Ghats Maps. The WGBIS database section (Figure 5) gives information on fauna, flora and the books on Western Ghats.

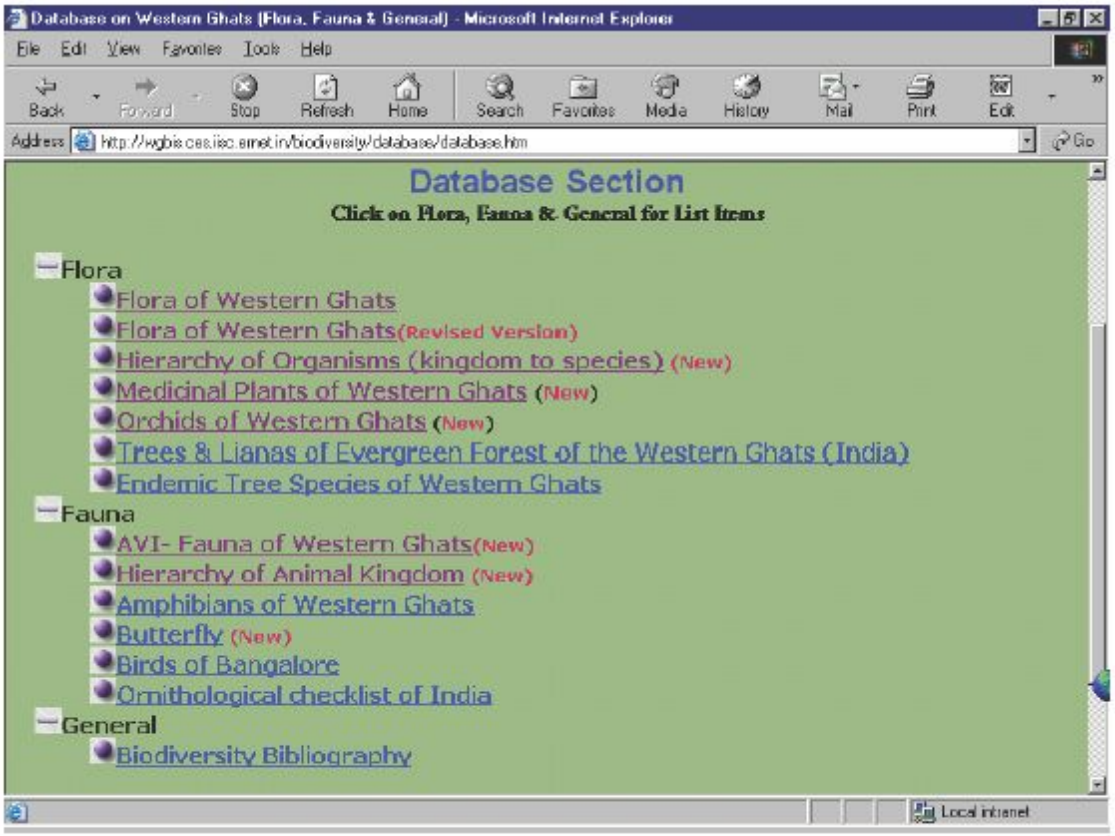

Figure 5: WGBIS Database Section

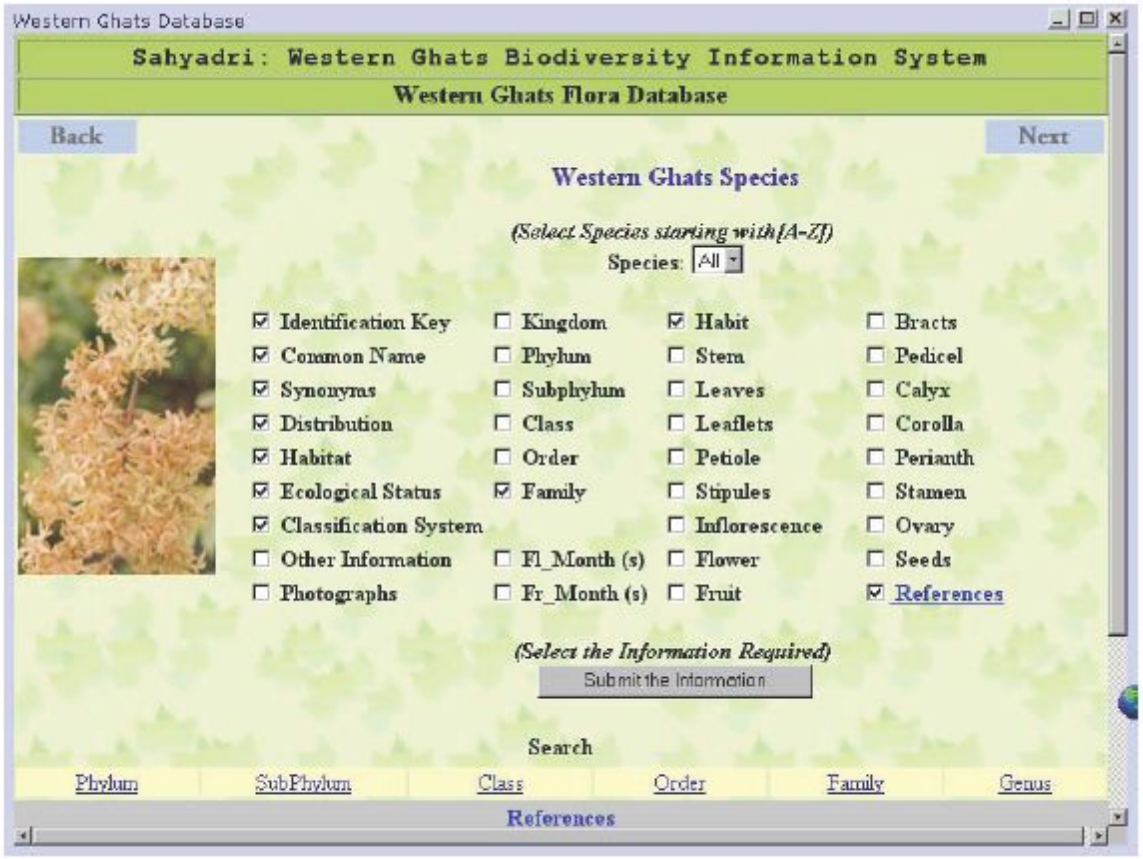

Figure 6: Attribute information accessible for each species

Figure 6 lists the attribute information that can be queried (Figure 7) for a particular species with taxonomical, spatial and attribute information.

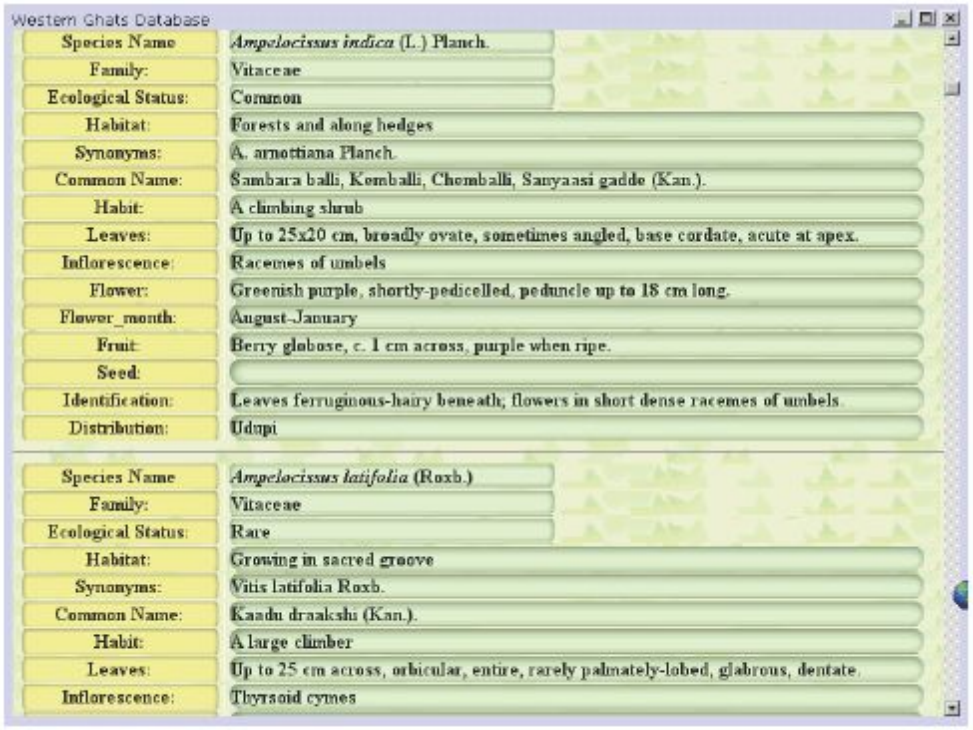

Figure 7: Typical Attribute Query output

Currently, 3500 flowering plants information can be retrieved from the Flora database which includes 266 species of orchids, 350 species of medicinal plants, 352 endemic tree species and a few monocots present in the Western Ghats. The Fauna database consists of information on 120 amphibians, 550 species of birds and 330 butterflies present in the region.

Conclusion

The Biodiversity Act, 1999 emphasizes on the conservation of biodiversity rich areas especially, in the developing countries. And for a country like India, which is diverse with all variety of flora and fauna, conservation of natural wealth becomes a priority in the urban sprawl. The International Convention on Biological Diversity obliges all parties, including India to prepare an inventory and monitor biodiversity and make all attempts to conserve these resources. This enormous task is not possible only by ground survey and research. The Global Biodiversity Assessment (UNEP, 1995) recommends that such assessment requires a detailed knowledge of species distribution in particular landscapes. This can be achieved by the use of remote sensing data, field surveys and by creating a spatial database.

Biodiversity information system gives specific information of the species and area to be conserved. This paper focuses on Western Ghats (Biodiversity hotspot of the country) for its enormous amount of floral wealth. The value of which is more or less to a large extent restricted to experts in the field and to the traditional folks. The diversity of medicinal wealth, in this area is still in the hands of the traditional folk medicinal practitioners. This endeavor is an initial attempt to bring out the enormous amount of floral wealth available in area, their distribution and their value for human life and Indian economy. The database also tries to emphasize on the species that are endangered due to their over exploitation. These species require immediate conservation strategies to be employed for their sustenance.

Through the database and the other section in the information system an attempt has been made to help the botanists and biotechnologists to identify the species, to do further research for the sustainability of genetic traits and for exploring more on the chemical composition of the species medicinal properties. Further using the data GIS analysis like habitat-wise species distribution can be carried out for widely used species, endangered species, economically important species etc.

The spatial database created and the information system as a whole for ecologically and biologically rich areas and on important species would surely add to the conservation endeavor to ensure the sustainability of nature's wealth for future.

Acknowledgments

We thank the Environmental Information (EI) section at the Ministry of Environment and Forests, Government of India for the financial assistance. The sustained financial assistance over the last decade has helped in inventorying, mapping of biological resources as well as design of a very robust Environmental Information System (ENVIS).

ENVIS webpage (http://ces.iisc.ernet.in/hpg/envis) is auto updated every day and receives the highest hits (visitors) every day. This endeavour is recognised with the **'Best ENVIS Centre'** award for the year 2004 by the Ministry of Environment and Forests.

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Western Ghats Biodiversity Information System:

RESULTS

FIGURES

PDF **HOME**

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