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# Seasonal and Land Use Effects on Amphibian Abundance and Species Richness in the Sakaerat Biosphere Reserve, Thailand

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**Abstract**

Habitat destruction and degradation in the tropics has led to a dramatic increase in altered habitats. Understanding the impacts of these disturbed areas on biodiversity will be critical to future conservation efforts. Despite heavy deforestation, Southeast Asia is underrepresented in studies investigating faunal communities in human-modified landscapes. This project assessed the herpetofaunal community in dry dipterocarp forest, secondary disturbed forest, and Eucalyptus plantations in the Sakaerat Biosphere Reserve. In May, June, and September of 2015, we surveyed using 10 passive trapping arrays. Both the Eucalyptus plantations and secondary disturbed forest habitats (224 and 141 individuals, respectively) had higher amphibian abundance than the dry dipterocarp forest (57 individuals), but we observed significant seasonal variation in amphibian abundance. During the wetter month of September, we recorded higher numbers of amphibian individuals and species. In particular, we noted that distance to a streambed influenced amphibian abundance during the rainy season. The three most abundant species in May and June were *Microhyla fissipes*, *Fejervarya limnocharis*, and *Microhyla pulchra*. In September, the three most abundant species were *Microhyla fissipes*, *Glyphoglossus molossus*, and *Kaloula mediolineata*. Our findings suggest that seasonal resources should be considered when conducting monitoring programs and making conservation decisions for amphibians.

**Keywords:** Amphibian; Conservation; Seasonal patterns; Protected area management

## Introduction

Protected areas alone cannot completely foster the world's biodiversity [1], thus understanding the role of human-disturbed areas in conserving the world's diversity is critical. The global protected area network covers 460 million ha (~12.5% of total forest area) [2] of forest cover from deforestation. However many reserves are becoming isolated from other large tracts of undisturbed landscapes [3-4]. Isolation could mean extinction for a multitude of species as global climate change puts additional pressure on populations by shifting suitable habitat ranges [5].

Deforestation and other anthropogenic impacts such as urbanization and poaching are causing declines across all taxa; however, amphibians are the most threatened of all terrestrial vertebrates [6]. Several studies from Southeast Asia report that amphibian species richness decreases in response to habitat disturbance and increased fragmentation [7-8]. Despite the high rate of deforestation [9-10], Southeast Asia is generally underrepresented in studies on faunal community response to habitat loss and response to human-modified landscapes [11-12].

Thailand is home to more than 183 species of amphibians [13]. The herpetofaunal diversity and the level of human disruption make Thailand an ideal site to investigate the impacts of land-use change on tropical amphibian communities. To address the knowledge gap we assessed the amphibian community in dry dipterocarp forest, secondary disturbed forest, and eucalyptus plantations in the Sakaerat Biosphere Reserve, Thailand.

## Materials and methods

### 1) Study sites

Our study was conducted at the Sakaerat Biosphere Reserve (SBR), located in Nakhon Ratchasima Province, Thailand (14.44–14.55°N, 101.88–101.95°E). The reserve consists of an 80 km$^2$ core area (Figure 1) combined with buffer and transitional zones totaling 360 km$^2$, consisting mostly of agricultural and settlement areas. The core area of the reserve consists of primary growth dry evergreen forest, dry dipterocarp forest and secondary reforestation [14].

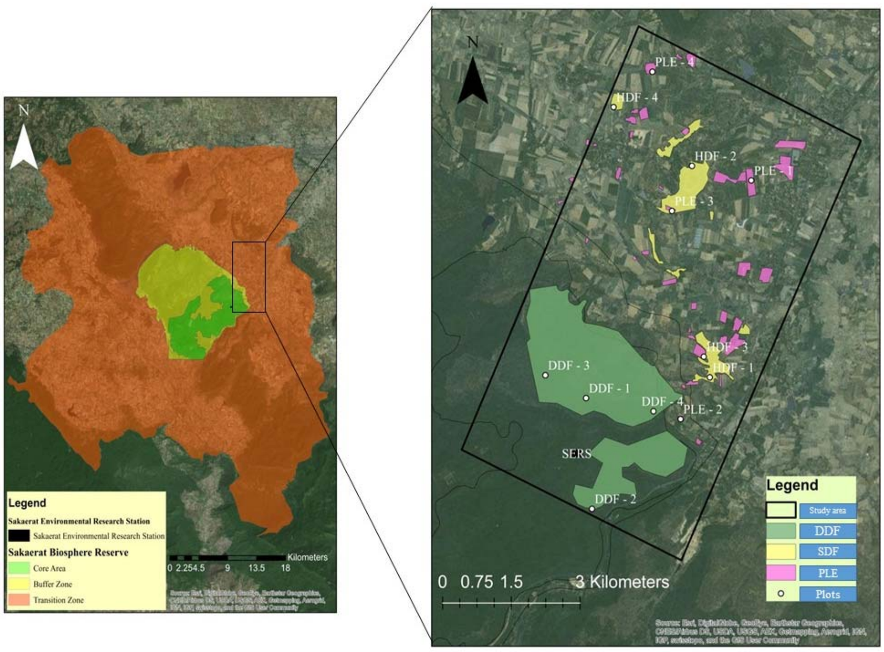


**Figure 1** Map of the Sakaerat Biosphere Reserve delineating core, buffer, and transition areas (left) and the study site with the dry dipterocarp forest (DDF), secondary disturbed forest (SDF) and *Eucalyptus* plantations (PLE) shown (right).

**2) Amphibian sampling**

We sampled amphibians in three habitats: dry dipterocarp forest (DDF), secondary disturbed forest (SDF) and small-scale *Eucalyptus* plantations (PLE). Both the SDF and the PLE sites were situated in the disturbed landscape of the transition zone of SBR, while the DDF sites were all located within the core area. We randomly selected each plot site using ArcGIS 10.1. We surveyed using 10 Y-shaped passive trapping arrays with each line measuring 15 m. Each array consisted of 12 double funnel traps and three 40 L pitfall traps (Figure 2). We assessed habitat characteristics at each site collected from six 1 m x 1 m quadrats at each site, with three set 7.5 m from the center away from each line, and three sets located 3 m away from the end of each line (Figure 2). We measured several environmental variables at each plot including percent canopy cover, percent groundcover and leaf litter depth. To collect landscape variables such as elevation and patch size, we used Arc-GIS mapping software. Elevation data was collected using a high resolution digital elevation model [15], while patch size was estimated using geometry tools in ArcGIS.

Both May and June had lower precipitation than September (Table 1). Despite the differences in precipitation of 2015, the average rainfall in May (107.8 mm) and June (90.8 mm) over the past 4 years are comparable. Due to differences in average temperature, relative humidity, and rainfall, May and June were categorized as dry season samples and September represented a single rainy season month. We sampled in May and June of 2015 to assess amphibians in the dry season, and in September for a wet season sample. By the end of September, four sampling sites had been lost to theft; unfortunately we did not have the material or manpower to replace the plots and thus had to conclude the study. Within the study area, only two species are listed as 'Near Threatened' (Kaloula mediolineata (Smith, 1917) and Glyphoglossus molossus (Günther, 1869) on the IUCN Red-list [16]. Over-hunting may be a serious concern for these species, as one study noted that local villagers were removing roughly 6 kg per person per day [17].

We elected not to sample in July or August as mortality rates were high in both May (16.4% of all captures) and June (15.5% of all captures), most likely due to the prevailing high temperatures and low relative humidity. We recorded high mortality rates despite adding wet sponges and building shaded coverings over traps. Each site was sampled for three days in May, June, and September. We sampled half of the plots, representing an equal number for each forest type for 3 days, and then switched to the second set. We elected not to use mark and re-capture, as toe-clipping can have negative impacts on individuals and cause biased re-capture rates [18].

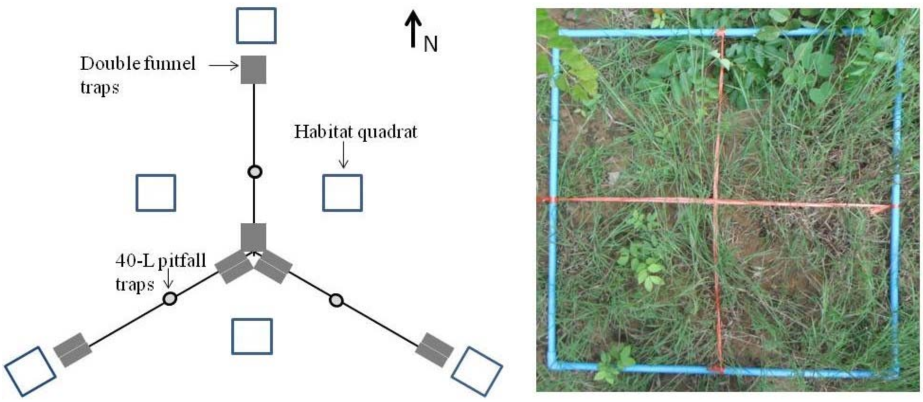


**Figure 2** Plot layout showing the locations used to assess habitats (left) and an example quadrat used to estimate ground cover in the study (right).

**Table 1** Monthly weather conditions for 2015 at the Sakaerat Biosphere Reserve showing the mean daily values for each month

| Month | Mean Daily Maximum (˚C) | Mean Daily Minimum (˚C) | Mean Daily Average (˚C) | Humidity (%) | Rainfall (mm) |
|---|---|---|---|---|---|
| January | 27.7 | 16.8 | 17.3 | 74 | 19.2 |
| February | 31 | 19.9 | 28.3 | 74 | 21 |
| March | 34.1 | 23.8 | 24.4 | 78 | 75.1 |
| April | 33.9 | 24.3 | 24.9 | 78 | 84.6 |
| May | 35.4 | 25.6 | 26.2 | 78 | 8.4 |
| June | 34 | 24.9 | 25.5 | 78 | 87.2 |
| July | 32.7 | 24.4 | 25 | 78 | 84.7 |
| August | 31.1 | 23.7 | 24.4 | 82 | 162.5 |
| September | 29.7 | 23.4 | 24 | 87 | 264.7 |
| October | 27.8 | 22.3 | 22.8 | 81 | 172.2 |
| November | 27.9 | 21.8 | 22.4 | 75 | 35.7 |
| December | 28.4 | 19.4 | 20.7 | 74 | 0.2 |

**3) Data analysis**

We assessed amphibian abundance among habitat types using an ANOVA test, after checking whether the data met the assumptions of normality and homoscedasticity. As the abundance data between months did not meet the assumptions for parametric analyses, we conducted a Friedman test with a Wilcoxon rank sum test to compare between months. We calculated diversity for each habitat type during each season using the Shannon-Wiener index (Eq. 1) which incorporates species richness and even-ness to calculate diversity [19].

$$H' = - \sum_{i=1}^{s} p_i \, ln \, p_i \qquad \text{(Eq. 1)}$$

where $p_i$ denoting the proportion in specie *s*.

**Results and discussion**

Throughout the course of the study, we captured 422 individuals from 14 species across all habitat types (Table 2).

Amphibian abundance did not vary significantly among habitat types when comparing total number of captures at each site (ANOVA; df = 2, F = 2.545, $p$ = 0.148). However, within each habitat type, there was significant variation across sites (Table 3). The high variation within forest types could explain why we did not observe any significant difference between forest types.

Amphibian abundance varied significantly between each month that we sampled (Friedman test; $\chi^2$ = 13.027, df = 2, $p$ = 0.001) (Figure 3). In September, we captured 290 individuals compared to 18 in May and 114 in June. Amphibian abundance differed significantly between September (V = 1, $p$ = 0.035) and June (V = 0, $p$ = 0.006) ha. However, June and September did not show a significant difference in amphibian abundance (V=12.5, $p$ = 0.138). Nevertheless, as we did not employ the mark and re-capture technique, the observed abundances may be inflated as we cannot confirm that each capture was a unique individual. In the disturbed habitats, this could be an important factor as viable amphibian habitat is likely smaller than in the protected forest, which could lead to higher recapture rate, as individuals cannot readily disperse from the trapping array. Diversity and species richness were highest in the PLE forest across all months (Figure 3). However, both species richness and diversity peaked in all habitat types during September. Our findings contrast with another study from Khao Yai National Park that reported highest amphibian abundance during the dry season [20]. However, the study sampled along a stream and did not look at sites further away from a permanent water source, which could account for the conflicting results.

**Table 2** Abundance of all amphibian species captured by habitat type sampled

| Family | Species | DDF | SDF | PLE | Total |
|---|---|---|---|---|---|
| Bufonidae | *Duttaphrynus melanostictus* | | 1 | 5 | 6 |
| Dicroglossidae | *Fejervarya limnocharis* | 2 | 20 | 31 | 53 |
| | *Occidozyga lima* | | | 5 | 5 |
| Microhylidae | *Calluella guttulata* | | 1 | 10 | 11 |
| | *Glyphoglossus molossus* | 18 | 2 | 28 | 48 |
| | *Kaloula mediolineata* | 20 | 27 | 11 | 58 |
| | *Kaloula pulchra* | 13 | 5 | 13 | 31 |
| | *Microhyla butleri* | 1 | 11 | 19 | 31 |
| | *Microhyla heymonsi* | 1 | 6 | 28 | 35 |
| | *Micryletta inornata* | | | 11 | 11 |
| | *Microhyla fissipes* | 1 | 37 | 51 | 89 |
| | *Microhyla pulchra* | 1 | 31 | 8 | 40 |
| Ranidae | *Hylarana erythraea* | | | 1 | 1 |
| | *Hylarana macrodactyla* | | | 3 | 3 |
| | Grand Total | 57 | 141 | 224 | 422 |

**Table 3** Descriptive abundance data on for amphibian abundance for each of the sampled habitats

| Habitat type | Total abundance | Mean ± SD |
|---|---|---|
| DDF | 57 | 14.25 ± 27.2 |
| SDF | 141 | 47 ± 27.7 |
| PLE | 224 | 74.7 ± 48.8 |

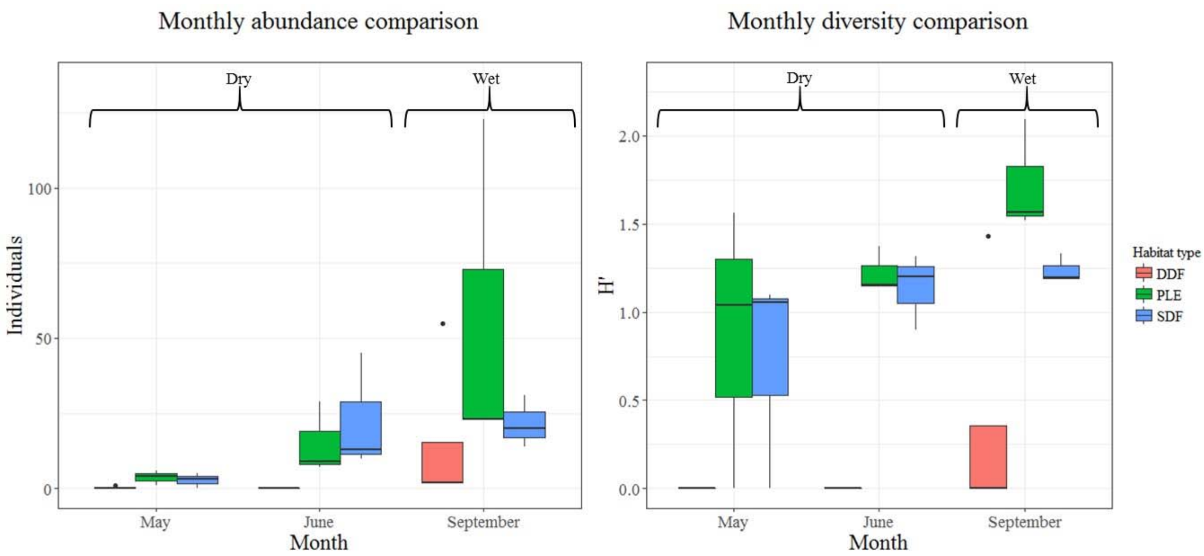


**Figure 3** Boxplots of monthly amphibian abundance (left) and monthly Shannon-Wiener index (right) for each habitat type.

Additionally, we observed higher species richness in September with 12 species compared to 9 in both May and June. While the rainy season yielded higher amphibian abundance and species richness, we noted that several species exhibited higher relative abundance in either May or June.

As seen in Table 4, several species showed larger shifts in seasonal relative abundance. In the case of the two species within the genus *Kaloula*, each species showed a different tendency, with *K. mediolineata* composing a large percentage of captures in June and September compared to *K. Pulchra*, which peaked during May. The trend shows possible seasonal partitioning between the two species. Identifying natural history differences between these two species may have conservation value as *K. mediolineata* is listed as Near Threatened on the IUCN Redlist while K. pulchra is classified as Least Concern [16].

The limited number of sampling sites restricted our ability to identify significant environmental factors in amphibian abundance; however, our results suggest several trends. The plantation (μ = 258) and secondary disturbed forest (μ = 263) sites were situated at lower elevations than the dry dipterocarp forest sites (μ = 361), meaning increased water drainage. Additionally, as the landscape had been modified for agricultural purposes, more water sources, such as ponds and irrigation canals, are available for amphibians as compared to the natural forest. Both factors may explain the much higher abundance of amphibians in the more disturbed habitats. Kaensa et al. [17] found that in upper northeast Thailand that unprotected forest habitats had lower abundance compared to similar protected forest habitats, in contrast to our own findings. However, they also reported that woodland habitats sites in protected areas had the lowest amphibian captures, supporting our results that sites in the DDF showed lower amphibian abundance. Sampling in stream beds within the protected DDF forest may reveal higher species richness and abundance.

**Table 4** Monthly abundance for each species captured along with percent of total captures for that month that each species accounted for using common names from [16]

| Species | Common name | Abundance | | |
|---|---|---|---|---|
| | | Dry | Wet | Total |
| *Microhyla fissipes* | Ornate Chorus Frog | 32 | 57 | 89 |
| *Kaloula mediolineata* | Median-striped Bullfrog | 19 | 39 | 58 |
| *Fejervarya limnocharis* | Asian Grass Frog | 37 | 16 | 53 |
| *Glyphoglossus molossus* | Balloon Frog | 0 | 48 | 48 |
| *Microhyla pulchra* | Beautiful Pygmy Frog | 24 | 16 | 40 |
| *Microhyla heymonsi* | Dark-sided Chorus Frog | 2 | 33 | 35 |
| *Kaloula pulchra* | Asiatic Burrowing Frog | 5 | 26 | 31 |
| *Microhyla butleri* | Noisy Chorus Frog | 2 | 29 | 31 |
| *Calluella guttulata* | Stripe Spadefoot Frog | 0 | 11 | 11 |
| *Micryletta inornata* | Inornate Chorus Frog | 1 | 10 | 11 |
| *Duttaphrynus melanostictus* | Asian Toad | 6 | 0 | 6 |
| *Occidozyga lima* | Common Puddle Frog | 1 | 4 | 5 |
| *Hylarana macrodactyla* | Long-toed Frog | 2 | 1 | 3 |
| *Hylarana erythraea* | Dark-sided Frog | 1 | 0 | 1 |
| Total | | 132 | 290 | 422 |

Water availability may have also influenced the observed differences in abundance and species richness between seasons. For instance, sites closer to streambeds showed increased amphibian abundance specifically in September. One site located within 150 m of a streambed captured no amphibians during May and June, but in September recorded 55 individuals. A second site located within 10 m of a streambed supported this trend as we recorded only 8 amphibians in May and June combined, compared to 123 in September. One possible explanation for the dramatic increase in amphibian abundance is that within the study area, streambeds typically remain dry for long periods of the year. During the rainy season starting around September, the streambeds fill for a brief period. As our study was limited to just three months, longer-term studies are needed to determine the influence of seasonal water resource availability on amphibian abundance and species richness. The results indicate that seasonal water availability may be an important factor in predicting amphibian abundance. Phochaya-vanich [21] found similar results with higher amphibian diversity in the wet season and in agricultural areas in the Num San Noi stream located in the Phuluang Wildlife Sanctuary. Our results suggest that amphibian diversity and abundance in agricultural areas can be high in small forest patches, in addition to the stream beds found, as noted by Phochaya-vanich [21].

## Conclusion

As a preliminary study on the effects disturbance on amphibians, this study provides useful results as a basis for future research in the Sakaerat Biosphere Reserve. Particularly, we documented changes in amphibian abundance over seasons. Our results also suggest that seasonal variation may not be based solely upon climatic factors such as temperature and rain, but also on changing water availability over time. We also noted the need to monitor how specific species respond to seasonal changes, as not every species exhibits similar patterns. However, this study did not assess amphibian developmental stage, which may be an important factor influencing both abundance and species richness patterns observed between seasons and land uses. All of these conclusions can contribute to natural land management to maximize the effectiveness of protected areas.

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