Future of systematics and biodiversity research in India: Need for a National Consortium and National Agenda for systematic biology research

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In spite of having a good network of R&D establishments, national and international policy framework, adequate natural and human resource wealth and advancements in biotechnology and information technology, India's achievements in biodiversity and related areas of research are not very promising. Lack of coordination and integrated efforts, reluctance to accept and support basic science disciplines like systematics and lack of collective vision and common agenda for tackling complex research and development issues are seen as some of the inherent weaknesses of our R&D systems, particularly of systematic biology research. The article examines the problems of systematic biology research and suggests to evolve a national mechanism to coordinate all ongoing and future research in systematics and taxonomy and to integrate it to meet the national goals of inventory, conservation, prospecting and sustainable use of biodiversity resources of our country. A proposal to set up a National Consortium and National Agenda for systematic biology research in India is also mooted.

THE dawn of the new millennium beckons the entire humanity into an era of unprecedented challenges from the order of the survival of the fittest to the survival of everything to the fittest level. While the millennium celebrations present us a euphoria of the tremendous scientific and technological achievements during the latter half of the last century, especially in the frontier areas of biotechnology, molecular genetics, atomic energy, space research and instrumentation and information technologies, it still keeps haunting us that we are living amidst several irreversible environmental catastrophes, the most pressing one of which is the unprecedented loss of biodiversity on earth.

Every time we read through a scientific report or a news column concerning global environment or biological conservation, we are reminded of the unabated loss of biodiversity happening throughout the world. It is predicted that about half of the estimated 13.6 million species on earth (conservative estimate) may become extinct by the year 2050, unless we take appropriate measures to save them[1–3]. The manifestations of the current biodiversity crisis also include the disappearance of many populations of the surviving species, depletion of genetic diversity of crop plants, domesticated animals and their innumerable wild relatives and fragmentation, degradation or destruction of several unique habitats and ecosystems (e.g. tropical rainforests, coral reefs, wetlands, etc.).

Recently over 5000 botanists from 85 countries, who attended the XVI International Botanical Congress at St. Louis, USA in August 1999, noted in a resolution that two-thirds of the world's plant species are in danger of extinction and that a new coordinating body associated with the United Nations (UN) be established to monitor the status of plants throughout the world, to detect those most in danger, and to take steps to conserve them in nature, in botanic gardens or in gene banks or preferably by a combination of these strategies[4]. Responding to this Congress resolution, an ad-hoc group drawn from major international and national institutions and other bodies involved in biodiversity conservation from 14 countries came together in Gran Canaria, Spain in April 2000 to consider the need for a global initiative for plant conservation. (The senior author of this article participated in this meeting as an expert representing the Asian region.) The group resolved that the creation of a Global Strategy for Plant Conservation and associated programme for its implementation should be urgently undertaken, within the context of the UN's Convention on Biological Diversity (CBD). The aim of this strategic programme would be to support and facilitate an appropriate plant conservation initiative at all levels, and to halt the continued loss of plant diversity. The group also stressed that this strategy

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should link existing efforts of relevant programmes such as DIVERSITAS, the UNESCO's Man and the Biosphere Programme (MAB), the Millennium Assessment of the World's Ecosystems, the International Agenda for Botanic Gardens in Conservation, and IUCN's Species Survival Commission's Plant Programmes, and should draw on the experience and resources of bodies undertaking the implementation of appropriate international mechanisms and instruments, including the FAO Global Plan of Action[5].

One of the main elements included in the proposed Global Strategy for Plant Conservation is to achieve comprehensive documentation of plant diversity of the world by way of preparing Floras and detailed accounts of plants of all regions, and developing an integrated interactive information system on distribution of plant diversity in the wild, its conservation status and trends, and its use and preservation in protected areas and *ex situ* collections. This indeed is a timely initiative, and similar global strategies to document faunal and microbial diversity are required to be carried out urgently. Such action programme could help countries to take stock of their biological resources and assess their status, values and potentials for conservation and sustainable use. Achieving national level inventory and creating a database on biodiversity are important facets in systematic biology research. And this would inevitably demand the knowledge and expertise of professional cadres of taxonomists who are well trained to identify, name and classify the diversity of living organisms on earth.

Systematic biologists and the biodiversity challenge

One of the foremost challenges faced by conservation biologists, in general and systematic biologists, in particular is completing the inventory of the world's biodiversity and its various components before they are lost forever. This indeed is an uphill task in terms of – what Michael E. Soule[6] has pointed out as – the unsuspected vastness of biodiversity and its current vulnerability, particularly in the tropical regions of the world. And what is far more startling is the fact that during the past 300 years of their research, systematic biologists have been able to identify, classify and catalogue only about 1.75 million species, i.e. nearly 13% of the minimum estimated world total of 13.6 million species of plants, animals, fungi and microorganisms[7,8].

The task ahead is therefore enormous and systematic biologists have to play a pivotal role in expediently executing the mission of biodiversity inventorying and monitoring. The overriding importance of systematics and its creative role in fulfilling the emerging needs of science and society have never been realized so greatly as at this particular point of time[9]. The fundamental and all-embracing nature of systematics will become far more evident by its increased use and application in almost every field of biology and biodiversity research. Systematic studies are becoming increasingly relevant in the following priority areas:

- Inventorying and monitoring biodiversity
- Biogeography, evolutionary biology and 'hot spot' analysis
- Mapping biodiversity
- In situ and ex situ conservation of biodiversity
- Prospecting and economic valuation of biodiversity
- Ethnobiology – Documentation of indigenous knowledge associated with biodiversity use and conservation
- Conservation biology of ecologically important and threat-prone species and fragile ecosystems; population biology, reproductive ecology and conservation genetics
- Community and ecosystem dynamics
- Study on demography, population and community ecology of indicator taxa, keystone mutualists, flagship species, umbrella species, etc.
- Chemosystematics – Identification of potential biodynamic compounds in plants, animals, fungi and microbes for biochemical, pharmaceutical and drug prospecting; resolving taxonomic disputes and evolving creative classification systems using chemistry as a tool
- Molecular systematics – Multidisciplinary characterization of biological and genetic resources at biochemical, cytological and molecular level; identification of potential genotypes of economic and other interest; conservation of genes and nucleotides in DNA libraries
- Cladistics and phylogenetic assays
- Environmental impact assessment
- Biomodelling and bioenergetics
- Bioinformatics

In spite of the importance attached to systematics in biodiversity research and related developmental activities, this science is not getting adequate attention, acceptance and support, nationally and globally. There are many reasons attributed to the present plight of systematic biology research in general and the classical or alpha taxonomy in particular. Instead of getting into a thread-bare analysis of the plausible reasons for the general decline of systematics, it would be prudent if we ponder over the following questions: (1) Why do systematic biologists fail to take the science of systematics to the forefront as a 'crisis management discipline', especially in view of the gigantic task of completing biological inventories of major biomes in the world, particularly tropical forests? (2) Why do governments/institutions fail to support systematic biology research, both classical and modern, through adequate capacity-building processes and infrastructure development? (3) Why does systematics fail to attract universities and young talented researchers at a time when the world requires more trained taxonomists to

fulfill the mandates of inventorying and monitoring biodiversity resources? (4) What is the functional status and present profile of the premier taxonomic research centres in the world, particularly in the biodiversity-rich tropical developing countries, including India? (5) How do systematic biologists respond to the ongoing decline or neglect of systematics, and what strategies are they planning to revive the practice of systematics and thereby provide new dimensions to biodiversity research?

Attempts to answer questions 1 to 4 would perhaps lead us to examine the very nature of the science of systematics itself, and to find its chequered history of evolution from the traditional Linnaean system to the modern age of molecular systematics. Perhaps there is no other discipline in biology which is so subjective as systematics. This high subjectivity has pushed systematics through endless processes of conceptualization and theoritization, leading to the genesis of prolific 'species concepts' and divergent schools of sub-disciplines like biosystematics, experimental taxonomy, chemosystematics, cytotaxonomy, mathematical or numerical taxonomy, cladistics and molecular systematics. In this process of diversification and in the quest of establishing academic credentials of each school's theories and practices, systematic biologists appear to have deviated from the ultimate goals and objectives of alpha or classical taxonomy, i.e. inventorying biodiversity on earth. Systematic biologists have also failed to impress upon the scientific community and the governments about the creative role and potentials of classical taxonomy in comprehending the current crises of environmental degradation and biological extinctions. Lack of coordination, inability to make use of the tools of other emerging sciences, particularly information technology tools, failure to create better job opportunities, and inadequate training and capacity-building programmes have caused further decline of systematics and taxonomic researches, particularly in the developing countries like India. Consequently, systematics has been relegated to an 'esoteric science' or 'hard-core taxonomy', and is now virtually overtaken by other emerging disciplines like genomics and molecular biology.

However, with the coming into force of CBD and launching of new international initiatives like DIVERSITAS[10], Systematics Agenda 2000 (ref. 11) and several national programmes in the line of Mexico's CONABIO[12], Australia's ERIN[13], etc. the thrust now is on the revival of alpha or classical taxonomy and its application, particularly in biodiversity inventorying and monitoring.

Systematics and biodiversity research in India

India has a reasonably good institutional set-up for biodiversity research. A host of institutions administered under the Ministry of Environment and Forests (MoEF), Department of Science and Technology (DST), Department of Biotechnology (DBT), Department of Space (DOS), Indian Council of Agricultural Research (ICAR), Council of Scientific and Industrial Research (CSIR), universities under the network of the University Grants Commission (UGC), science, technology and environment departments in various states, non-governmental organizations like Bombay Natural History Society (BNHS), M.S. Swaminathan Research Foundation (MSSRF), Tata Energy Research Institute (TERI), Foundation for Revitalization of Local Health Traditions (FRLHT), World Wildlife Fund for Nature (WWF-India), etc. are currently involved in diverse fields of research and development on India's biodiversity. The broad spectrum of R&D pursued at these centres includes systematics and taxonomy, biogeography, biodiversity conservation, biotechnology, bioprospecting, bioinformatics, biosafety and environmental education.

Our attempt here is not to provide an extensive review of the current status or overall progress of the ongoing R&D efforts on biodiversity. But our immediate concern is to take stock of the existing institutional framework, current trends and prospects of research on the most pertinent aspects of systematics and taxonomy that are relevant to inventorying, mapping and monitoring biodiversity and its various biological and spatial elements for long-term conservation, management and sustainable utilization.

Biodiversity inventorying and monitoring in India

Inventorying and monitoring[14] of biodiversity has been one of the priority areas of research pursued at the three premier survey organizations of our country, viz. Botanical Survey of India (BSI), Zoological Survey of India (ZSI) and Forest Survey of India, and other institutions like Central Marine Fisheries Research Institute (CMFRI), National Institute of Oceanography (NIO), Wildlife Institute of India (WII). The Bioinformatics Cell of NBRI with the support of CSIR and DBT is developing a value added multimedia web-based database (plants-of-india.org) on plant genetics resources of India.

Organized efforts by BSI, since its inception in 1890 (reorganized in 1957) have resulted in botanical exploration and inventorying of about 60% of the geographical extent of our country, whereas faunistic surveys undertaken under the aegis of ZSI (founded in 1916) have so far covered about 35% of India's geographical area. This indicates that a sizeable area, covering several unique wilderness sites, both in our protected and non-protected systems, 'hot spots', the unknown and unexplored canopies of tropical rain forests, wetlands, coral reefs, etc. still remains under- or unexplored. So far systematists have identified, catalogued and classified about 126,565 species of plants, animals, fungi and micro-organisms from

different biogeographic zones of India. Extrapolations, however, indicate that further explorations and intensive systematic studies could lead to the discovery of another 4,00,000 species from India.

It may be noted that the focus of all our past and present programmes of systematic research has been on a few target groups of higher taxonomic orders like vascular plants, birds, mammals, reptiles, fishes, etc. The lower plant kingdom, micro-organisms, lower invertebrates, including insects and arthropods, however, received little attention and they still remain largely as imperfectly studied groups. Completing survey and inventorying in the as yet unexplored regions in India and undertaking creative systematic research on the less known taxonomic groups are urgent tasks to be fulfilled in a foreseeable time frame, possibly before most of our remaining wilderness areas are degraded and their biodiversity depleted further.

Publication of updated comprehensive treatises on *Flora of India* and *Fauna of India* is yet another mandate of BSI and ZSI, respectively. However, the current pace at which these series on flora and fauna of India are being brought out causes a little concern, whether the task would be realized within the stipulated target period.

BSI and ZSI are the custodians of millions of valuable specimens of plants and animals that are preserved in their herbaria, museums and archives. The treasure of this authentic collections provides valuable information and serves as a readily accessible resource base for systematic biology research in particular and other related biodiversity enterprises in general. Proper maintenance of these collections is also a great responsibility for the nation.

BSI and ZSI along with other collaborating institutions have also been instrumental in cataloguing the endemic species of flora and fauna, and preparing red data books on threatened plants and animals of India. These two institutions also serve as nodal centres for the operationalization of CITES in the country. The yeoman service and substantial contributions rendered by BSI and ZSI in furthering our knowledge on taxonomy, biogeography, ecology and conservation of India's flora and fauna deserve special mention. But, of late, it is unfortunate to realize that these two centres – perhaps the unique institutions for biological survey in the world – are finding it difficult to carry forward their legacy and mission in executing time-bound action-oriented research programmes. Lack of trained manpower in classical and modern taxonomy, weak management and inadequate technological capabilities and above all the mounting problem of trade union activism seem to be the stumbling blocks coming in the way of effective functioning of several of our taxonomic institutions like BSI and ZSI. Yet we cannot keep a blind eye on the ongoing decline of such institutions. It is in the fitness of things that the MoEF has taken initiatives to revamp BSI and ZSI[15,16]. A Capacity Building Programme in Taxonomy, launched by MoEF at a three-day workshop held at Jaipur in February 1997 is seen as a welcome step towards strengthening taxonomic research in India. Recognition of centres of excellence in taxonomic research, creation of Taxonomic Chairs, and launching of an 'All India Coordinated Project on Taxonomy (AICOPTAX)' are some of the important exercises initiated by MoEF in connection with its capacity-building programmes in taxonomy. Such initiatives are indeed expected to offer ample opportunities for BSI, ZSI and other taxonomic research institutions to reorient their efforts and help achieve their set goals and objectives.

The present trend of teaching and research in systematics at our colleges and universities is also equally disappointing. Even some of those esteemed departments or schools of biology at universities of Delhi, Kolkata, Mumbai, Chennai, BHU, etc. which once produced world-class research in classical systematics, embryology, cytogenetics, phycology, mycology, entomology and ecology are now unable to sustain and carry forward basic research in classical systematics. The current methods of teaching systematics through extensive classroom lectures but too little fieldwork, as practiced in many colleges/universities, should be discouraged. At graduate and post-graduate levels, students in biology or natural history may be given assignments to work on small time-bound dissertations or thesis work relating to taxonomy, biogeography or ecology of local flora and fauna near their colleges/universities. This kind of field biology project work will help enthuse students and give them the right orientation to take up future R&D programmes in systematic biology and allied disciplines. The field data generated through such student projects will also help improve our knowledge on biodiversity, its conservation, sustainable use and management at local levels.

Biodiversity mapping

Biodiversity mapping is relatively a recent initiative in India. Research in this direction includes the initiative made by the National Remote Sensing Agency (NRSA), Forest Survey of India (FSI) and French Institute of Pondicherry (FIP) in collaboration with departments of forests and wildlife in some of the states, in forest vegetation mapping using conventional and remote sensing techniques. This is being augmented by a national level coordinated research programme on 'Biodiversity characterization at landscape levels using remote sensing and GIS', launched by DBT, Space Application Centre (SAC) and NRSA in collaboration with other biodiversity research institutions located in different biogeographic zones of our country. MoEF through its programme on National Natural Resource Management Systems (NNRMS) also supports a number of project studies on biodiversity mapping that involve application of remote sensing and GIS techniques. All these mapping programmes are only

at their preliminary phase and going further ahead with extensive and intensive countrywide biodiversity mapping requires an integrated eco-biogeographic approach involving very many partner institutions specialized in systematics and taxonomy, ecology, biogeography, forestry, geomorphology, soil science, remote sensing, GIS, Global Positioning System (GPS), computer cartography and other relevant disciplines and tools of super highway of informatics like sharing of texts, images and maps through web interface, etc.

Mapping is a pre-requisite to setting priorities for conservation and monitoring of biodiversity and its components at local, national and regional levels. Mapping of biodiversity requires intense ground truthing for verification and integration of various sets of data (physical and spatial) generated through various techniques. This ground truthing is of fundamental importance to mapping and it becomes truly operational and successful only when we are able to determine or predict with precision – what are we going to map? Only a trained professional taxonomist can give an answer to this question.

Conservation, prospecting and sustainable utilization of biodiversity

In situ and *ex situ* conservation of biodiversity are the key areas of research supported by MoEF at several of its R&D institutions, departments of forests and wildlife in the states and union territories, botanic gardens, arboreta, zoos, natural history museums and NGOs. Whereas the thrust of R&D in many institutions under the network of DST, DBT, ICAR and CSIR is on the most promising areas of conservation of biological and genetic resources through conventional methods and biotechnological intervention, bioprospecting (chemical, pharmaceutical, drug and gene prospecting), genetic engineering, bioinformatics, biosafety, etc. Now in almost all such frontier areas of biotechnological or bioprospecting research, involvement and partnership-building between systematic biologists and other user groups are becoming increasingly evident. For example, all the three major bureaus, i.e. National Bureau of Plant Genetic Resources (NBPGR), National Bureau of Animal Genetic Resources (NBAGR) and National Bureau of Fish Genetic Resources (NBFGR), entrusted with survey, exploration, characterization, evaluation and conservation of genetic resources would require the services of more number of trained taxonomists to complete their task as quickly as possible. The recent initiative by DBT in launching two major research programmes in bioprospecting and molecular taxonomy is a clear-cut indication of a progressive trend for integrating taxonomic expertise with other disciplines like biochemistry, cytology, molecular biology, etc. In essence, all our vital enterprises relating to biodiversity research, both in classical and modern realms demand the service and contributions of talented professional taxonomic cadres. How shall we meet this requirement?

Challenges of systematic biology research in India

In spite of having a good network of R&D establishments, national[17–19] and international policy framework[20–24], adequate natural and human resource wealth, advancements in modern technologies, especially biotechnology and information technology, our achievements in biodiversity and related areas of research are not very promising. Apparently, lack of coordination and integrated efforts, reluctance to accept and support basic science disciplines like systematics, and lack of collective vision and common agenda for tackling complex research and development issues (like biodiversity) are seen as some of the inherent weaknesses of our R&D systems, particularly of systematic biology research. This would become far more evident if we examine the current pace of achievements in inventorying India's biodiversity. Despite major efforts by a number of national institutions and other agencies, we are yet to cover about 30% and 65% of the biogeographic zones in India for floristic and faunistic inventories, respectively. It is equally disappointing that we still do not have a comprehensive national database that can provide baseline information, including a realistic estimate on the number of species of various groups of biota reported to occur within the territories of the Indian Union. What we often project as the national estimate on species diversity is nothing but mere extrapolations or guesstimates of data generated by BSI, ZSI and other agencies during early 1990s or before.

Furthermore, our knowledge on the diversity, distribution, ecology, biology, conservation status and utilization prospects of even the taxonomically well-known species is awfully inadequate. We cannot be complacent either with our actual contributions to the cause of conservation of endangered species and genetic diversity, restoration of fragile habitats and ecosystems, sustainable management of our protected area networks or development of new products, processes, technology based on our past and present efforts in biotechnological and bioprospecting research programmes.

All these, however, do not mean that India is not awakened to the issues and challenges faced by our biologists and the scientific community. There have been substantial initiatives to address such issues by several stakeholder institutions and agencies involved in biodiversity and systematic biology research in India. But, what we really lack is a holistic approach to streamline our R&D efforts, particularly systematic biology research, with a view to achieve tangible results in conservation and sustainable development.

It is now time to have an introspection by all stakeholders, particularly systematic biologists, as to how best

their existing policies, programmes and action plans could be implemented to contribute directly or indirectly to India's social, cultural and economic development goals.

Some of the major challenges of systematic biology research in India are:

1. Completing the unfinished task of inventorying floristic, faunistic and microbial diversity in the under- or unexplored regions.
2. Setting priorities for mapping biodiversity and its components in all the biogeographic zones through application of remote sensing, GIS, GPS and other relevant tools of space and information technology.
3. Conducting creative revision and monographic studies on important taxonomic groups, with special focus on lower plant kingdom, microbes and the less known animal groups.
4. Execution of flora of India and fauna of India work within a definite time frame.
5. Undertaking conservation biological studies on ecologically important and threat-prone species of flora and fauna on priority basis.
6. Conducting integrated taxonomic research for multidisciplinary characterization of biogenetic resources at morphological, cytological, biochemical, molecular and genetic levels.
7. Creating computerized online databases on various aspects such as taxonomy, nomenclature, biogeography, ecology, conservation, economic uses and potentials of flora, fauna and microbial diversity and dissemination of such up-to-date information system through internet.
8. Capacity building and infrastructure development in classical and modern systematics.
9. Documentation and maintenance of valuable collections of specimens, literature, manuals, etc. in herbaria, museums and biological archives, and computerization of data accession on the above for effective management and updation.
10. Documentation of rare, endangered and endemic species so as to aid their conservation, both *ex situ* and *in situ*.

It can be seen that the areas identified above have already been on the agenda of many national institutions, organizations and their bodies involved in systematic biology research in India. It is also true that progressive efforts to bridge some of the gap areas in systematic biology research have been initiated under the aegis of MoEF (e.g. capacity building programme in taxonomy), DST (e.g. special programme on taxonomic research), DBT (e.g. molecular taxonomy and biodiversity mapping), ICAR (e.g. National Agricultural Technology Project [NATP] – Fish Genetic Resources and Agro-biodiversity) and other agencies. Systematics and taxonomy have been identified and supported as key areas of research by all these agencies. However, the success of all our existing programmes in biodiversity and systematics research should be rated not in terms of their academic results alone, but in terms of their practical utility in achieving specific goals of inventory, conservation and sustainable use of biodiversity resources of our country. Systematic biologists, the funding agencies and their programme-implementing agencies must ensure that the outcome of their research is utilized meaningfully for the purpose of planning and implementation of appropriate development programmes. Such an orientation is clearly lacking in the planning and execution of systematic biology research programmes in India. It is necessary to evolve a national mechanism for coordinating all the ongoing systematic biology research programmes so that the results of these endeavours can be effectively pooled in and integrated to meet sustainable growth and environmental protection. This would help avoid duplication of research efforts and evolve a well-focused, goal-oriented systematic biology research programme that could be well-suited to address the priority issues of conservation and sustainable use of biodiversity of our country. It is with this end in view we propose that a National Consortium for systematic biology research be set up with the active involvement and partnership of all major taxonomic research centres in India. A consortium thus established would be made responsible for streamlining systematic biology research in the country with the back up of a newly evolved and comprehensive National Agenda for systematic biology research.

Strategies for setting up National Consortium and National Agenda for systematic biology research in India

In order to realize the above objectives and to set out our immediate options and priorities, systematic biologists should strive to evolve dynamic strategies that could help revive and rejuvenate taxonomic enterprises to find new realms in biodiversity research. The strategies, both long-term and short-term, are to be formulated after conscientious discussions and consultations among all stakeholders who are concerned and committed to setting our systematic biology research agenda in order. We propose here a few ideas that might be useful for further discussions and finalization of the strategy.

The strategy may be approached from a multi-dimensional perspective. The possible ways of approach to the strategy may be a combination of the following:

1. Biogeographic zone-wise approach.
2. Taxon-wise approach.

The specific components of the strategy can include the following :

1. Formulation of a National Agenda for Systematic Biology Research in India (NASBRI) by integrating relevant programmes initiated by major ministries and departments, including MoEF's All India Coordinated Pro-

gramme on Taxonomy and creation of Taxonomic Chairs in universities, colleges and taxonomic research institutions. The agenda may focus on setting definite goals and time frame for all kinds of systematic and taxonomic research programmes, including inventory of flora, fauna and microbes; revision or monographic studies on important taxa so as to improve our knowledge on all aspects of the taxa under investigation, up to species and infraspecific level; up-to-date and comprehensive resource checklists useful for other end-users.

2. Building up a National Consortium of systematic biology research centres for overseeing and implementing the systematic biology research agenda. The CONABIO or the ERIN models can be followed. The existing facilities and expertise available with BSI, ZSI and other leading taxonomic research centres may be strengthened to equip them to take a leadership in the creation of the Consortium as envisaged here.

3. Identification of potential research centres and recognition of their infrastructure and expertise in respective fields of systematics.

4. Setting up task forces for stringent evaluation and monitoring of each of the priority components of the research agenda.

5. Training and capacity-building in systematic biology and other frontier areas of biotechnology, and information technology relevant for systematic biology research.

6. Integration of systematic biology findings with information technology tools for efficient storage, retrieval, dissemination and management through databases on electronic systems.

7. Collaboration and networking among and between systematic biologists and other experts in related fields, both in India and abroad.

8. Creation of mission-oriented systematic biology training school for building up a cadre of trained and committed systematic biologists and ensuring job opportunities for them. The model of BARC Training School[25] may be followed for this purpose.

9. Providing self-sustaining mechanisms for systematic biology research centres by promoting creation of marketable electronic database systems on various aspects of systematics for other end-users.

10. Encouraging partnership-building between systematic biologists and bioprospecting ventures. Such partnership programmes would be mutually beneficial as the bioprospectors would require taxonomic expertise for successful execution of their programmes and the systematic biologists in turn would benefit by mobilizing financial resources to support their research through the bioprospecting partnership programmes.

Many more strategic components can be added to this and we refrain from doing an elaborate exercise here, as we feel that each of the proposed components will require collective opinion and decisions by all those involved in systematic biology research and its promotion in our country. Mobilizing financial resources to support systematic biology research is yet another component that needs to be addressed promptly by the scientific community and the policy-decision makers. Funding for systematic and taxonomic research is the biggest handicap. This can be overcome partly through strategic initiatives by converting all findings and results of taxonomic research into user-oriented and marketable databases of practical applications for various end-users. The information technology tools and bioprospecting ventures offer tremendous opportunities for systematic biologists to enter into prospective partnership programmes and find ways for mobilizing money to support systematic biology research. International funding through agencies like GEF may also be made available to support systematics and taxonomic research, besides coordinating all systematic biologyresearch programmes in the country through a single window system of project formulation and funding.

Conclusions

Evolving a consensus on formulation of a National Consortium and National Agenda for systematic biology research is not an easy task. It requires lot of homework, planning and healthy interactions among various stakeholders. MoEF, DST, DBT and CSIR can take the leadership in pioneering a strategic initiative in this line. And, much before that, the systematic biologists in India should have an introspection as to what kind of a strategy could help demonstrate that systematics is a powerful and dynamic crisis-management discipline that would cater to the ever-increasing needs and aspirations of human societies.

Systematic biologists and our policy-decision makers may have to think now in terms of dynamic action plans, not unpragmatic policies, programmes or strategies. Let us remember the oft-quoted warning from Peter Raven[26]: 'It is too late in history of the world to think that there is time to produce ordered classifications of all plants, animals, fungi and micro-organisms, and then to employ these classifications to seek new kinds of generalities while these organisms are still extant.' This message points to the enormity of the tasks ahead amidst the escalating crisis of human-induced biological extinctions.

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We, P. Balaram and S. Ramaseshan, hereby declare that the particulars given above are true to the best of our knowledge.

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