Cataloguing life in India: the taxonomic imperative

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Taxonomy, the science of discovering, describing and naming new species has become critically important in this era of declining biodiversity. Cataloguing species is fundamental to conservation and sustainable use of biodiversity. Taxonomy also forms the basis of elucidating evolutionary relationships among agricultural crops, parasites, pathogens and insect pests. Many pharmaceutical products are based on plants and the indigenous systems of medicines are based on our ability to accurately classify and describe living organisms. Thus taxonomy plays a vital role in the human well-being.

India is tremendously rich in biodiversity. It is one of the 17 mega-diversity countries. India's land mass encompasses four global hotspots of biodiversity: the Western Ghats, the Himalayas, Indo-Burma (northeast India south of Brahmaputra) and Sundaland (Nicobar Islands). The hotspots are unusually rich in endemic species. India is also the centre of diversity for many agricultural and horticultural crops and their wild relatives, and is well known for richness of medicinal plants.

The exact number of species in India is not known, but may be well over one million. The world is estimated to have 12 million species of eukaryotic organisms[1]. Among the three groups of eukaryotes, i.e. flowering plants, birds and mammals, India, respectively has about 18,000, 1200 and 350 species, or 5%, 13% and 7% of the world's total. From these figures, we extrapolate that India may have 8% of the world's eukaryotic species, assuming that species numbers of other groups at least at continental scales are correlated with species richness of these three groups. Insects, worldwide have not been well described, and in India, amphibians and reptiles too have been poorly explored especially in the Himalayas.

Recent explorations of relatively small areas in the Himalayas have revealed more than 300 new species of plants, vertebrates and invertebrates[2]. Many more are yet to be discovered. Clearly we do not know the upper limit to the number of species in India or the world.

Of the world's estimated 12 million species of eukaryotes, less than 2 million have been described and given a scientific name. The proportion of named species for Indian organisms is likely to be less because many parts of the country have not been fully explored. Apparently then hundreds of thousands of species in India are yet to be described and named. The exact number of eukaryotic species that are being described every year from India is also not known, but is not likely to exceed 200. At this rate, it would take many millennia to catalogue the diversity of life in the country's ecosystems.

Clearly taxonomy in India should be an active and vibrant field, but it is not, as indicated by many articles (see references). Here I discuss taxonomic research hurdles in the country and suggest ways to overcome them.

Taxonomic imperative

Almost 15 years ago, T. N. Khoshoo[3] lamented on the state of taxonomy in India. According to Khoshoo, '*all wisdom begins by calling all living (including humans) and non living things by their proper names*'. Khoshoo called for a country level review of the state of taxonomy, and for revitalization of the field to meet current and future challenges.

Following Khoshoo's pleas, both the Department of Biotechnology (DBT), and the Ministry of Environment and Forests (MoEF), Government of India undertook some initiatives to strengthen taxonomy. The DBT started a programme on molecular taxonomy, funding a number of research projects on the application of molecular techniques to resolve taxonomic problems. The MoEF organized some workshops to highlight taxonomic research[4]. The impact of these initiatives is uncertain. There is little evidence that efforts of government agencies have improved the state of taxonomy. In fact, one can argue that the practice of taxonomy may have declined since Khoshoo argued for its revitalization.

There are still no checklists for major groups and monographic work that forms the backbone of taxonomy is scarce. Indeed, due to efforts of extraordinary individuals, we have outstanding volumes on groups of organisms being published in increasing numbers. Examples include accounts of snakes[5], butterflies[6], amphibians[7], orchids[8] and rhododendrons[9], but such endeavours are not substitutes for serious monographic work, nor are they intended to be.

Collections in museums and herbaria form the foundation of taxonomic work, but collections in the herbaria of the Botanical Survey of India (BSI) or the museums of the Zoological Survey of India (ZSI) have remained stagnant in terms of numbers and curation. While collections all over the world are being digitized and organized, and databases are being made available on the web, such initiatives are largely lacking in India[10,11]. Thus scientists interested in taxonomy and who are not affiliated with BSI or ZSI have limited opportunities to expand the scope of their work.

More serious is the declining number of taxonomists at a time when more are required. Exact numbers are lacking, but it is evident from the profiles of universities and departments that although there is an overall increase in the number of scientists, this is not the case for taxonomists. Taxonomy is a part of a cluster of biological sub-disciplines that constitute environmental biology. As compared to cell and molecular biology, environmental biology has not received much attention from those who make decisions about funding science in India.

However, India is not unique in being indifferent to taxonomy. Worldwide, funding for taxonomy, and support for museums and herbaria have been decreasing[12]. A recent article in *Science* notes the plight of taxonomy in China[13]. Nevertheless, because of growing interests in biodiversity conservation, there are signs of revival. Chinese scientists for example are collaborating with Western scientists to enhance their expertise as well as to improve the profile of taxonomy.

Opportunities

The opportunities for strengthening taxonomy in India are greater now than ever

before due to several reasons. First, the government has been increasing its investment in science, and such increases are likely to continue. Furthermore there is more interest in basic science and biodiversity and this again should translate into larger investment in taxonomy.

Secondly, interest in natural history outside government agencies is increasing, and this could revitalize the field. India has witnessed a strong growth in autonomous or independent, non-governmental research centres in the field of environment and biodiversity. Examples include Foundation for Revitalization of Local Health Traditions, Nature Conservation Foundation, M.S. Swaminathan Research Foundation, Bombay Natural History Society, The Energy and Resources Institute, and the Ashoka Trust for Research in Ecology and the Environment. These organizations have taken several initiatives to encourage exploration and discovery of species.

Thirdly, individual entrepreneurship in exploration of flora and fauna because of increasing interest in the environment is rising. Individuals who are not affiliated with any university, BSI or ZSI, largely wrote the 'monographs' listed under references. Easy access to collections and field sites and the recognition that such individuals do and can make significant contributions can propel taxonomy out of its current situation.

Finally, developments in information technologies and deployment of new tools in molecular biology – and India has considerable expertise in both – can accelerate the pace of discovery and cataloguing of life forms, dissemination of information, and involvement of amateurs in advancing taxonomic knowledge. Misguided application of new technologies, as discussed here, can also derail progress and greater investments in taxonomy.

What needs to be done?

Several steps need to be taken to strengthen taxonomy in India.

First and foremost we must develop outstanding institutions to support taxonomic work. BSI and ZSI do much of the taxonomic work in the country. It was perhaps a good idea at the time these institutions were set up to have separate agencies to catalogue India's plants and animals. However, both institutions have suffered due to lack of linkages with academic institutions that are a source of new ideas and centres of conceptual and theoretical developments in not only taxonomy but also in fields such as systematics, biogeography, evolution, ecology and the new discipline of conservation science that underpin, support and enrich taxonomy. Museums and herbaria, so vital for taxonomic work, have been under the control of BSI and ZSI and so have been the country's investments in taxonomy. This focus on BSI and ZSI has led to the neglect of taxonomy as well as collections in academic institutions, curtailing opportunities for the growth of the discipline as well as training of new taxonomists. The BSI and ZSI have also suffered due to lack of strong scientific leadership, and excessive bureaucratic control, in the Ministry of Environment and Forests that oversees these agencies. Strong hierarchical structures within BSI and ZSI curb initiatives at lower levels. The government must think of ways to develop BSI and ZSI into dynamic and effective institutions that have the capacity to usher the country into a new era of exploration and discovery, and cataloguing of our diverse life forms.

Apart from BSI and ZSI, other centres for taxonomic work in academic institutions must be strengthened or created. Unless ways can be found to enable BSI and ZSI to become truly knowledge rather than information generating institutions, and intellectual centres of taxonomy, academic institutions will remain as the only primary places for training of new taxonomists. Academic centres will require resources to enlarge their collections and libraries. Collections are particularly important. Museums, herbaria and botanical gardens associated with most major universities in the West are the most effective knowledge generating centres for taxonomy and systematics.

Taxonomy as a discipline must be strengthened in colleges and universities. With the rise of biotechnology there is increasing emphasis on molecular and cell biology. As a result, investments in such disciplines as evolution, ecology and systematics have declined. Hopefully, with anticipated increase in funding for basic sciences, it would be possible to pay special attention to environmental biology.

Training of a new breed of taxonomists well versed in modern concepts and application of latest technologies to advance taxonomy will be required. A fellowship programme that would allow taxonomists to spend one or two years at the world's major museums, herbaria and botanical gardens can rapidly build a good cadre in a few years. Good herbaria or museums, libraries rich in taxonomic literature, and some knowledge of Latin are critical to learning taxonomy. Unfortunately at this time only global centres can meet these requirements. Twenty Fellows every year would cost less than Rs 5 crores per year, a relatively minor amount to build leadership in a vital field.

Taxonomists in India should enhance the use of emerging information technologies as well as new tools in molecular biology. Collections must be digitized and organized as electronic databases so that data are readily and widely available. A vast number of old type specimens of Indian plant and animal species are outside the country and not accessible to Indian taxonomists. Collaboration with institutions holding these collections for digitization of specimens and development of databases would be necessary for Indian taxonomists to use these collections. Environmental and biodiversity portals can further help in assembling, organizing and disseminating databases, and advancing the field. Similarly, molecular tools can rapidly elucidate evolutionary and bio-geographical relationships, but undue emphasis on approaches such as DNA bar coding can distract from other more pressing priorities in taxonomy.

India has a rich body of traditional knowledge about plant and animal species. This knowledge can be harnessed in a wide variety of ways to fasten the pace of discovery. Local communities and citizens everywhere can be involved in exploration and description of life forms. Similarly, the engagement of millions of students can enhance accumulation of information and data that can be directly fed into information portals (see for example, India NatureWatch: www.indianaturewatch.net).

The recent discovery of hundreds of species from the eastern Himalayas[2] and continuous description of new species from other sites in India[14] underscores the importance of exploration and fieldwork. Many areas in India, particularly in the four biodiversity hotspots, remain poorly explored. The government agen-

cies that fund as well as regulate access to biodiversity should encourage new discoveries rather than place hurdles for scientists[15–17]. China is contemplating a national plan to catalogue all biodiversity[13]. A similar initiative can be helpful in training taxonomists, involving citizens and students in cataloguing biodiversity and meeting an urgent need in conservation planning.

Finally, India must end its isolation from global networks and collaborative with scientists abroad engaged in taxonomy. Practice of taxonomy is a global enterprise. Plant and animal species do not respect political boundaries, and we share a vast majority of species with other countries. Furthermore, no single country, institution or scientist has the capability to deal with all major taxonomic groups. That is why taxonomy, more than any other discipline, relies on continuous exchange of ideas, information and specimens of organisms across the world. Moreover, many type specimens of Indian plant and animal species are in the museums and herbaria outside the country, making exchanges critical for the advancement of the field. However, misplaced fears of bio-piracy have led Indian agencies to tighten regulations for exchange to such an extent that it has stifled taxonomy[17,18]. The government urgently needs to review regulations, and join international network not only to advance taxonomy in India, but also to influence regulations and decisions about biodiversity at the international level.

Note added in the proof: After this manuscript was submitted for publication, a task force constituted by the Ministry of Environment and Forests (MoEF), Government of India to make recommendations to the Government for strengthening of Botanical and Zoological Surveys of India was submitted. The report, available from MoEF, reinforces several suggestions made in this article.

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