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INTRODUCTION

EXPLORING SRI LANKA'S BIODIVERSITY

Rohan Pethiyagoda
Wildlife Heritage Trust of Sri Lanka, 95 Cotta Road, Colombo 8, Sri Lanka
Email: rohan@wht.org

The fauna and flora of Sri Lanka have generally been considered an extension of that of southern India, especially the southern Western Ghats, the range of mountains that borders the western littoral of the Indian peninsula (Myers et al., 2000). It has been widely recognized that the Western Ghats and Sri Lanka are "strikingly similar in their geology, climate, evolutionary history, and biodiversity" (Mittermeier et al., 2000: 353). The western Ghats-Sri Lanka region is now treated as a Global Biodiversity Hotspot, given that it has lost more than 70% of its original habitat and contains the required minimum 0.5% of Earth's vascular-plant species endemic to it (Myers et al., 2000; Mittermeier et al., 2004).

Sri Lanka's exceptional biodiversity is justly celebrated, but our knowledge of it rests largely on work done a century or more ago, in the heyday of colonial natural history activity. The standard specimen-based faunas even for many vertebrate groups, though long out of date, continue to be treated as current (and worse, reliable). However, as fashionable and important as biodiversity science has become, there is precious little exploration being done. Biodiversity inventories in Sri Lanka are for the most part antiquated, rarely based on recent field studies or taxonomic treatments involving critical comparison with type material. While everyone is agreed that biodiversity demands urgent conservation, our knowledge of its components—the very assets we seek to conserve—is both out-dated and incomplete.

Such knowledge can only be accumulated through intensive exploration: days and weeks of field work—sore hands and muddy feet—together with careful laboratory study (Dennis & Aldhous, 2004). Sadly, exploration is not a concept deeply engrained in Sri Lankan culture. Indeed, there is no local-language expression for it, the most widely used word, "gaveshanaya", deriving from the roots for "to search for cattle" (P. B. Meegaskumbura, pers. comm.). In any case, would-be explorers are disheartened by the dwindling extent of habitat remaining to be explored. Little Sri Lankan wilderness, and less than 5% of rainforest, has survived the massive expansion of agriculture the past two centuries have witnessed. Other trends too, do not auger well: Sri Lanka's population growth continues at over 1.4% yr^{-1} and population density in its biodiversity-rich south-western wet zone quarter is 700 km^{-2}, the highest of all the gobal biodiversity hotspots (Anon., 2003; Cincotta et al., 2000).

After languishing for several post-Independence decades, natural-history studies in Sri Lanka began to gather momentum with the commencement of a revision of the entire vascular-plant flora by Dassanayake & Fosberg (1980–2004), extensive studies of hymenoptera by Krombein (see Krombein, 1980, for an overview) and the tradition of field biology initiated by Senanayake (1980). The 1990s witnessed a steadily growing output of works across an increasing diversity of taxa and disciplines.

Encouraged by these developments, and several promising parallels across the Palk Strait, a new phase of biodiversity exploration has now clearly begun in the Western Ghats-Sri Lanka biodiversity hotspot. Recently, the discovery of a new family of frogs was announced from the foothills of the Western Ghats of Kerala State, southern India: the first newly-discovered amphibian family since 1926 (Biju & Bossuyt, 2003; Frost, 2002). Only last year the discovery of a new species of owl from Sri Lanka—the first new bird-species described from the island in 132 years—was reported by Warakagoda & Rasmussen (2004). Since ca. 1990, a steady but modest growth in biodiversity exploration has led to the discovery and description of five new species each of freshwater fish, amphibians and lizards, together with ~ 20 flowering plants and a large number of insects, not counting those described in this volume.

As might be expected, the disciplines being researched too, have been steadily increasing. In this supplement of *The Raffles Bulletin of Zoology*, the editors have sought to present reports representative of work done or in progress by many of the workers engaged in biodiversity research on Sri Lanka. It is poignant that almost a century and a half ago, the pioneer

Sri Lankan naturalist E. F. Kelaart (1852) had planned that publications such as this should be produced periodically as volumes of his (1853) "Prodromus faunæ Zeylanicæ" (see Pethiyagoda & Manamendra-Arachchi, 1997). While Kelaart intended mostly the building of a taxonomic inventory, the picture being painted by present-day workers on Sri Lanka's biodiversity weaves together geology, biogeography, ecology, ethology, taxonomy, conservation science, climatology, palaeontology and many other disciplines.

The recent surge in interest in Sri Lanka's biodiversity is serving to show that both species richness and endemism are for most groups of animals much higher than previously estimated. The reasons for this (apart from, simply, more exploration), are finally becoming clearer. It has long been known that Sri Lanka, being a continental island separated from southern India by only the ~ 20 km-wide, 10 m deep Palk Strait, has experienced prolonged connection to India during much of the Pleistocene, when sea levels were repeatedly depressed for extended periods. During the last glacial maximum (~ 20,000 ybp) for example, sea levels were ~ 120 m lower than today, resulting in a ~ 140 km-wide land bridge with southern India; indeed, such connections have existed for more than half of the past 500,000 yr and until more recently than 10,000 ybp (Rohling et al., 1998). The present-day island's high biotic endemism therefore comes as something of a surprise.

Recent molecular investigations across many groups of animals and plants have begun to paint an increasingly more interesting picture. Working on molecular genetics of leopards, Miththapala et al. (1995) showed the Sri Lankan population to be an endemic subspecies (*Panthera pardus kotiya*) genetically distinct from the mainland one. Following on this, Fernando et al. (2000) demonstrated that Sri Lankan elephant populations were not only clearly distinct from their mainland counterparts, but also that they themselves displayed significant geographic differentiation within the island. Schulte et al. (2002) went on to show that the endemic radiation of Sri Lankan agamid lizards of the genus *Ceratophora* were derived from a common 'Indian' ancestor ~ 13 mya and that even closely-spaced insular populations had been genetically isolated for several million years. Macey et al. (2000) and Austin et al. (2004) showed that the Sri Lankan members of the agamid lizard genus *Calotes* and the skink genus *Lankascincus* both represent endemic insular radiations. Investigating a much more speciose group, Meegaskumbura et al. (2002) revealed the same to be true for the 32 species of Sri Lankan *Philautus* shrub-frogs they analysed. Finally, through a molecular analysis of Indian and Sri Lankan uropeltid snakes, caecilians, shrub frogs (*Philautus:* Rhacophorinae), freshwater fish (*Puntius:* Cyprinidae), crabs and atyid shrimps, Bossuyt et al. (2004) showed that despite frequent and prolonged land connections with India, exchange between the mainland and insular faunas has been extremely restricted during the past 500,000 yr. These faunas are rich and largely autochthonous, the island—especially its south-western wet zone—being in effect a hotspot within a hotspot. Independent studies have reinforced this conclusion: e.g. Dubois & Ohler (2001) showed the presence in the island of an endemic monotypic subfamily of frogs (Ranidae: Lankanectinae). Roelants et al. (2004) have argued compellingly that that this ancient relict lineage branched off well before the ranine and rhacophorine radiations that now dominate this family in Asia.

The reasons for Sri Lanka's extended biotic isolation despite prolonged terrestrial connections to the mainland are not yet clearly understood, but probably relate to desertification of the land bridge during relatively dry glacial maxima (a conclusion supported in part also by the pollen-core study of Premathilake & Risberg, 2003). Indeed, the degree and duration of isolation appear to be such that significantly higher species-level endemism should not be unexpected even in the more vagile taxa, such as the birds (and indeed, a recent partial taxonomic review has served to increase the number of endemic bird species from 24 to 33: Rasmussen & Anderton, 2005).

In addition to documenting newly-discovered diversity, many of the papers presented in the present volume underline the distinctiveness of the Sri Lankan biota vis-à-vis that of India. A total of 43 new species of vertebrates are described from the island (one mammal, five geckos, two agamid lizards and 35 frogs), together with a new genus and a new species of shrimps, 14 new species of freshwater crabs and five mosses new to the island. Two further field studies demonstrate that diversity and endemism among both land snails and caecilians are significantly higher than previously suspected. These discoveries are not altogether unexpected, and indeed, are long overdue. More than a century-and-a-quarter ago, William Ferguson knew of Sri Lanka's 'cryptic' diversity of tree frogs: "When Dr. Günther's great work on the reptiles of British India (including Ceylon) was published in 1864," he wrote, "there were then only three species of a genus of small tree frogs, named *Ixalus*, and confined to the damp forests of the interior, known to be in the island, whilst no less than eleven new species have been added since the publication of Dr. Günther's work, and I have reason to believe that from twenty to thirty species of this genus alone exist in the island, besides frogs of several other genera" (Ferguson, 1877).

These discoveries provide, however, little cause for jubilation. Assessments of the conservation status of the freshwater crabs and agaimid lizards shows that 37 of 51 and 11 of 17 species respectively, are threatened. The status of the Amphibia is arguably worse still: the recently-concluded Global Amphibian Assessment (Stuart et al., 2004) showed that 42 of Sri Lanka's current total of 94 amphibian species are threatened, and a further 19 extinct (i.e., 56% of the world total of 34 confirmed amphibian-species extinctions in the past five centuries). Two freshwater fish species too, appear to have become extinct in the past two decades (Pethiyagoda, 1994).

The pattern across less-studied groups is probably just as grim: in their revision of the angiosperm flora, Dassanayake & Fosberg (1980–2004) failed to discover living populations of ~ 130 species, 23 of them endemic trees. The ravages of habitat loss in Sri Lanka's once rain-forested wet zone have been severe, and there is a compelling argument for intensive conservation management of the surviving forests. Indeed, in the present volume, taking hills within lowland rainforest landscapes as an example, Gunatilleke et al. make a compelling argument for replacing the current species-protection paradigm with one of habitat prioritisation and landscape management.

We need to bear in mind also that many threats to biodiversity are subtle and difficult to detect except through the recording of long-term trends. A telling recent example comes from the study by Dahdouh-Guebas et al. (2005) of the impacts of upstream impoundment of the Walawe River, Sri Lanka, on down-stream mangrove-species composition. An examination of data accumulated over 38 years showed that the extent of mangroves had increased by 24–550%, something that would be widely perceived as positive. Ominously however, the authors found that the relative abundance of individual mangrove species had altered dramatically, with some freshwater-adapted species increasing their abundance up to 30 fold. In an exemplary interdisciplinary treatment, they also found that the changes had resulted in significant and unforeseen negative socio-economic impacts. Studies such as this underline the limitations of broad-brush estimates of, for example, forest extent, that are so widely used to assess ecosystem health; they also emphasize the need for long-term population, species and site-based research programmes.

While many authors advocate improved conservation practices and further research, the regulatory framework for access to biodiversity (access being necessary for both conservation and research) in Sri Lanka is hardly conducive to either activity. This situation, ironically, has deteriorated following the 1992 Convention on Biological Diversity (CBD) and its assertion of sovereign ownership of biodiversity (Pethiyagoda, 2004). Many developing-country governments, by (correctly) asserting sovereign ownership, have unwittingly alienated their own citizens, who are the de facto custodians of biodiversity. Change can come not just through legal reform, but through a genuine adoption of the CBD's goals: conservation, sustainable use and the equitable sharing of benefits. Mechanisms for the wise use of the products of biodiversity are yet to be devised in Sri Lanka, and the rights and obligations of society with regard to biodiversity identified. It is also yet to be generally recognized that the objects of the CBD cannot be delivered in the absence of sound, scientifically accumulated data and a wide range of informed opinion. The papers in this volume are intended to deliver such data.

These papers are also a tribute to international cooperation as envisaged in the CBD. Many of them have become possible only through international scientific collaboration and funding, the improvement of institutional capacity, and the exchange of materials in a manner consistent with the CBD's objects. Biodiversity cannot be conserved unless its components are understood, together with the interactions between them, the trends that affect them and the causes of these trends. It is only by the unfettered flow of resources, knowledge and materials among scientists worldwide that urgently needed research for conservation can be conducted, transcending the constraints of suspicion and nationalism that are the legacy of centuries of colonial exploitation.

One can but hope that the research presented in this issue will help place nature conservation in Sri Lanka on an emergency footing, with the present protectionist paradigm (Rahmani, 2001; Madhusudan & Shankar Raman, 2003) giving way to one of scientific conservation. Habitat loss and fragmentation, invasive species, soil erosion and environmental pollution arguably pose the most immediate threats to the survival of Sri Lanka's biodiversity, and these cannot be addressed by protection alone. In the coming years, these problems will be exacerbated by climate change and human population pressure. The solutions can come only from the intensive monitoring of key biotic and environmental parameters, leading to sustained scientific management interventions at the species, site and ecosystem levels, hand in hand with building public awareness of the need to conserve biodiversity, and empowering citizens to deliver on the CBD's objectives.

Scientific conservation interventions have been retarded in Sri Lanka by the unfortunate disconnect that exists between scientists and biodiversity managers. While hundreds of threatened species have been identified and enjoy legal "protection", scientific recovery strategies or site management plans either do not exist, or in the few cases where they do exist, are rarely based on scientific data and principles. The challenges that face biodiversity scientists in Sri Lanka go beyond the usual developing-country constraints of funding and technical capacity: the need of the hour is engagement between the scientific community and nature conservation managers so as to deliver truly scientific conservation practices.

The papers in this Supplement represent but a small fraction of the formidable body of exploration and research that remains to be done in order to secure the conservation of Sri Lanka's unique biodiversity. Even as the pace of biodiversity research accelerates however, the conservation dividend will continue to be poor unless the divides that exist between the government and the people on the one hand, and biodiversity managers and scientists on the other, are bridged through much greater engagement. Only then can an effective strategy be developed for securing the integrity of biodiversity as a whole, and preventing further extinctions.

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