Integrated biodiversity research for India

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As we reach the turn of the present century, we find that the cumulative impacts of industrial civilization have jeopardized the future of a large number of species, leading to mass extinction[1]. The causes for this major catastrophe are: habitat loss and fragmentation, unplanned introduction of exotic species, over-exploitation of plant and animal resources, pollution of soil, water and atmosphere, and the possible global climate change. Today we are losing at least one higher-plant species per day from tropical forests alone. If the present trend continues, about 25% of the total 250,000 higher-plant species will be lost in the next few decades and another 25% by the end of the twenty-first century[2]. Further, we can expect the demise of 20–60 animal species per plant species lost. Worldwide, about 492 genetically distinct populations of tree species are endangered[3]. At least five major mass extinctions have occurred in the past. The two most serious were those occurring at the end-Permian (245 myr ago) and end-Cretaceous (65 myr ago) when 96–76% species of marine animals were lost[4]. The end-Cretaceous extinction is also estimated to have removed more than 50% of plant species and may have played a pivotal role in structuring the Cenozoic flora[4]. While the past extinctions occurred each time over a span of a million years or less, the present mass extinction may well occur within a short period of about 200 years. Biotic recoveries after mass extinctions are known to have occurred[5] and there is no reason why this will not occur after the present anticipated mass extinction. The prospects of recovery have little practical value; however, because calculations based on the recovery period in the prehistoric past suggest that the time required will be at least 5 million years, or possibly several times longer. If the present mass extinction is allowed to proceed, the recovery may need a period equivalent to 20 times over the period of human tenancy of this planet[2].

Biological diversity is the very basis of human survival and economic well-being as it provides food, medicine and industrial raw materials, and offers a potential for providing many more yet-unknown benefits to future generations. Species and their population contain precious 'genetic library' maintained by natural ecosystems. The number of genes ranges from about 1,000 in bacteria and 10,000 in some fungi to 400,000 or more in many flowering plants and a few animals[6]. Biodiversity among organisms arises from variations in the sequence of their DNA and from their adaptive response to the environment. The amount of genetic diversity found within species is important as it is the ultimate source of biodiversity at higher levels, is the major determinant of successful species response to disturbances, and determines the species potential for subsequent evolutionary change[7]. Biodiversity is thus linked with the sustainability of ecosystems. In view of growing threat to biological diversity it is important to learn how natural communities/ecosystems are affected by progressive erosion of biological diversity.

The present communication highlights the current concern about biodiversity and proposes a research programme for India.

Global concern

There is a conspicuous lack of information on the magnitude and functional role of biodiversity. Of the 30 million or more species thought to be occurring on the earth, only 1.4 million have so far been named and described. Biologists have noted the marked unevenness in global distribution of species diversity and have raised several hypotheses to account for the apparent gradients with respect to latitude, elevation, disturbance and succession (see ref. 5 for a review). The International Union of Biological Sciences (IUBS) became interested in biological diversity in 1983 through 'species diversity and its significance in tropical ecosystems' under the 'Decade of the Tropics' programme. A resolution to undertake a feasibility study for launching a biodiversity research programme was adopted by the IUBS Canberra Assembly in 1988. IUBS-SCOPE jointly organized a Workshop on Ecosystem Function of Biological Diversity at Washington, USA in 1989 which again emphasized the need for biodiversity research. In 1991, IUBS, SCOPE and UNESCO jointly organized another Workshop 'From genes to ecosystems: a research agenda for biodiversity', and the proceedings edited by O. T. Solbrig have been published recently by IUBS[8]. During the IUBS Assembly in Amsterdam another symposium was organized on biological diversity and global change, and the programme 'Ecosystem function of biodiversity' developed by IUBS, SCOPE, UNESCO and IUMS was included in the 'Options for agenda 21' prepared by the Preparatory Committee of the UN Conference on Environment and Development for the Rio de Janeiro Conference. This programme, baptized *Diversitas*, has three major areas: Ecosystem function of biodiversity, origin, loss and maintenance of biodiversity and inventorying and monitoring of biodiversity[9].

Over 155 countries including India have signed the convention on biological diversity adopted at the Earth Summit in Rio de Janeiro. The convention establishes commitments on conservation, access to genetic resources, transfer of technology and benefit sharing and finance that are likely to make it an extremely important instrument for the conservation and sustainable use of all components of biological diversity. Article 7 of the convention obliges each party as far as possible and as appropriate, to identify components of biological diversity important for its conservation and sustainable use, to monitor through sampling and other techniques, the components of biological diversity so identified and to identify processes responsible for significant adverse impacts on the biological diversity and monitor their effects. Because we are now party to this International Convention, and even otherwise, it is our obligation to protect and safeguard the biodiversity for posterity

Indian scenario

India is a vast country with a rich diversity of biotic resources. India's biodiversity is largely due to a varied physical environment – latitude, longitude, altitude, geology and climate[10]. The geographical area of India is 329 million ha and its coastline stretches to 7,000 km. Almost all shades of climate from hottest Thar desert to arctic in the Himalaya with all intermediate gradations occur. The rainfall varies from about 100 mm in Thar desert to over 5,000 mm at Cherrapunji in Meghalaya. Though the area of the country is only 2% of the world land mass it has over 5% of all known species of plants and animals. Botanical and zoological survey organizations have done commendable work in cataloging vascular plants and animal resources. Being a mega-diversity zone where almost all the biogeographic regions are represented, India harbours about 45,000 species of plants[11] and 65,000 species of animals[12]. Western Ghats, Andaman and Nicobar Islands, Himalaya, North East India and the wetlands in general, including river valleys are locations of special significance. These areas have high species diversity and have high levels of endemism. Western Ghats alone have 1800 plants, 16 birds, 6 mammals, 77 reptiles and 84 endemic amphibians[13]. The Nilgiri Biosphere Reserve which accounts for 0.15% of India's land area harbours 20% of all angiosperm species, 15% of all butterflies and 23% of all vertebrates (excluding the marine species) known from India[14].

To meet the challenges of providing basic human needs in view of land degradation, pest and pathogen epidemics and abiotic stresses like salinity, drought, etc., plant breeders need primitive cultivars and wild relatives of cultivated plants. The Indian subcontinent has centres of origin and diversity of more than 20 major agri-horticultural crops, and has a large number of endemic species and over 800 species of ethnobotanical interest[15]. The National Bureau of Plant Genetic Resources (NBPGR) is entrusted with explorations and *ex situ* conservation of genetic variability of cultivated plants and their wild relatives. These efforts are important but have to be supplemented by *in situ* conservation of wild relatives of cultivated plants. This requires identification and close monitoring of important centres of high biodiversity having wild progenators of cultivated plants.

Our biotic resources are under increasing pressure for a variety of reasons. Important among them are population pressure, changing land use, soil erosion, desertification, land degradation, acid rain, growing pollution of air, water and soil and greenhouse effect syndrome. More than half of the landmass of the country is degraded in some way; out of 143 million hectares of agricultural land 56% is degraded due to bad agricultural practices[16], and now dense forest cover has been reduced to only 11% of the geographical area[17]. Ambient SO_2 levels in the industrialized Gangetic Plains are now similar to those of the industrialized regions of Europe and the north eastern US[18]. It is feared that 15–20% (i.e. over 2500 species) of the total vascular flora of India now fall in one or the other category of threatened species[11], and animal species are estimated to be disappearing at the rate of one species or more per year[12]. BSI has brought out 3 volumes of Red Data Book[19–21]. However, information on species abundances and their functional attributes is altogether lacking. The task is more difficult for microbes which provide the basis for functional stability of ecosystems. There is an urgent need to (i) quantify the effect of the above factors on species diversity and ecosystem functions, (ii) assess the level of existing biodiversity, and (iii) determine how different ecosystems respond to human disturbance. Studies are needed for developing scientific basis for identifying priorities in conservation of ecosystems and habitats, species and communities, and genomes and genes of significance, as required by the Convention on Biodiversity. Bawa[22] has rightly urged the Indian biologists to take up in-depth study of biodiversity.

Basic questions

The current level of information on biodiversity raises many fundamental questions. Some are:

(i) How is the biodiversity distributed in different biogeographic regions of India?, what conditions lead to hyper diversity (hotspots), and to what extent do peaks in biodiversity of different taxonomic groups coincide?

(ii) Can more and more species be packed into a community, or are there upper and lower limits?, what are the optimal levels of diversity and what are the factors that control them?, and how is number of species related with number of biotic interactions in a community?

(iii) In ecosystems in which there are many species but only a few dominants, what is the role of rare species?, what is the role of biodiversity in ecological processes, such as water and nutrient cycling, energy flow, soil formation, etc?, are diverse ecosystems with complex food webs more productive and/or stable than simple ecosystems?, and is there a threshold below which the present complex ecosystems lose their stability?

(iv) What is the relationship between levels of disturbance and biodiversity?, what is the impact of protecting an area to preserve a spectacular wildlife species on biodiversity of the ecosystem?, and what is the relation between loss of habitat area and species disappearance?

(v) What is the effect of habitat fragmentation on species ranges and on the probability of disappearance and speciation?, whether fragmented habitats are more prone to invasion?, how invasion and introduction of alien species influences biodiversity?, and what is the effect of increased geographical isolation on population and species?

(vi) What will be the effect of global climate change on biodiversity?, how can the threats posed by climatic change to biodiversity of natural ecosystems be mitigated?

Many ecosystems have species whose loss would cause a greater than average change in populations of other species or ecosystem function. These are 'keystone' species. One important aspect of a biodiversity study is identification of these 'keystone' species for various ecosystems and the ways by which these species influence the biodiversity function. We do not know what molecular parameters enable a microbial species to become a keystone species in the soil system.

Objectives

Biodiversity problems deserve immediate attention on two counts: (i) the need to conserve and prevent further loss of biodiversity, and (ii) to generate concrete knowledge of biotic diversity in the absence of which effective conservation of plant and animal resources is impossible. Therefore, a vigorous research programme to quantify, conserve and utilize the biodiversity wealth is long overdue. In the present paper we, however, limit the research programme to quantification of biodiversity with the following major objectives:

(i) To quantify levels of biological diversity at species, community, ecosystem and landscape levels in different biogeographic regions of India.

(ii) To identify keystone species in different ecosystems and to assess their role in sustaining biodiversity.

(iii) To examine the relationships between diversities of different taxonomic groups in different habitats, and to identify indicator groups.

(iv) To evaluate the patterns of biological diversity and their role in ecosystem functioning (e.g. productivity, stability).

(v) To evaluate the potential effect of global change on biodiversity and to identify threatened genetic populations/species/ecosystems.

Basic research approach

In order to meet the above objectives the biodiversity research has to be a multidisciplinary effort. It should have bias on ecology and taxonomy but investigations have to include fundamental genetic, morphological, physiological, and behavioral properties of key organisms. Information not only on quality but on quantity (species abundances) and species interactions is needed. Even to predict species loss, information on the rate of habitat loss, shape of the species-area curve, and the absolute number of species is required. The overall study has to be framed in holistic concept since complex interactions among taxa are implicated in determining biodiversity at specific locations.

A geographic information system (GIS) with statistical and analytical capabilities needs to be developed. Measures that are indicative of diversity and are more easily obtained must be used For example, satellites can detect standing biomass and productivity, and research can help to establish the relationship between biodiversity and these measures.

Broad strategies for the measurement of biodiversity at different levels include (see ref. 8 also) (i) Species level: Protein and DNA polymorphism, and analysis of restriction fragment length polymorphism (RFLP) and highly variable nuclear genes (including DNA fingerprinting), application of newly developed technique of *in-vitro* DNA amplification known as the polymerase chain reaction (PCR), are important in documenting the extent and pattern of genetic variation in a population. (ii) Community level: Measurements of species richness and evenness or dominance are needed for ecological analyses of diversity. Role of different populations of individual species contributing to the biodiversity of the community needs to be examined. (iii) Ecosystem level: There is a need to look for patterns in the interactions of organisms and their environmental milieu which manifest in fluxes of matter, energy and genetic information, and (iv) Landscape level: The landscape diversity can be measured using the approaches of pattern diversity and mosaic diversity[23]. Pattern diversity, is 'a measure of the relative arrangement of subunits within an ecological unit, such as communities in a landscape'. Compositional pattern diversity is measured as mosaic diversity using affinity analysis. Mosaic diversity measures landscape complexity and is a function of two properties of species patterns: the variation in species richness among communities and variation in commonness or rarity among species (evenness).

Study design

Our suggested approach is to divide the country into regions to sample biodiversity patterns in different areas. For this purpose, to begin with, classification of 10 biogeographical zones proposed by the Wildlife Institute of India (WII) can be utilized[24]. Initially a few contrasting ecoregions representing diverse environmental conditions, and ranging from wetlands to forests need to be selected. The regions deserving priority attention are: Western Ghat Mountains, Upper Gangetic Plains, East Himalaya, Andaman and Nicobar Islands, West Himalaya, Central Highlands, and Hot Desert of Kutch.

Study design for each of the selected eco-region should include permanent sites with proper replication for intensive data collection at all levels. A complementary set of sites for extensive studies only on selected focal taxa/guilds is also required[25]. Sites should be selected along measurable environmental gradients such as biotic disturbance, rainfall and elevation so that relationship between diversity and environment can be examined. Some of these sites can be identified for long-term monitoring particularly of focal groups, to keep track of changes in biodiversity. The existing protected area network can offer some attractive sites to mount the programme. Selection of standard sampling methods should be made at a workshop of experts. The workshop may be organized at the beginning of the programme to prepare a document containing recommendations for sample size, appropriate research methodology and parameters to be quantified. It may be necessary to launch a pilot study in a selected ecoregion for standardization of sampling techniques and for creating a critical group of trained manpower Other biogeographic regions can be covered speedily in the next phase.

Expected output

This research effort should try to give a theory and relevance of biodiversity for India's sustainable development. A GIS-based map of regional distribution of biological diversity may be generated Identification of indicators for pragmatic monitoring of biodiversity should be one of the major outputs of this study. The proposed study should provide capability of predicting changes in biodiversity in response to environmental stresses. Study results should be expected to build up reliable base line information which can be of immense value to policy makers in taking informed decisions in developmental context.

Constraint

Shortage of expertise in the area of taxonomy is a major problem. There is also a lack of specialists for many important groups of organisms The problem is not unique to India. The world distribution of biologists (which reflects the world distribution of economic wealth) is such that areas supremely rich in species content have comparatively few endemic biologists[26] Manpower training for building indigenous expertise is therefore important for the success of biodiversity research programme Taxonomists alone, however, cannot tackle the diverse issues related to biodiversity A collaborative effort by many kinds of biologists, including ecologists, geneticists, and physiologists is required and therefore training has to be multifaceted in order to develop a transdisciplinary approach for carrying out integrated biodiversity studies. One solution is to create centres groups specialized in inventorying and quantifying biodiversity at all levels A greater interaction among survey organisations and such centres in universities is needed.

Initially the quantitative biodiversity research will be costly. Perhaps the Departments of Science and Technology, Environment and Forests, and Biotechnology can pool the resources to provide a joint umbrella for these studies. The Global Environment Facility may also be tapped for financial resources

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COMMENTARY

Foundation science and technology education

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In the middle of this century, the two science courses offered to students of arts at the high-school level were: (i) elementary physiology and hygiene and (ii) everyday science. Then the bifurcation into arts and science, and even further into 'pure' science and biology, used to take place just after the middle school, i.e. class VIII. The system was given up in the early eighties; now the students study history and geography along with physics and biology up to class X. At the plus-two stage (i.e. the higher secondary or advanced level) they begin to specialize in a few subjects – three, four or five: they can for instance, study geography and economics, politics and history along with a selection of science subjects.

The emphasis is now generally on familiarity with a broad range of fields rather than specialization in a narrow area. This has many advantages. The school prepares the student to correlate different areas of knowledge after one has specialized in a particular subject.

The philosophy of broad-base education has been accepted by the Indira Gandhi National Open University (IGNOU) even at the tertiary level. In contrast to many universities, where they do not teach any language to their