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Short Communication

Drivers of reptile and amphibian assemblages outside the protected areas of Western Ghats, India

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ABSTRACT

Biodiversity conservation in forested landscapes outside protected areas is important to sustain populations of species with restricted ranges. However, such habitats face many anthropogenic threats, including logging, extraction of firewood and leaf-litter for mulch in plantations. In this study, we determined the effects of forest degradation on amphibians and reptiles in forests outside protected areas by measuring their species richness and community composition across a disturbance gradient from near pristine to highly degraded forests in Agumbe, Western Ghats, India. Twenty-one strip 15 m × 150 m transects were laid across the disturbance gradient and diurnal visual encounter surveys were conducted. Sampling was repeated three times per transect covering the dry, intermediate and wet seasons. Amphibian and reptile communities were affected by the decrease in canopy cover and leaf litter volume, respectively. Our results indicate that the collection of firewood and leaf-litter can severely affect amphibian and reptile populations. Structured conservation planning outside of protected areas is therefore imperative.

Introduction

Protected areas are one of the major ways to conserve tropical biodiversity (Laurance et al., 2012; Thomas et al., 2012; Jenkins & Joppa, 2009). However, in this changing world, it is not sufficient to conserve biodiversity only in protected areas because around 90% of the world's remaining tropical forest area lies beyond the borders of protected areas (WWF, 2002; Chazdon et al., 2009). Forests outside protected areas are often managed and modified by humans actively for a wide variety of traditional and commercial purposes. Examining the factors driving diversity patterns within these unprotected forest habitats can be helpful in assessing their conservation value (Klein et al., 2006; Clough et al., 2009; Sreekar et al., 2013a). The information obtained (direct threats and their contributing factors) from such studies will facilitate managers to more efficiently set priorities and allocate resources for effective management and conservation (Salafsky et al. 2008; Chazdon et al. 2009).

Unprotected forests in the tropics are primary targets for firewood extraction, and around 75% of the wood harvesting in Asia is for firewood (FAO, 2010). Such practices can significantly alter the canopy cover and leaf-litter volume, which are considered to be the most important drivers of amphibians and reptiles respectively (Inger & Colwell, 1977; Wanger et al., 2009, 2010). Amphibians and reptiles are the most threatened vertebrate taxa globally, with around 41% and 25% of all evaluated species respectively threatened with extinction (Butchart & Bird, 2010; Bohm et al., 2013; Faruk et al., 2013). Though, the biological diversity of reptiles and amphibians in different plantation types have been well documented (Wanger et al., 2009, 2010; Faruk et al., 2013), studies on their assemblages in forests outside protected areas are rare (Anand et al., 2010; Sodhi et al., 2010). Therefore, for better preservation of reptile and amphibian diversity outside protected areas, it is crucial to understand the environmental drivers of species responses to habitat degradation (Wanger et al., 2010; Gillespie et al., 2012).

Scientific studies on reptile and amphibian assemblages are particularly important in biodiversity hotspots such as the Western Ghats in southwestern India where around 86% of amphibians and 62% of reptiles are endemic (Gunawardene et al., 2007; Dinesh & Radhakrishnan, 2011). We determined the drivers of reptile and amphibian species richness, abundance and community

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composition across a disturbance gradient outside protected areas in Agumbe, Western Ghats, India and provide recommendations for conserving reptiles and amphibians outside protected areas.

Methods

Agumbe (13°50′ N, 75°09′ E; 560 m above sea level; Supplementary Material, Figure S1) experiences low temperature variation (26–33 °C), high humidity (75–96%) and high rainfall (7000–8000 mm), most of which is during the monsoon season (June–September; Sreekar et al., 2013b). The human population settled in and around Agumbe cultivate *Areca catechu* in their home gardens and an individual household collects an average of 3490 kg of leaf-litter for mulch and 1295 kg of firewood per year for domestic use (Gaffar, 2011).

The reptile and amphibian assemblages in the unprotected forests of Agumbe were sampled using a time-constrained visual encounter survey (Campbell & Christman, 1982) between March and August 2011. Twenty-one 15 m × 150 m strip transects were systematically laid to capture gradients in habitat characteristics from structurally primary to highly degraded forests. These habitats were sampled three times covering the general dry (March-April), pre-monsoon (May–June) and monsoon seasons (July–September). Sampling was conducted between 8:00 and 11:00 h in the morning. Each transect was thoroughly searched for one hour (in leaves, under logs, on bark and branches); all the reptiles and amphibians observed below 2 m height were noted (Supplementary Material, Table S1). Reptiles and amphibians that were sighted above 2 m height and outside the strip transect (15 m × 150 m) were not recorded, as perfect detection is a central assumption of this method. To control for the time chosen for sampling, only diurnal and crepuscular species were included in the analysis, strictly nocturnal species were removed from the data prior analysis. Two, closely-resembling, fast-moving, leaf-litter skinks *Eutropis macularia* and *Eutropis allapallensis* were grouped together due to difficulties in identifying them by sight and further taxonomic ambiguities (Mirza et al., 2010). This is also justifiable owing to their similar ecological niche and microhabitat use in the study site (RS, *pers. observ.*). Most *Fejervarya* species were only identified to genus level and given morphospecies identity (e.g. sp1, sp2) due to the existence of several cryptic species in this genus (Kuramoto et al., 2007).

To characterise each transect we measured the following habitat characteristics in five randomly selected points and used the mean of each parameter: (1) basal area of trees (tree defined as an individual with diameter at breast height greater than10 cm) using point centred quarter method, (2) canopy cover using a spherical densitometer (Forestry suppliers, Jackson, Mississippi, USA) (3) shrub density by counting the number of woody stems (<10 cm in girth and >30 cm in height) within 2 m radius, and (4) leaf litter volume by collecting leaf litter from an area of 1 m^2 and estimating the amount of litter in each sample by pressing the leaf litter samples in a bucket of known circumference (5000 cm^3) and measuring height (in cm) of the column (Supplementary material, Table S2). Data were suitably transformed for analysis: logit transformation of canopy cover (percentage data) and square-root transformation of shrub density (count data; Zar 1999).

Data analysis

To evaluate the effectiveness of sampling effort, the original reptile and amphibian species richness was transformed to an estimated richness by randomly adding 50 sampling sessions to the original data by using the bootstrap estimator, a measure that is considered more robust than other analytical estimators (Magurran, 2004). We used a regression model to estimate the correlation between the randomised original and bootstrap estimator data (Shahabuddin et al., 2005; Wanger et al., 2010; Sreekar et al., 2013a).

To examine the environmental variables that affect reptile and amphibian species richness and abundance patterns in the unprotected forests of Western Ghats, we used a generalised linear model with Poisson errors and a log link. Predictor variables included canopy cover, leaf litter volume and shrub density. Basal area was not included in the model because it was correlated with canopy cover (Spearman's rho = 0.58, P = 0.01). We employed an information-theoretic approach to examine the effects of our predictor variables on response variables (Burnham & Anderson, 1998). For each analysis, the full model, the null model and models with all valid combinations of the explanatory variables were generated. We compared and ranked models using Akaike's information criterion (AIC_c) (Anand et al., 2008; Hobbs & Hilborn, 2006). Akaike weights (wAIC) provided a relative weight for any particular model, which varies from 0 (no support) to 1 (complete support) relative to the entire model set (Burnham & Anderson, 1998). We summed up the wAIC of all the models containing a particular covariate (covariate weight) within the subset to identify the covariates that had the strongest influence (Anand et al., 2008; Burnham & Anderson, 1998). We present model averaged estimates and their unconditional standard errors for covariates with highest Akaike weight (w).

To examine variation in species composition across the landscape, we used a multivariate generalised linear model (Wang et al., 2012) with environmental parameters (canopy cover, leaf litter volume and shrub density) as predictor variables using the function *manyglm* in the package *mvabund*. Negative binomial regression structure was specified in our models. We calculated the test statistics with Monte Carlo resampling (999 iterations). We used multivariate generalised linear models instead of traditional distance-based analyses (e.g. correspondence analysis and non-metric dimensional scaling) because of the community-level heteroscedasticity in point count matrices that causes Type I and II errors (see Warton et al. 2012). All analyses were conducted in the programming and statistical language R 2.15.2 (R Development Core Team, 2012).

Results

During this study a total of 199 amphibians and 129 reptiles were recorded (see Supplementary Material Table S1). Consequently, nine (32%) of 28 amphibian species and eight (15%) of 53 reptile species known from the study area were used in the analysis (Purushotham & Tapley, 2011; Ganesh et al., 2013). Sampling across points seemed to be sufficient for analysis, as estimated raw species richness was only slightly higher than observed richness (mean percentage increase in site richness with bootstrap estimator, amphibian = 8.7 ± 6.4%; reptile = 4.6 ± 5.9%). Moreover, the randomised original and the bootstrap estimator data were highly correlated (amphibians: R^2 = 0.998; reptiles: R^2 = 0.995), so we made further direct comparisons with original species richness data rather than estimated values.

Patterns in amphibian species richness and abundance were best explained by canopy cover (Table 1 and Fig. 1). Abundances of *Frejervaya rufescens, Frejervarya sp2 and Hylarana aurantica* increased with canopy cover, while the abundance of *Hylarana temporalis* increased with leaf litter volume and the abundance of *Clinotarsus curtipes* decreased with increase in shrub density (Table 1). Reptile species richness and abundances were best explained by leaf litter volume (Table 1 and Fig. 2). Though leaf litter volume best explained the patterns of reptile species richness, the