ESSAY 4.1. PICKLED FROGS HELP BIODIVERSITY ASSESSMENT

At a time when amphibian populations globally are in decline, the recent discoveries of large numbers of new frog species on Sri Lanka, an island from which the pathogenic chytrid fungus has not yet been reported, may seem heartening (Meegaskumbura *et al.* 2002). A total of 42 new species of anurans have been described since 1993, and many more species are in the process of being formally described. Description of these new species necessitated the examination of all available type material, as well as other preserved voucher material, for all Sri Lanka's amphibians. As a result of the country's five-century history of colonial occupation, these specimens, collected largely between 1850 and 1950, lie scattered amongst natural history museums in Europe, the United States and India. In particular, since Sri Lanka was a British colony from 1796 to 1948, most type specimens are housed in The Natural History Museum (formerly the British Museum of Natural History), in London. Sri Lanka's own national museum contains no amphibian types whatsoever. Although locality information beyond 'Ceylon' is usually lacking on the specimen labels, these specimens provide the only available baseline of Sri Lanka's amphibian fauna before the island's primary rainforests were reduced to their present-day extent of approximately 750km^2.

The recent review of historical material served to highlight several key aspects. First, a number of species described in the 19th century, and since relegated to synonymy, were shown to represent valid taxa. Second, several 'new species' lay silently undiscovered among the old collections (Manamendra-Arachchi and Pethiyagoda 2005; Meegaskumbura and Manamendra-Arachchi 2005). At the same time, the Wildlife Heritage Trust's 1993-2005 comprehensive survey of the island's amphibian fauna provides a reliable record of the species still persisting on the island and their relative abundance. A comparison of the results of the recent biodiversity survey, together with the historically preserved specimens, revealed that 19 named anuran species have apparently disappeared from the island (an additional two undescribed species also appear to be extinct). Given that these 19 species had not been reported since their original collections before 1940, and were not recorded during the recent surveys across the island's remaining forests, they were formally declared Extinct according to the IUCN Red List categories and criteria (GAA; Stuart *et al.* 2004). Apart from a single species each from the endemic genera *Adenomus* and *Nannophrys*, the Extinct species all belong to the Oriental shrub-frog genus *Philautus* (Ranidae: Rhacophorinae), which shows a remarkable radiation in Sri Lanka. A total of 62 of the approximately 140 species currently recognized in this genus are endemic to Sri Lanka.

To put these findings in a global context, according to the results of the Global Amphibian Assessment, 19 of 34 amphibian species confirmed as Extinct worldwide are from Sri Lanka. Even though a further 122 species are considered 'possibly extinct' globally, the Sri Lankan total is still remarkably high. Given that the island accounts for only around 2% of the world's anuran species (which is high given its relatively small size: 65,000km^2), it is surprising that more than half of the confirmed amphibian extinctions worldwide have occurred on Sri Lanka.

This extinction phenomenon in Sri Lanka (19 of the 103 native species described to date) appears to have been driven largely by the destruction of suitable habitat. Since 1815, approximately 95% of the island's 16,000km^2 of rainforest was lost to coffee and cinchona plantations, later to be replaced by tea and rubber (Kumar *et al.* 2004). While large expanses of dry forest and scrub persist elsewhere in the island, these habitats only support three of the 68 extant endemic amphibian species, with only a single species, *Philautus regius* (DD), restricted to dry forest. Of Sri Lanka's 84 surviving anuran species, 11 are Critically Endangered (seven of them *Philautus*) and 28 Endangered (20 *Philautus*). Many of these surviving amphibian species, especially the *Philautus*, have extremely restricted ranges. Even where there are larger tracts of contiguous forest, the ranges of many of these species are restricted by altitude or vegetation, resulting in the total contemporary range of some species being as small as 5km^2. Some 17 species are known only from a single site each (per Ricketts *et al.* 2005), with some sites, such as Morningside and Knuckles Forest Reserve, being home to several endemic and threatened species.

Interestingly, though not unexpectedly, the results of the GAA also suggest that, among threatened direct-developing species worldwide, 65 out of the 115 (57%) species that are closely associated with freshwater are threatened by disease, compared with only 45 out of the 650 (7%) species not closely associated with freshwater. Given that the major global threat to direct developers appears to be habitat loss (Chapter 4), and most of the extant Sri Lankan direct developers are not associated closely with freshwater habitats, the role of waterborne diseases in Sri Lanka's extinction of direct developers may have been slight.

The large-scale extinction of many of the island's amphibians might have gone undetected if not for the historical collections in the world's natural history museums; unfortunately, old amphibian collections in Sri Lanka's National Museum have not survived the years to help facilitate this effort. Clearly, the extraordinary value historical collections represent by way of biodiversity baselines against which present-day surveys may be assessed, remains to be widely appreciated (Fig. 1). This is especially relevant at a time when the contemporary role and value of natural history collections is being questioned, and with many museums facing financial crises (Dalton 2003; Suarez and Tsutsui 2004; Winker 2004). Furthermore, historical collections can be useful in several other ways, as exemplified most recently by the detection of chytrid fungus in the skin of a museum specimen collected from near Monteverde, Costa Rica, and deposited in a museum well before declines were documented in the area (Puschendorf *et al.* 2006).

Interestingly, since most of the species that were recently described (Manamendra-Arachchi and Pethiyagoda 2005; Meegaskumbura and Manamendra-Arachchi 2005) were absent from early museum collections, it seems that past surveys of the island were not very thorough. The documentation of the extinction of so many species from such a limited collection suggests that these extinct species may be only a fraction of a much larger extinction event in Sri Lanka. The account of Sri Lanka's amphibian declines is also novel in that it combines a recent comprehensive survey of the island's amphibians with a re-examination of almost all preserved material worldwide. Many other tropical countries are similarly under-explored, and it is therefore likely that the global tally of recent amphibian extinctions will rise significantly when their historical collections are similarly evaluated and compared with current assessments of amphibian diversity.

Madhava Meegaskumbura, Rohan Pethiyagoda, Janice Chanson, David Wake and James Hanken

References

Dalton, R. 2003. Natural history collections in crisis as funding is slashed. *Nature* **423**:575.

Kumar, A., Pethiyagoda, R. and Mudappa, D. 2004. Western Ghats and Sri Lanka. Pp. 152-157, in: R.A. Mittermeier, P. Robles-Gil, M. Hoffmann, J.D. Pilgrim, T.M. Brooks, C.G. Mittermeier, J.L. Lamoreux and G. Fonseca (eds.), *Hotspots Revisited*. Cemex. 392 pp.

Manamendra-Arachchi, K. and Pethiyagoda, R. 2005. The Sri Lankan shrub-frogs of the genus *Philautus* Gistel, 1848 (Ranidae: Rhacophorinae), with description of 27 new species. *The Raffles Bulletin of Zoology*, Supplement No. **12**:163-303.

Meegaskumbura, M., Bossuyt, F., Pethiyagoda, R., Manamendra-Arachchi, K., Bahir, M.M., Schneider, C.J. and Milinkovitch, M.C. 2002. Sri Lanka: an amphibian hotspot. *Science* **298**:379.

Meegaskumbura, M. and Manamendra-Arachchi, K. 2005. Description of eight new species of shrub frogs (Ranidae: Rhacophorinae: *Philautus*) from Sri Lanka. *The Raffles Bulletin of Zoology*, Supplement No. **12**:305-338.

Puschendorf, R., Bolanos, F., and Chaves, G. 2006. Amphibian chytrid fungus along an altitudinal transect before the first reported declines in Costa Rica. Biological Conservation **132**:136-142.

Ricketts, T.H., Dinerstein, E., Boucher, T., Brooks, T.M., Butchart, S.H.M., Hoffmann, M., Lamoreux, J.F., Morrison, J., Parr, M., Pilgrim, J.D., Rodrigues, A.S.L., Sechrest, W., Wallace, G.E., Berlin, K., Bielby, J., Burgess, N.D., Church, D.R., Cox, N., Knox, D., Loucks, C., Luck, G.W., Master, L.L., Moore, R., Naidoo, R., Ridgely, R., Schatz, G.E., Shire, G., Strand, H., Wettengel, W. and Wikramanayake, E. 2005. Pinpointing and preventing imminent extinctions. *Proceedings of the National Academy of Sciences USA* **102**:18497-18501.

Stuart, S.N., Chanson, J.S., Cox, N.A., Young, B.E., Rodrigues, A.S.L., Fischman, D.L. and Waller, R.W. 2004. Status and trends of amphibian declines and extinctions worldwide. *Science* **306**:1783-1786.

Suarez, A.V. and Tsutsui, N.D. 2004. The value of museum collections for research and society. *BioScience* **54**:66-74.

Winker, K. 2004. Natural history museums in a postbiodiversity era. *BioScience* **54**:455-459.

The collections of the world's natural history museums represent important biodiversity baselines. Here, preserved amphibian specimens collected in Sri Lanka ca. 1900 are stored on the shelves of The Natural History Museum in London © Barry Clarke/NHM

ESSAY 4.2. AMPHIBIANS AND HUMANS SHARING ONLY ONE PLANET

To effectively conserve amphibian populations in the wild it is not only necessary to understand the needs of the individual species, but also the context in which conservation efforts will need to take place. By comparing overlays of individual species range maps with recent and future human demographic variables (such as human population density, population growth, Gross National Income, and poverty), it is possible to elucidate the social and economic context in which conservation action must be implemented. Here, we investigate the relationships between amphibian species richness and two of these variables, human population density and levels of poverty – using Infant Mortality Rate data (CIESIN 2005) as a surrogate – not as a means of looking for causal relationships, but rather to identify regions where conservation may be more challenging.

Human population density

By comparing the current human population density in 2005 (LandScan 2005) with the global distribution of all amphibian species it is possible to identify the regions that are favoured by both humans and amphibians (Figure 1). Regions with a large number of amphibian species and a high population density are mostly found in Asia, in particular southern and eastern India, south-east China, southern Sri Lanka, and Indonesia (especially Java), as well as coastal parts of West Africa, the Ethiopian Highlands, and the Albertine Rift of Central Africa. There are also similar regions in the eastern United States, which is a hotspot for salamander diversity. In South America, the Atlantic Forest is the most prominent region.

Considering that humans and amphibians are dependent on freshwater for survival, the arid regions of the world are the places with the fewest amphibians (often none at all) and very low human population densities. For example, the deserts of North Africa, central Australia, central North America, and Central Asia. The majority of amphibians prefer moist tropical conditions, and many of the regions rich in amphibian species, but with low human population densities, are the world's tropical rainforests, for example the Amazon, the Congo, the tropical Andes, Southeast Asia and northern Queensland in Australia (the Queensland Wet Tropics). Regions with low diversity of amphibians, but high human population densities, are in general cooler regions such as northern India, northern China and much of Europe.

By comparing the diversity of threatened amphibians with human population density it is possible to highlight regions where species conservation is most likely to come into conflict with increasing demand by humans for natural resources (Figure 2). Many of these regions are the same as those highlighted in Figure 1, for example south-east China, Java (Indonesia), the Albertine Rift of Central Africa, coastal West Africa, and the Ethiopian Highlands. Notable additions are the larger islands of the Caribbean, southern Mexico, and the Philippines. In India, the highest density of threatened amphibians is focused on the Western Ghats. Parts of the eastern United States, Europe and India that are rich in amphibian species and have high human population densities are no longer highlighted as they have relatively few or no threatened species. In Europe and the United States this may be because species susceptible to habitat loss may have declined a long time ago, and perhaps also because many of the resources on which humans in these areas rely on come from other regions, for example the forests of Africa and Asia.