

Conservation and biogeography of threatened Amphibians of Eastern Sinharaja

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Despite some recent remarkable discoveries of new species (Manamendra-Arachchi and Pethiyagoda, 2005; Meegaskumbura and Manamendra-Arachchi, 2005), Sri Lanka has already lost 21 species of amphibians, this is about half the confirmed extinctions in the world. Nineteen of these Sri Lankan amphibians belong to genus *Pseudophilautus* (Meegaskumbura et al. 2007), all of which are terrestrial direct developers and many of which are habitat specialists, often requiring the shade of a canopy covered forest for survival. Eighty six percent of the currently known 67 *Pseudophilautus* species described from Sri Lanka are



Fig. 1. *Ps. procax*, a Critically Endangered, forest dwelling species, restricted to Eastern Sinharaja.



Fig. 2. *Ps. papillosus*, a Critically Endangered, forest dwelling species, restricted to Eastern Sinharaja.



Fig. 3. *Ps. lunatus*, a Critically Endangered, forest dwelling species, restricted to Eastern Sinharaja.



Fig. 4. *Ps. simba*, a Critically Endangered, leaf litter dwelling species, restricted to Eastern Sinharaja.



Fig. 5. *Ps. limbus*, currently designated as Critically Endangered, but has a wide extent of occurrence, lowland to Rakwana hills.



Fig. 6. *Ps. poppiae*, an Endangered, forest dwelling species, restricted to Eastern Sinharaja.



Fig. 7. *Ps. ocellaris*, an Endangered, forest dwelling species, restricted to Eastern Sinharaja.



Fig. 8. *Ps. auratus*, an Endangered, forest and open-area dwelling species, occur in Eastern Sinharaja.



Fig. 9. *Ps. decoris*, an Endangered, forest dwelling species, restricted to Eastern Sinharaja.



Fig. 10. *Ps. regius*, a Data Deficient species, lives in open areas and has a wide distribution.



Fig. 11. A satellite picture of Morningside area showing the amount of fragmentation to the habitat.



Fig. 12. Road, open grasslands and regenerating forest patches.

threatened with extinction (CR, EN or VU, IUCN Red List Categories) or are extinct (EX). Eastern Sinharaja (ES) harbors 10 *Pseudophilautus* species of which 5 are Critically Endangered (*Ps. procax*, *Ps. papillosus*, *Ps. lunatus*, *Ps. simba* and *Ps. limbus*), 4 are Endangered (*Ps. poppiae*, *Ps. ocellaris*, *Ps. auratus* and *Ps. decoris*) and 1 is Data Deficient (*Ps. regius*) (Fig 1-10); seven of the ten species are endemic to ES, highlighting the importance of ES as a refuge for threatened frogs (Fig. 11 & 12). Many of the *Pseudophilautus*, including the seven ES forms are point endemics (very restricted distributions). The point endemic nature of *Pseudophilautus* is due to a combination of the following characteristics: terrestrial direct development, habitat specialization, requirements of unique climatic conditions and constraints to reproduction.

Through *ex-situ* and *in-situ* observational studies (Bahir et al. 2005) and molecular phylogenetic analyses (Meegaskumbura et al. 2002) it is confirmed that all *Pseudophilautus* species show direct development. These frogs also show two major reproductive



Fig. 13. *Ps. hallidayi* laying eggs, shown to exemplify soil nesting behavior.

behaviors: soil nesting (most species; Fig. 13) and arboreal nesting (only seen in three species; Fig. 14); both these behaviors are observed in ES *Pseudophilautus* species.

Seven of the ES species, especially the Critically Endangered forms are only found in canopy-covered forests. Three of the ten species are found both in canopy covered forest and grasslands. The forest species specialize further by selecting certain perching heights and microhabitats (distance from water) within the forest strata. Species that survive in grassland take refuge amongst litter and grass tufts.



Fig. 14. *Ps. femoralis* female with egg clutch on leaf, soon after egg deposition, shown here to exemplify leaf nesting. The leaf nesting species in Eastern Sinharaja is *P. poppiae*, which is closely related to *Ps. femoralis*.

Recent microclimate monitoring work by us for temperature (Fig.15), relative humidity (Fig.16), light intensity and UV-radiation daytime fluctuations are dramatically different for forest habitats (includes natural and regenerating forests) and degraded grasslands and roads. However, the nighttime, fluctuations were more or less similar in all habitats. Some of the forest species, do not hide but lay on leaf surfaces, exposed to the subdued light and UV rays (in small amounts, UV is important for frog metabolism) that filters through the canopy, this they will never be able to do in an open habitat due to extreme conditions. So it seems that daytime climatic conditions, that are regulated by the particular habitat types is important in species distribution, rather than the night time conditions. When restoration of habitats is attempted, to help conserve amphibians, the conditions needed during the daytime should be closely considered.

When the distribution of Eastern Sinharaja *Pseudophilautus* are traced on a molecular phylogenetic tree (that of Meegaskumbura and Manamendra-Arachchi, 2011) it is apparent that they are distinct evolutionary lineages representative of the major clades of *Pseudophilautus* in Sri Lanka. The basal nature of several of the clades and the high endemism suggest that ES is a montane refugium and a center of endemism. Moreover, sister species of some of the Eastern Sinharaja *Pseudophilautus* are found in Lower Sinharaja (Kudawa) region (eg. *P. decoris* and *P. mittermeieri*, *P. procax* and *P. abundus*, *P. papillosus* and *P. reticulatus* sister species pairs). This shows the importance of maintaining the quality of habitat of Eastern Sinharaja and also the connectivity between Eastern and lower Sinharaja.

Several species that were not discovered in extensive surveys that were carried out from 1996-2004, have now arrived in ES. These

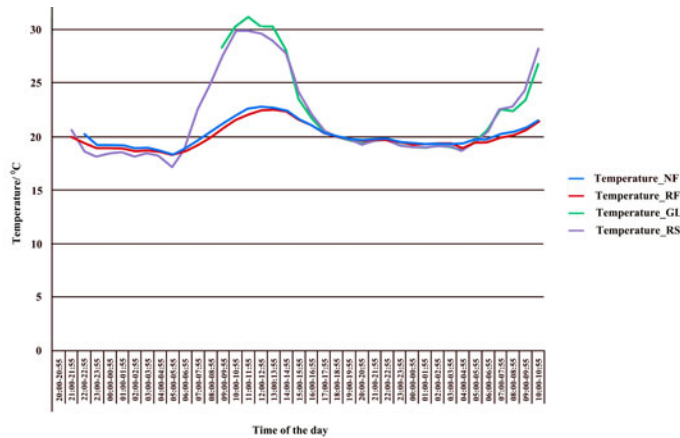


Fig. 15. Graph depicting the daily fluctuation of temperature in Natural Forests (NF) regenerating forests (RF), Grassland (GL) and Road-side (RS).

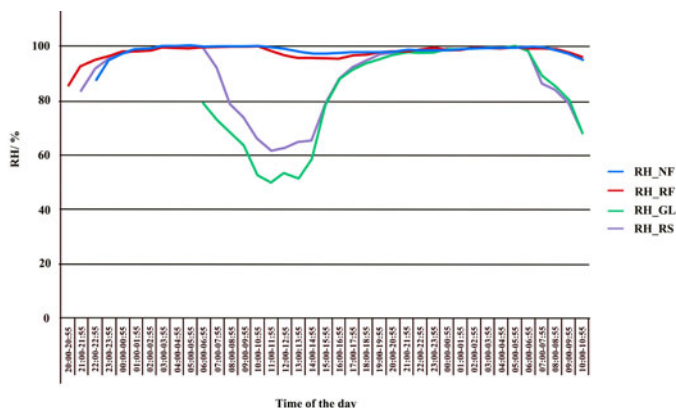


Fig. 16. Graph depicting daily fluctuation of relative humidity in Natural Forests (NF) regenerating forests (RF), Grassland (GL) and Road-side (RS).

are *Pseudophilatus rus* (LC: least concern, IUCN category; Fig. 17), *Ps. hallidayi* (VU; Fig.18) and *Ramanella obscura* (LC; Fig. 19); all these species are not threatened. If these species already occurred in Eastern Sinharaja prior to 2004, we should have found them, as they are common species where they occur (non threatened IUCN statuses also suggests this). However in 2005, *Ps. rus* was observed on the roadside to Morningside Bungalow; *Ps. hallidayi* was observed near Morningside Bungalow and *R. obscura* was observed in a regenerating forest patch; however at the time, their population size was low. By 2011, *Ps. rus*, was very common and occupied all habitat types; *R. obscura* and *Ps. hallidayi* were still a small population. In 2011, a dramatic drop of *Taruga fastigo* (CR) (Meegaskumbura et al. 2010), and *Ps. decoris* population was also observed.



Fig. 17. *Ps. rus*, a least concern species, which is a recent arrival at Eastern Sinharaja.



Fig. 18. *Ps. hallidayi*, a vulnerable species, inhabiting rocky areas (also live close to human dwellings); a recent arrival at Eastern Sinharaja.



Fig. 19. *Ramanella obscura*, a least concern species that often tolerates human made conditions well, a recent arrival at Eastern Sinharaja.

The issues discussed and the trends delineated portend a bleak future for the *Pseudophilatus* and other endemic animals of ES. The entire Sinharaja, together with ES, provides a gradual gradient for animals to disperse, especially with climatic change. In the event of a warming event, mid-elevation species can migrate over to ES, if they are to track colder climates.

Thus the maintenance of this altitudinal habitat gradient is critically important for the conservation of both ES and lowland rain-forest forms of Sinharaja. To ensure the non-establishment of invasive species, and to facilitate the ES endemic species, immediate action is needed to connect many of the scattered forest fragments through research driven reforestation programs. Activity, such as road building, encroachments, new plantations, which destroys connectivity in ES area should be minimized, while research activities and reforestation work is maximized. We have now started a long-term monitoring study in Morningside, which is being extended to an effort to restore critically important habitats.

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