HERPETOLOGICAL JOURNAL, Vol. 12, pp. 175-178 (2002)

THE AMPHIBIAN FAUNA AT TWO ALTITUDES IN THE SINHARAJA RAINFOREST, SRI LANKA

MAYURI R. WIJESINGHE AND P. N. DAYAWANSA

Department of Zoology, University of Colombo, Sri Lanka

Key words: frogs, diversity, abundance, distribution

Rainforests, which typically harbour rich assemblages of amphibian species, are heterogeneous environments exhibiting habitat diversity in terms of vegetation structure and composition, moisture and temperature levels, and resource availability. In turn, these factors significantly affect the distribution of amphibian populations therein (Scott, 1976). Sri Lanka is a biologically diverse island with a rich complement of endemic plant and animal species. The high percentage of endemism has resulted in south-west Sri Lanka – where almost 90 % of the endemic vertebrates are concentrated (Erdelen, 1989; Senanayake *et al.* 1977) – being named as a biodiversity "hot spot" (Myers, 1990; Myers *et al.* 2000). Faunal inventories to date have revealed the presence of at least 53 species of amphibians in Sri Lanka (Dutta & Manamendra-Arachchi, 1996), of which 26 species are endemic to the island. It has been suggested more recently that the amphibian population in the country represents a far greater number of species than hitherto recognized (Pethiyagoda & Manamendra-Arachchi, 1998).

Despite the high proportion of endemic species in Sri Lanka, the amphibians have received very little attention from research scientists in the past. Rapid assessment by transect sampling in the forests of Sri Lanka to collect data on fauna and flora has provided limited information on the occurrence of amphibian species (IUCN & WCMC, 1997), while data on abundance are virtually absent.

We present here the results of the first quantitative study carried out to determine the abundance of amphibian species in the Sinharaja forest, which is the only relatively large, undisturbed, lowland rainforest on the island of Sri Lanka. Altitudinal variation in Sinharaja gives rise to two main habitat types – lowland and submontane forest. Therefore, we sampled sites at two different elevations so as to get a more complete idea of the diversity of species within this rainforest ecosystem than would have been possible had we restricted the study to a single site.

Correspondence: M. R. Wijesinghe, Department of Zoology, University of Colombo, Sri Lanka. *E-mail*: lcaw@slt.lk

The Sinharaja forest is located in the south-western part of Sri Lanka, between latitudes 6°21' and 6°26' N and longitudes 80°21' and 80°38' E. It comprises the Sinharaja Reserve of 6130 ha and the Proposed Reserve of 5201 ha (IUCN, 1993), both of which are under state control. The Sinharaja forest was declared a World Heritage Site under the World Heritage Convention in 1989. The forest lies between the 3810 mm and 5080 mm isohyets, and rainfall is well distributed throughout the year, with no identifiable dry period (Gunatilleke & Gunatilleke, 1983).

Location 1: Kudawa. This site is located at the north-western end of the rainforest and is approached from the Kudawa village. Most of the area consists of parallel ridges and valleys, and in general the elevation does not exceed 400 m, with the exception of a few peaks. The vegetation here is classified as lowland wet evergreen forest, as originally described by De Rosayro (1950). The canopy of dominant trees reaches a height of around 40 m (Gunatilleke & Gunatilleke, 1983).

Location 2: Morning-side. Morning-side is situated at the eastern side of the Sinharaja forest at an elevation of around 900 m. The land here is relatively flat and is covered by sub-montane evergreen forest. The vegetation is essentially transitional, being intermediate in structure and physiognomy between the lowland wet evergreen and tropical montane forest types (IUCN, 1993). The height of the canopy trees is considerably lower than at Kudawa, and the Thangamalai plain at the extreme east has stunted vegetation and grasslands. The latter area was added to the Sinharaja Reserve only in 1988, and the boundaries have not been clearly demarcated as yet. Some areas contiguous with the Sinharaja forest, and proposed for inclusion within it, are still under private ownership (IUCN, 1993).

A population census of amphibians was conducted during the period April 1997 to April 1998 in the two selected locations within the Sinharaja forest. In total, forty-five quadrats were surveyed at each of the two study sites. Each quadrat measured 8 m x 8 m. The placement of the quadrats at the two sites was intended to represent a stratified random sample, inasmuch as the numbers of quadrats located by streams and within the drier areas of the forest were similar at both sites. Quadrats were not located in grassland areas at the edge of the forest at Morning-side. Sampling was undertaken monthly, with at least two quadrats being investigated at each site in each month. No sampling was conducted during days of heavy rain.

The technique used was the Visual Encounter Survey, a standard technique which has been recommended for the study of amphibian populations in tropical ecosystems (Heyer *et al.* 1994). The quadrats were systematically searched by walking in parallel paths across the plot, thoroughly searching among the litter, logs, rocks and vegetation up to a height of 3 m. Sampling was carried out at night when most species of amphibians are active. For all quadrats, a field crew comprising four persons made searches lasting one hour per quad-

rat, and sampling was carried out between 1900-2400 hr, using headlamps and torches. All the amphibians we captured were collected in bottles and were identified and released at the same locations the following morning. Collection of the animals enabled accurate identification and avoided double counting. Dipnets were used to sample amphibian populations in streams and pools.

TABLE 1.The numbers of amphibians captured in forty-five 64 m^2 quadrats at each of two study sites, Kudawa and Morning-side, in the Sinharaja rain forest, Sri Lanka. *Endemic species; ** Endemic genus. [1] *Adenomus kelaartii* (Manamendra-Arachchi & Pethiyagoda, 1998) was previously named as *Bufo kelaartii* (Dutta & Manamendra-Arachchi, 1996). [2] Bufonids with a small tympanum (less than one third of eye diameter) were earlier classified as *Bufo microtympanum* (Dutta & Manamendra-Arachchi, 1996) but now reclassified as *B. noellerti* (Manamendra-Arachchi & Pethiyagoda, 1998). [3] Species described by Manamendra-Arachchi & Gabadage, 1996. [4] An endemic rhacophorid, *Theloderma schmarda,* was observed opportunistically at Kudawa.

Species	Kudawa	Morning-side
Bufonidae		
Adenomus kelaartii **[1]	9	43
Bufo noellerti *[2]	-	3
*B. kotagamai**	10	-
B. melanostictus	2	-
Ranidae		
Rana aurantiaca	20	123
R. temporalis	10	54
*Limnonectes corrugatus**	3	27
*L. kirtisinghei**[3]	1	3
*Nannophrys ceylonensis***	4	-
Euphlyctis cyanophlyctis	1	-
Rhacophoridae[4]		
*Philautus nasutus**	1	-
P. variabilis	11	90
P. leucorhinus	11	9
*P. temporalis**	2	-
*P. hypomelas**	2	-
*Rhacophorus microtympanum**	11	48
*R. reticulatus**	2	5
*R. macropus**	31	90
*R. cavirostris**	8	3
*Polypedates cruciger**	4	3
P. maculatus	16	60
*P. eques**	1	1
*P. longinasus**	2	1
Microhylidae		
*Microhyla karunaratnei**	-	8
*Ramanella obscura**	-	3
Kaloula taprobanica	1	-
Ichthyophidae		
*Ichthyophis glutinosus**	1	1
Total	164	575

Litter depth was measured at 25 randomly selected locations in each study site.

A total of 739 individuals of 27 species was recorded from the two study sites, including 19 endemic species – two belonging to endemic genera (Table 1). The number of species far exceeds the total number of species previously recorded in this rainforest (Fernando & Perera, 1998; IUCN & WCMC, 1997). Kudawa (lowland site), with 24 species, had a greater species richness than Morning-side, which had 19 species. Although the majority of the species were recorded from both sites at varying abundance, the following 11 species were recorded from only one of the two sites: *Bufo kotagamai*, *B. melanostictus*, *Nannophrys ceylonensis*, *Euphlyctis cyanophlyctis*, *Philautus nasutus*, *P. temporalis, P. hypomelas* and *Kaloula taprobanica* from Kudawa, and *Bufo noellerti*, *Microhyla karunaratnei* and *Ramanella obscura* from Morning-side.

In general, the number of individuals of most species was rather low, with as many as 17 species, 14 of which are endemic, represented by no more than ten individuals at either site. Although Morning-side had a lower diversity in terms of species, the abundance of most of those species that were present in both sites was greater at Morning-side than at Kudawa. Nine of the species recorded from both the sites were represented by at least ten individuals at one or both of the sites. Eight of these species (*Adenomus kelaartii*, *Rana aurantiaca, R. temporalis, Limnonectes corrugatus, Philautus variabilis, Rhacophorus microtympanum, R. macropus* and *Polypedates maculatus*) had higher numbers of individuals at Morning-side than at Kudawa. We recorded significantly higher numbers of bufonids, ranids, rhacophorids and microhylids at Morning-side than at Kudawa. It is noteworthy that only one caecilian, *Ichthyophis glutinosus,* was recorded from each of the two sites; this, however, may have been because the sampling regime was not geared to sample such deep-burrowing species. The depth of litter at Morning-side (mean±SE: 52±1.0 mm) was much greater than at Kudawa (13±1.5 mm).

Our results indicate that the amphibian fauna was richer in species but poorer in abundance in the lowland site than in the sub-montane site within the Sinharaja rainforest. In our survey, eight species were restricted to the lowland site while only three species were restricted to the upland site. Surveys carried out at three higher-elevation forests in Sri Lanka (above 1500 m) recorded fewer species than we found, providing evidence that species richness declines with altitude (Bambaradeniya & Ranawana, 1998).

A number of factors may contribute to the differences between the amphibian assemblages. For example, it has been reported that, in contrast to Amazonian species, most south-east Asian amphibian assemblages are riparian or develop in water, with only a few species developing terrestrially (Zimmerman & Simberloff, 1996). At Morning-side there are flat areas of grassland where permanent and semi-permanent pools

provide suitable breeding habitats for many species of amphibian, as compared to the fast flowing streams at Kudawa. Morning-side also has several man-made, aquatic micro-habitats in the form of abandoned pits from illegal gem-mining in the past (IUCN, 1993); the pits have now become breeding sites for many species (Fernando & Perera, 1998). It has been found elsewhere that as the number of pools in a habitat increases, so the probability of an amphibian species occupying that habitat also increases (Mann *et al.*, 1991; Vos & Stumpel, 1996). It is likely that the higher abundance of species requiring water to breed (e.g. *Rana aurantiaca*) observed at Morning-side primarily reflects the availability of pools.

Terrestrial habitat structure is also an important factor that influences the occurrence of amphibians within an ecosystem (Dupuis *et al.*, 1995; Morrison *et al.*, 1995). The vegetation structure and composition at our two study sites are strikingly different. The vegetation of the north-western part of Sinharaja, at the lower elevation zone, is dominated by large trees belonging to the family Dipterocarpaceae (Gunatilleke & Gunatilleke, 1983). The forest has a closed canopy, trees are tall and of large girth, and undergrowth is sparse. Morning-side, in contrast, has a relatively open canopy and a relatively dense understorey. It has been reported that tropical forest treefrogs usually prefer to perch on understorey vegetation, which seldom exceeds 3 m in height, and that only a few species occupy or forage in large canopy trees because of their intolerance of desiccation (Stewart & Pough, 1983). The rhacophorids at Morning-side were seen to forage preferentially among the leaves of *Pandanus* sp., a common shrub in the understorey at this site. Thus, the vegetation structure of the two sites may have been a significant factor in accounting for the differences in distribution of rhacophorids at the two sites. An increase in depth of the litter layer with increasing altitude has been noted previously (Scott, 1976: Woods & Gallegos, 1970), and the greater depth of litter at Morning-side may account, in part, for the greater abundance of bufonids, ranids and microhylids inhabiting the upland site.

The findings of this study have important implications for conservation policy. With regard to Sinharaja itself, the inclusion of the eastern sector within the reserve forest is seen to provide a boost to the survival of the amphibian species that prefer cooler temperatures and high levels of moisture. This area was included within the protective framework of the Sinharaja forest only in 1988 and a part of the forest still remains under private ownership. A large extent of this area had been severely degraded by illegal gem mining, cultivation and deforestation in the past, and the peripheral areas of the forest still continue to be used for the cultivation of cardamom. Interestingly, the abundance of gem pits may have facilitated breeding by some species. Since the area was included within the reserve many illegal activities have ceased, resulting in the regeneration of the forest. Because of the importance of adjacent peripheral habitats for breeding of forest-dwelling species, conservation efforts should not be limited to the forest habitats but should be extended to the surrounding areas that could be said to form an integral part of the forest ecosystem.

The Kudawa section of the forest has received considerable protection over many years. Despite the high degree of protection, it is surprising to note that many species, especially those that were restricted to this site, were found in low numbers. This warrants further investigations to identify the ecological needs of these species and to determine whether the current conservation measures are adequate to maintain viable populations.

Acknowledgements. We are indebted to the Forest Department, Sri Lanka, for granting us permission to carry out this investigation in the Sinharaja rain forest. We are also grateful to the students of the University of Colombo who eagerly volunteered to work with us at night despite the rains and the hordes of leeches.

REFERENCES

Bambaradeniya, C. N. B. & Ranawana, K. B. (1998). Some amphibians observed in three montane forests of Sri Lanka. In: *Biology and conservation of the amphibians, reptiles and their habitats in South Asia,* 108-113. de Silva, A. (Ed). Amphibia and Reptile Research Organization of Sri Lanka, Peradeniya.

De Rosayro, R. A. (1950). Ecological conceptions and vegetational types with special reference to Ceylon. *The Tropical Agriculturist* **56**, 108-121.

Dupuis, L. A., Smith, J. N. M. & Bunnell, F. (1995). Relation of terrestrial-breeding amphibian abundance to tree stand age. *Conservation Biology* **9**, 645-653.

Dutta, S. K. & Manamendra-Arachchi, K. (1996). *The amphibian fauna of Sri Lanka.* Wildlife Heritage Trust of Sri Lanka, Colombo.

Erdelen, W. (1989). Aspects of the biogeography of Sri Lanka. *Franz Steiner Verlag Stuttgart* pp. 73-100.

Fernando, P. & Perera, R. (1998). Amphibia of the Sinharaja rainforest. In: *Biology and conservation of the amphibians, reptiles and their habitats in South Asia,* 118-125. De Silva (Ed). Amphibia and Reptile Research Organization of Sri Lanka, Peradeniya.

Gunatilleke, C. V. S. & Gunatilleke, I. A. U. N. (1983). A forestry case study of the Sinharaja rainforest in Sri Lanka. In: *Forest and watershed development and conservation in Asia and the Pacific* pp. 289-357. Hamilton, L. S. (Ed.). Westview press, Inc., Colarado.

Heyer, W. D., Donnelly, M. A., McDiarmid, R. W., Hayek, L. C. & Foster, M. S. (1994). *Measuring and monitoring biological diversity – standard methods for amphibians.* Smithsonian Institute, Washington.

IUCN (1993). *Management plan for the conservation of the Sinharaja forest (Phase III),* IUCN-The World Conservation Union, Country office, Colombo.

IUCN & WCMC (1997). *Designing an optimum protected areas system for Sri Lanka's natural forests, Vol. 2.*

IUCN-The World Conservation Union, Country office, Colombo.

Manamendra-Arachchi, K. & Gabadage, D. (1996). *Limnonectes kirthisinghei*, a new species of ranid frog from Sri Lanka. *Journal of South Asian Natural History* **2**, 31-42.

Manamendra-Archchi, K. & Pethiyagoda, R. (1998). A synopsis of the Sri Lankan Bufonidae (Amphibia: Anura), with description of two species. *Journal of South Asian Natural History* **1**, 213-246.

Mann, W., Dorn, P. & Brandl, R. (1991). Local distribution of amphibians – the importance of habitat fragmentation. *Global Ecology and Biogeography Letters* **1**, 36-41.

Morrison, M. L., Block, W. M., Hall, L. S. & Stone, H. S. (1995). Habitat characteristics and monitoring of amphibians and reptiles in the Huachuca mountains, Arizona. *Southwestern Naturalist* **40**, 185-192.

Myers, N. (1990). The biodiversity challenge: expanded hotspots analysis. *The Environmentalist* **10**, 243-256.

Myers, N., Mittermeir, R. A., Mittermeir, C. G., da Fonseca, G. A. B. & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature* **403**, 853-858.

Pethiyagoda R. & Manamendra-Arachchi, K. (1998). Evaluating Sri Lanka's amphibian diversity. *Occasional Papers of the Wildlife Heritage Trust*, No. 2, 1-12.

Scott, N. J. Jr (1976). The abundance and diversity of the herpetofaunas of tropical forest litter. *Biotropica* **8**, 41-58.

Senanayake, F. R., Soulé, M. & Senner, J. W. (1977). Habitat values and endemicity in the vanishing rainforests of Sri Lanka. *Nature* **265**, 351-354.

Stewart, M. M. & Pough, F. H. (1983). Population density of tropical forest frogs: relation to retreat sites. *Science* **221**, 571-572.

Vos, C. C. & Stumpel, A. H. P. (1996). Comparison of habitat-isolation parameters in relation to fragmented distribution patterns in the tree frog (*Hyla arborea*). *Landscape Ecology* **11**, 203-214.

Woods, F. W. & Gallegos, C. M. (1970). Litter accumulation in selected forests of the Republic of Panama. *Biotropica* **2**, 46-50.

Zimmerman, B. L. & Simberloff, D. (1996). An historical interpretation of habitat use by frogs in a Central Amazonian forest. *Journal of Biogeography* **23**, 27-46.

Accepted: 24.7.02