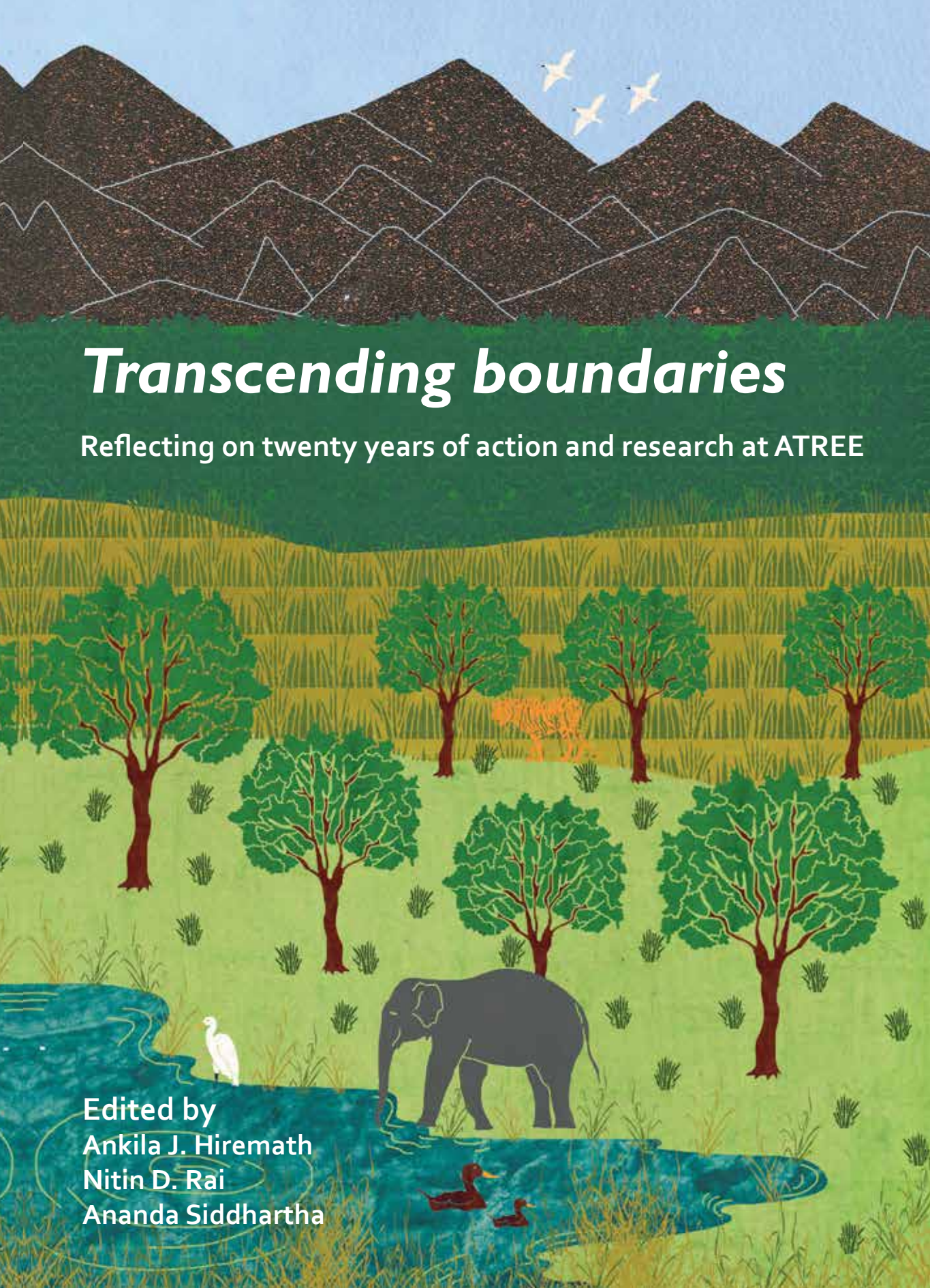

Transcending boundaries

Reflecting on twenty years of action and research at ATREE

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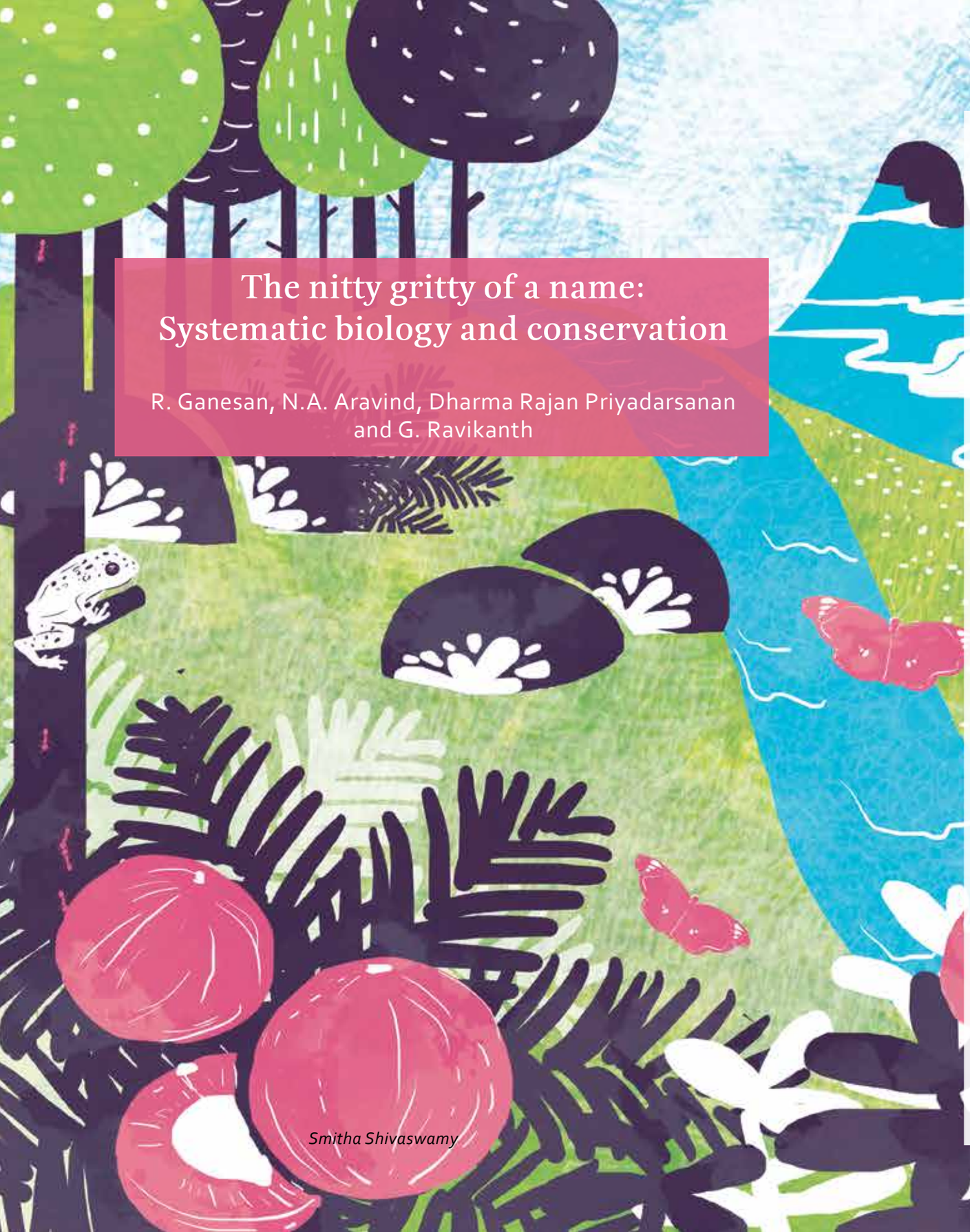


Smitha Shivaswamy

"Without taxonomy to give shape to the bricks, and systematics to tell us how to put them together, the house of biological science is a meaningless jumble," Robert May (1990)

INTRODUCTION

Effective conservation and management of biological diversity depends on our understanding of taxonomy. Taxonomy is the science of naming, describing, and classifying flora, fauna, and microorganisms. Taxonomists identify, describe, and classify species—including those that are new to science—on the basis of characteristics that include morphology, behaviour, genetics, ecology, and biochemistry. Systematics, on the other hand, is about the evolutionary inter-relationships of each and every named and described organism. Thus, taxonomy and systematics provide basic knowledge of biological diversity to underpin conservation, management, and implementation of national commitments under the Convention on Biological Diversity (CBD). Unfortunately, inadequate taxonomic information hinders our ability to make informed decisions about conservation, sustainable use, and benefit sharing.

India, a signatory to the CBD, is one among the 17 mega-diversity countries of the world, with four biodiversity hotspots. It has 136,000 species described till date, and has a unique assemblage of biodiversity. This rich biodiversity can be attributed to its varied climatic zones and geological features such as the Himalaya, the Western and Eastern Ghats combined with the Deccan Plateau, hot and cold deserts, mighty rivers such as the Ganga and Brahmaputra, with their flood plains, and a long coastline. The subcontinent's diverse cultures and hundreds of ethnic communities are, in turn, intricately connected to this biodiversity and its conservation. However, the process of biodiversity documentation in India lags behind when compared to neighbouring countries such as Bhutan, China, Nepal, Pakistan, and Sri Lanka. As part of achieving the Aichi targets (20 new biodiversity targets for 2020) related to the CBD's Strategic Plan for Biodiversity 2011–2020, India needs to better document its biodiversity, improve the conservation status of endangered species, and conserve ecologically representative landscapes.

Taxonomy and conservation go hand-in-hand. Efforts to understand the consequences of environmental change and degradation will be incomplete if the components of the ecosystems are not identified or described. Hence, documenting and assessing the biodiversity of a region is the first step to devising conservation plans to achieve the goal of biodiversity conservation. Although biodiversity in India was well documented during the pre- and post-independence period, recent studies have described numerous new plants and animals in the last 15 years, though they are restricted to selected groups such as frogs, butterflies, orchids, and rhododendrons. New descriptions of species are either due to intensive exploratory efforts in the Himalayas, or due to monographic studies involving molecular biological approaches (e.g., in the case of amphibians).

Cataloguing and documenting India's biological diversity, from genes to ecosystems, and reconstructing the evolutionary history and phylogeography (i.e., the distribution of genetic lineages) of India's biodiversity, are the primary objectives of the Systematic Biology Group at ATREE. Our group works on systematics of plants, insects, freshwater and terrestrial snails, and frogs. We draw upon this work to illustrate how systematic biology (i.e., the study of the diversification of living forms, and their evolutionary inter-relationships) underpins biodiversity conservation.

WHAT'S IN A NAME?

Correct identification and naming are critical in planning for conservation, management, and sustainable harvest of resources, and also for prioritising sites for conservation programmes such as species recovery programmes. A good example is the case of *amla* or *nelli* (Indian gooseberry), an important fruit resource from Indian forests that is widely used in indigenous health practices and is also heavily traded. A large proportion of fruit collected still comes from wild populations, though the plant is also being cultivated for commercial-scale harvest. In India it has been collected from the plant botanically called *Phyllanthus emblica*, which is widely distributed in the Indian sub-continent, Sri Lanka, China, and most Southeast Asian countries. Interestingly, fruit from the Deccan Plateau of southern India are harvested from another species called *Phyllanthus indofischeri*[1]. The *Soliga*, an indigenous community that resides primarily in the Biligiri Rangaswamy Temple Tiger Reserve (BRT), are aware of the distinct morphological features and spatial distribution of these two species, and have distinct vernacular names for them—*bettada nelli (P.emblica)*, and *ittu nelli (P. indofischeri)*.

P. indofischeri is endemic to dry forests of the Deccan region, and its distribution is spatially segregated from that of *P. emblica*. Dry forests in the Deccan region are highly fragmented, denuded, or have been converted to farming, urbanisation, and other land use practices. In addition, *P. indofischeri* populations are also threatened by destructive harvesting practices, where branches are lopped for the collection of fruit. Most of the herbarium collections of this endemic species were wrongly identified as *P. emblica*. Similarly, many ecological and bioprospecting studies also have not distinguished between these two species of *amla*. Wrong identification led to a faulty status for the endemic species in the Deccan Plateau. This case study, which highlighted the taxonomy of *amla*, its restricted distribution, and threats to the habitat of the endemic species, *P. indofischeri*, resulted in it being listed in the vulnerable threat category by the International Union for Conservation of Nature (IUCN), and it has now been prioritised for conservation efforts at the national level. This example illustrates how bad taxonomy could 'kill' a species.

The importance of taxonomy and identification in assigning conservation priorities for rare plants and threatened habitats is highlighted by another plant species, *Crotalaria digitata*, which has a narrow distributional range. *C. digitata* was described from a single collection from Madurai district in Tamil Nadu in 1829[2]. Since then, it has not been recorded either from the location of its first collection (what taxonomists would call its 'type location'), or anywhere else, and was considered extinct. However, there were reports about the plant from Coorg in the Central Western Ghats, and we found that it was due to wrong identification that it was confused with yet another species, *C. grahami*. Recently we collected *C. digitata* from a small hillock (surrounded by farmlands) on the periphery of Madurai. Rediscovery of *C. digitata* highlighted the fact that it is indeed restricted to Madurai region, and that its habitat is highly threatened. The present distribution and habitat status of this species indicates that *C. digitata* needs to be prioritised for conservation, e.g., through a species recovery programme.

CLASSICAL TAXONOMY

Classical taxonomy was used for the Western Ghats Insect Inventory Programme, which is a large-scale insect inventory and documentation project planned and implemented by the team at ATREE. This programme was aimed to source new collections and data for the terrestrial insect fauna of the Western Ghats. Insect collections were made from all over the Western Ghats. The samples were curated and specimens are catalogued in the ATREE Insect Museum – Bangalore (AIM-B). A number of taxonomists from within India and abroad are collaborating in this effort. Taxonomists at ATREE are also involved in the revisions of a few ecologically important groups such as dung beetles (*Scarabaeinae*), ants (*Formicidae*), and parasitic wasps (*Chalcidoidea*).

Several new species, especially of ants (*Vombisidris humboldticola, Discothyrea sringerensis* and *Anochetus daedalus*), moth flies (*Gondwanoscurus jezeki, Saximormia gladiator*, and *Telmatoscopus arcuatus*), parasitic wasps (*Neorichohalticella sringerensis, Australomymar formosum*, and *Kiggaella oryzae*), and dung beetles (*Onthophagus jwalae, Onthophagus pithankithae, Onthophagus tharalithae, Onitis bhomorensis, Onitis kethai*, and *Onitis visthara*), which are new to science, were described from this collection. Of these, *Neorichohalticella* and *Kiggaella* are genera that are new to science, and *Gondwanoscurus* and *Saximormia* are genera that are new to India.

Crotalaria digitata, *only found in Madurai district, Tamil Nadu. We recently collected a specimen from a small hillock on the outskirts of Madurai-the first such record since its original collection in 1829. (Photo: R. Ganesan)*

[1] Ganesan, R. 2003. Identification, distribution and conservation of Phyllanthus indofischeri, another source of Indian gooseberry. *Current Science* 84(12): 1515-1518.

[2] Muthu, RK and R. Ganesan. 2012. Rediscovery of Crotalaria digitata (Fabaceae) from Madurai district, Tamil Nadu, India. *Rheedea* 22(2): 103-106.

UNRAVELING HIDDEN TREASURES FROM HERBARIUM AND MUSEUM COLLECTIONS

As part of the strategy to allocate resources towards improving taxonomic studies in India, systematic revisions (which entail revising taxonomic knowledge of organisms to the global standard) involving rich collections in herbaria and museums, and explorations in regions that are less explored, have been highlighted. Globally, collections in herbaria and museums are curated for their current systematic position due to systematic revisionary studies. However, collections in India are still far behind in curation for taxonomic details with updated taxonomic status.

A plant belonging to genus *Litsea* (Lauraceae)[3], collected from long-term vegetation monitoring plots established in Kalakad Mundanthurai Tiger Reserve (KMTR; see Ganesh et al, this volume), was not comparable with any described species available in floras or collections from regional herbaria. Later, we referred to collections from India and adjacent floristic regions, deposited at the Kew Herbarium, and at the British Natural History Museum (NHM) in London. Interestingly, in NHM we found unnamed specimens from KMTR (at that time known as Singampatty Hills and Courtallum Hills), collected by Col. Richard Beddome, which resembled the unidentifiable plant collected from KMTR by us. It was confirmed that the plant was new to science. The collections from NHM and Kew also showed that the plant is endemic to the Agasthyamalai forest in southern India. This highlights the importance of herbarium collections, field collections, and systematic revisions in documenting and assessing biodiversity, even in regions such as the Western Ghats. Also, the number of new discoveries of plants in the Himalayan region, especially in well-studied groups such as Rhododendron, indicates the potential for more studies that could unearth many new discoveries.

Hidden treasures in museums are not only restricted to plants. Another example comes from land snails of the genus *Allopeas*. Col. Henry Haversham Godwin-Austen, one of the pioneers who worked on Indian snails in the 18th and early 19th century, had collected 19 species from India (two from South India, and 17 from Northeast India), and had described the species in an unpublished manuscript, that remained hidden in the archives of the NHM in London. We are now collaborating with researchers at NHM to describe these 19 species.

The recent discovery of a novel ant species, *Anochetus daedalus* by ATREE entomologists further underscores the importance of museum collections. It was a single specimen of an ant collected 165 years ago, and safely preserved in a museum abroad that helped to reveal the identity of this mysterious ant collected during a field trip. On a vertical fall along a forest trail in Sirsi (Karnataka), we found an elaborate, maze-like structure made of mud. Excavating this structure revealed a few trap jaw ants (genus *Anochetus*) moving around in horizontal galleries. *Anochetus* is a genus of carnivorous ants, possessing long

Anochetus daedalus, *a new ant species discovered by Aniruddha Marathe and Dharma Rajan Priyadarsanan in 2016. (Photo: Aniruddha Marathe)*

pincer like mandibles that snap shut on their prey like a bear trap, with such force that the prey may get cut into pieces. These ants form small nests with around 100 individuals in a colony, and are very shy and cryptic. Moving silently through the leaf litter, they forage on insects and other small invertebrates on the ground. From a detailed study of a few collected specimens in the lab, scientists found it different from all other 11 species of *Anochetus* known from India; it closely resembled *Anochetus neitneri*, another species described from Sri Lanka by the British Entomologist, Roger, in 1891. Roger got only a single specimen of this ant, which he had described as *Odontomachus neitneri*, and this remains the only authentic report of this species till now. Luckily, this holotype was safely preserved in the National Museum of Natural History in Berlin (Museum für Naturkunde) with its new valid name *Anochetus neitneri*. (A holotype is the authentic reference specimen based on which a new species is described; museums take special care to keep such specimens safe and to make them available for scientists from all over the world to study.) On our request, the curators of the museum arranged good quality in-focus images of the holotype. The availability of the data of this 165-year old specimen was instrumental in accurately identifying this ant, found along a forest trail in Sirsi, as a new species[4].

MULTIPLE APPROACHES IN TAXONOMIC RESEARCH

There are criticisms that frequent name changes, or the changing taxonomic position of organisms lead to a change in the prioritisation of species for conservation, and therefore undermine conservation efforts. Stability of the names and their taxonomic position (species, genus, family, etc.) is debated by taxonomists themselves. However, like any other scientific discipline, newer knowledge and tools are getting integrated into taxonomy. This 'integrative taxonomy' (classical taxonomy complemented with molecular, acoustic, anatomical, numerical, and niche modelling tools), is leading to a better resolution of relationships among different taxa within a group, and necessitates shifting the taxonomic location of species from one genus to another, or even shifting genera from one family to another.

Integrative taxonomic approaches have been used to delineate species, especially those that are cryptic in nature, such as the genera *Raorchestes* (bush frogs) and *Nyctibatrachus* (night frogs). (Cryptic species are those that are difficult to tell apart.) The Systematics Biology Group at ATREE, along with researchers from other institutes, has recently described four new frog species from the Western Ghats based on molecular, morphological, and numerical taxonomic methods (e.g., *Nyctibatrachus kumbara, Raorchestes kakachi, R.*

[3] Ganesan, R. 2011. *Litsea kakkachensis* (Lauraceae) – a new species from Agasthyamalai, Western Ghats, India. *Rheedea* 21(2):143–146.

[4] Marathe, A. and DR. Priyadarshanan. 2016. A new ant species of the genus *Anochetus* (Hymenoptera: Formicidae) from India with a remarkable nest entrance architecture. *Current Science* 110(6): 1105–1107.

honnametti and *Microhyla laterite*)[5,6]. Similarly, in the case of freshwater snails (belonging to the genus *Cremnoconchus*), reproductive anatomy and radula (tooth) structure, apart from morphological characters, were used to identify these highly cryptic species that live in waterfalls. This genus has nine species, all of which are endemic and restricted to waterfalls of the western slope of the Western Ghats escarpment. We are also applying molecular tools to complement morphological and anatomical results for land and freshwater mollusc systematics[7]. The integrative approach is being used to revise selected families of land snails and freshwater molluscs of India.

TAXONOMIC DATABASES AND CONSERVATION

Taxonomic databases are the knowledge base upon which all discussion of conservation rests. Inventories derived from the synthesis of such taxonomic information give an overview of the state of biodiversity, and enable the identification of key indicators, and the analysis of important patterns and processes. Inventories also provide baseline information for the assessment of change, and data for conserving and managing biodiversity. Many of the issues in biodiversity assessments in India revolve around a central problem of a lack of such collated data of various inventories available from a single source. In addition to the conventional roles of revising and publishing new taxa and preparing monographs, taxonomists have the added duty to disseminate taxonomic information worldwide in digital formats, to shorten the distance between discovery and delivery.

We have developed taxonomic databases for several taxa (land and freshwater snails, rattans, amphibians, balsams, ants, bees, dung beetles, and grasshoppers). These databases are extensively used to identify regions of high conservation importance, and also to assess the conservation status of species. For example, the database on freshwater molluscs developed at ATREE was used in assessing the Red List status for 120 species for IUCN[8]. Similarly, the database on amphibians was used to assess the effectiveness of protected areas for conservation. We also propose to use these databases to generate digital keys for identification of species on mobile platforms.

As part of our conservation initiatives, we have also carried out species recovery efforts (i.e., efforts to slow the decline of an endangered or threatened species and to remove threats to its survival) for some critically endangered species of the Western Ghats. Along with researchers from other institutes, species recovery has been carried out for tree species such as *Semecarpus kathalekanensis* and *Myristica malabarica* in the Western Ghats. The recovery programme was carried out after obtaining critical information on the distribution of the species, identifying their ecological niches, and assessing the levels and distribution of genetic variability, besides understanding the demographics and the reproductive biology of the species. We have also carried out habitat restoration for some *Myristica* swamps in the Western Ghats that were on the verge of extinction.

[5] Priti, H., RS. Roshmi, B. Ramya, HS. Sudhira, G. Ravikanth, NA. Aravind, and KV. Gururaja. 2016. Integrative taxonomic approach for describing a new cryptic species of Bush Frog (*Raorchestes*: Anura: Rhacophoridae) from the Western Ghats, India. *PLoS ONE* 11(3): e0149382.

[6] Priti H., Gururaja, KV., and G. Ravikanth. 2015. Morphology, natural history and molecular identification of tadpoles of three endemic frog species of *Nyctibatrachus* Boulenger,1882 (Anura: Nyctibatrachidae) from Central Western Ghats, India. *Journal of Natural History* 49(43-44): 2667-2681.

[7] Raheem, D., H. Taylor, J. Ablett, RC. Preece, NA. Aravind, and F. Naggs. 2014. *A systematic revision of the Land Snails of the Western Ghats of India*. Bangkok: Chulalongkorn University.

[8] Aravind, NA, NA Madhyastha, GM. Rajendra and A. Dey. 2011. The status and distribution of freshwater molluscs of the Western Ghats. In: *The status and distribution of freshwater biodiversity in the Western Ghats, India* (Compilers: Mollur, S., KG. Smith, BA. Daniel, WRT Darwall. Cambridge, UK and Gland, Switzerland: IUCN, and Coimbatore, India: Zoo Outreach Organisation, Pp 59–72.

POLICY AND SYSTEMATICS

In the recent past, many researchers have highlighted the numerous impediments to the practice of taxonomy in India. Lack of support for taxonomic research, the dwindling number of research institutions involved in taxonomy, and the lack of trained human resource in taxonomy—specifically who can apply integrated taxonomic approaches for effective and sound conservation action, have been major obstacles to taxonomic research. Restrictions in specimen collections for taxonomic work imposed by Forest Departments and the National Biodiversity Authority (NBA), and restrictions on sharing herbarium specimens and other biological materials with experts abroad, are yet other stumbling blocks to practicing taxonomy. This will have a cascading effect on conservation of biodiversity and biological resources in India. We have made a significant effort in bringing various taxonomists and conservationists together to discuss appropriate amendments to the NBA regulations related to collection and sharing of biological materials to facilitate systematic revisions of Indian plants and animals. We have also written a series of critiques on the Biological Diversity Act, 2002, to improve the policy decisions that could facilitate taxonomic research in India[9,10].

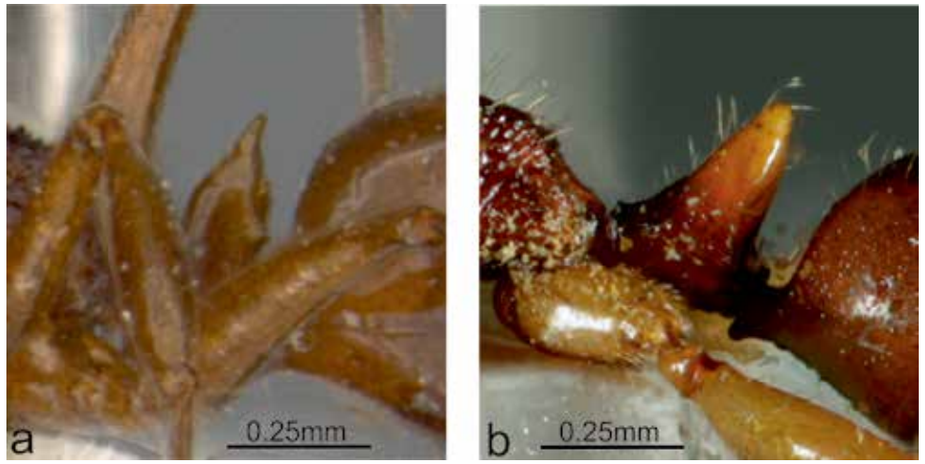
The Honnametti bush frog, collected from Biligiri Rangaswami Temple Tiger Reserve, highlights the importance of field studies in documenting biodiversity. (Photo: NA. Aravind)

KNOWLEDGE DISSEMINATION

Except for a few well-known taxa, the existing biological inventory data are largely patchy and incomplete in India. Availability of collated taxonomic information in an easily accessible form for the public or the policy maker could facilitate decision making for the conservation of species or habitats. One such effort is the India Biodiversity Portal (IBP), an open access biodiversity information platform developed by a consortium of organisations, including ATREE (http://indiabiodiversity.org/). The portal aims to establish a collaborative information system that will integrate an array of biodiversity

[9] Prathapan, KD., DR. Priyadarshanan, TC. Narendran, CA. Viraktamath, NA. Aravind, and J. Poorani. 2008. Death sentence on taxonomy in India. *Current Science* 94(2): 170–171.

[10] Prathapan, KD., and DR. Priyadarsanan. 2011. Biological Diversity: a common heritage. *Economic & Political weekly* 46(14): 15–17.



The curved tip of the projection found in the waist region is a unique distinguishing character for the ant, Anochetus daedalus *(b), from the other ant species of the genus* Anochetus neitneri *(a) . This photo (on left) emphasises the importance of museum collections in species discoveries.*

knowledge in order to identify and prioritise conservation of biodiversity in India[11].

Secondly, availability of curated information on plants and animals is critical for identification by the common public, either to document biodiversity at a regional scale, or to create awareness about rare plants and animals, and their habitat. We contribute to the India Biodiversity Portal in the form of species pages for selected group of plants, snails, insects, and invasive species. Curated information, including the taxonomy (valid published names, synonyms, etc.), description, distribution, species images, and scanned images from herbarium or museum collections are included in these species pages.

Contributions to IBP in the form of observations, pictures, notes, checklists, etc., from citizen scientists are also curated by us. Through annual interaction meetings, workshops for IBP at the regional level, taxa or group specific campaigns (e.g., the Neighborhood Tree Census, Moth Week, Bioblitz), ATREE contributes towards building ownership among contributors by documenting and disseminating information through IBP.

CONCLUSION AND THE WAY FORWARD

The Systematic Biology Group in ATREE, with its expertise in generating primary knowledge, has contributed towards describing new species of plants and animals, especially less charismatic and lesser known groups such as snails, dung beetles, ants, and frogs. Plant and animal species, and their habitats, have been prioritised for conservation and sustainable use of biological resources based on the taxonomic studies that have been carried out with the help of herbarium and museum specimen studies. Efforts have also been made to convince policy makers about the importance of allowing collection, and sharing of plant and animal specimens between experts globally to improve the science of systematics in India.

Outreach activities by the group in the form of sharing knowledge through online portals (IBP) and social media, involving citizen scientists, and courses and workshops related to biodiversity documentation and conservation, have increased public support for biodiversity conservation at the national level. The research- and outreach-based outputs from this group have influenced conservation planning for biodiversity and natural resources in India. Such efforts as biodiversity documentation, and prioritising species and habitats for conservation, have contributed to achieving national biodiversity targets related to biodiversity conservation.

Quality taxonomic research requires extensive collaboration and cooperation among specialists and institutions across countries, as biological species are distributed across national boundaries. For accurate generic and species determinations, it is essential to study specimens from across political boundaries and even continents. With our experience in addressing taxonomic impediments and biodiversity conservation issues in India, we plan to upscale our effort by partnering with other institutions in India and neighbouring countries. We also plan to harness communication and visual technologies to advance the science of systematics and to garner more support for conservation. Through research outputs, engagements with policy makers, and with the general public, we plan to influence policy related to biodiversity documentation and management in India.

Further Reading

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