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Forest-land use complementarity modifies community structure of a tropical herpetofauna

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ABSTRACT

Different human land uses are not uniform in their ecological effects on remnant faunas. Explicitly recognizing the relative habitat value of prevalent land uses in comparison to forest will help improve conservation theory and practice in human-modified landscapes. To better understand how common land uses influence habitat quality and buffer forest fragments in tropical landscapes, we characterized reptile and amphibian assemblages across forest-pasture and forest-peach palm (palmito) ecotones in north-eastern Costa Rica. We found that forest remnants contained significantly greater overall richness and abundance of reptiles and amphibians than either palmito or pasture; palmito supported greater species richness and abundance of herpetofauna than pastures. Assemblages of reptiles and amphibians in palmito also exhibited greater similarity to those found in forests than did assemblages in pasture, particularly for reptiles. Species exhibited distinctive responses to forest-land use ecotones, with some species reaching their highest abundances in non-forest habitat. Our results show that two important land uses in Costa Rica differ in their capacity to buffer forest patches and promote landscape connectivity for reptile and amphibian populations. Understanding these differences is crucial for identifying matrix environments that can complement the natural forest habitats of sensitive reptile and amphibian species.

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1. Introduction

As many as 30% of reptile and amphibian species may be threatened with extinction (Vié et al., 2009). Habitat loss, particularly forest conversion, is regarded as a primary threat to these groups, and is most severe in species-rich tropical zones (Alford and Richards, 1999; Furlani et al., 2009; Vié et al., 2009). Efforts to reverse amphibian and reptile declines associated with landscape change are therefore a critical component of managing the greater biodiversity crisis (Gibbons et al., 2000; Stuart et al., 2004; Mendelson et al., 2006; Alford, 2011). Given the continuing expansion of cropland in the tropics and the insufficient protection provided by reserves (FAO, 2009), there is a need to look for conservation opportunities in the land use matrix surrounding habitat remnants and preserves (Morse et al., 2009). Fortunately, a clear conceptual understanding of the effects of complex matrices (sensu Kupfer et al., 2006) on remnant wildlife communities

has started to emerge in recent years (Watling et al., 2011; Driscoll et al., 2013).

The traditional island-biogeography view of the matrix as uniform and uninhabitable (MacArthur and Wilson, 1967; Whitcomb, 1977) is giving way to an understanding of modified landscapes as complex mosaics composed of remnant habitat embedded in a heterogeneous land use matrix (Haila, 2002; Daily et al., 2003; Kupfer et al., 2006). Land uses surrounding forest fragments can modulate the influence of habitat loss and fragmentation by increasing or reducing effective patch size, modifying edge effects and disturbance regimes or altering movement among patches (Ricketts, 2001; Rothermel and Semlitsch, 2002; Bender and Fahrig, 2005; Mazerolle and Desrochers, 2005; Watling et al., 2011). The degree of structural similarity between land uses and forest may be a key factor affecting the dispersal, survival and reproduction of organisms in the matrix (Kupfer et al., 2006; Driscoll et al., 2013). A predicted outcome of these processes is that land uses that create low structural contrast at forest edges will support greater levels of abundance and diversity than land uses that create high-contrast ecotones. Information on the complementarity of land uses adjacent to forest habitat could inform efforts to create low-contrast ecotones around reserves and maintain landscape connectivity; however, these data are currently lacking for most systems, particularly in the tropics (Gardner et al., 2007a,b).

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Many existing studies of herpetofauna suggest that agricultural land uses are not substitutes for natural forests. Species richness and abundance tend to be higher in forest fragments than in matrix habitat just a few meters away (Toral et al., 2002; Faria et al., 2007; Gardner et al., 2007b, 2007c). However, research has shown that both forest fragments (Bell and Donnelly, 2006) and matrix habitat can support large proportions of assemblages known to occur in intact forest (Gascon et al., 1999; Pineda et al., 2005; Urbina-Cardona et al., 2006; Pardini et al., 2009), or even herpetofaunal assemblages comparable to those in reference primary forest (Folt and Reider, 2013). Thus, as cattle grazing and agricultural production in the tropics increase (FAO, 2009), the survival of many species may depend on using agricultural areas to increase the effective size of forest fragments and maintain connectivity among them (Ranganathan and Daily, 2008; Watling et al., 2011). Still, few studies have assessed the value of more than one replicated land use for maintaining herpetofaunal assemblages, and compared those results with forest (e.g., Vallan, 2002; Kanowski et al., 2006). These comparisons will be necessary before land uses can be ranked according to their relative habitat value.

Northeastern Costa Rica contains a diverse herpetofauna (Donnelly, 1994; Guyer, 1994). Widespread regional deforestation has slowed while agricultural intensification is homogenizing vegetation structure in the matrix (Sesnie et al., 2008; Karp et al., 2012). Approximately 30% of this landscape is fragmented remnant forest, surrounded primarily by cattle pastures as well as monoculture crops such as cassava, pineapple, banana, maize and peach palm (*Bactris gasipaes*) (Hengsdijk et al., 1999; Sesnie et al., 2008). Our primary objective was to compare the effects of pasture and peach palm (hereafter “palmito”) on the structure of reptile and amphibian assemblages across two types of forest-land use ecotones. Aside from their agricultural importance in our study area, pasturelands (high-contrast compared to forest) and palmito (low/medium-contrast) differ in vegetation structure, and may therefore differ in their suitability as habitat for native reptiles and amphibians. We asked how reptile and amphibian richness and relative abundance differ among forest, palmito and pasture habitats. Most importantly, we determined whether palmito plantations and pasturelands complement forest remnants by supporting ecologically overlapping yet distinct amphibian and reptile assemblages.

2. Materials and methods

2.1. Study area

This study was performed in forest remnants and matrix habitat in the landscape surrounding La Selva Biological Station (10°N, 84°W), located in the Sarapiquí region of northeastern Costa Rica. The native vegetation type that dominates the region is tropical lowland wet forest with an average temperature of 25 °C and average annual rainfall of 4375 mm (McDade and Hartshorn, 1994). La Selva and the contiguous Braulio Carrillo National Park contain primarily old growth forest, but the landscape surrounding the reserve is a highly heterogeneous mix of pasture, plantations, fragmented forest and developed areas.

Our study sites consisted of ten forest remnants and the adjacent agricultural land uses: five remnants bordered pastureland and five bordered palmito plantations (actively grazed and managed, respectively). Pastures were characterized by short, grassy vegetation, with occasional trees, bushes and forbs interspersed throughout. Palmito plantations contained rows of 2–3 m tall *B. gasipaes* palms, grown in monocultures. In Costa Rica, cattle pasture is more common than palmito, and the creation of pasture has been responsible for much higher rates of deforestation than

palmito cultivation (Kok and Veldkamp, 2001; Wassenaar et al., 2007). However, land cover data show that, over a recent 15-year period (1986–2001) in our study region, there was a fourfold increase in the area covered by palmito plantations (Sesnie et al., 2008). Forest remnants ranged in area from 5 to 381 ha and each fragment shared an edge of at least 200 m with either pasture or palmito. Most sites contained at least one water source, usually a wetland or stream.

2.2. Amphibian and reptile sampling

From June–August 2011, we sampled amphibians and reptiles at ten sites using a total of 400 transects (40 per site, 100 per habitat type) positioned perpendicularly with respect to the forest-matrix edge. At each site, twenty 50 m transects extended into the forest fragment and twenty 50 m transects extended into the pasture or palmito. We sampled equal numbers of transects during the day and night as our focal assemblages included both diurnal and nocturnal species. We also sampled equal numbers of transects at “near” (0–50 m from the forest-matrix edge) and “far” (50–100 m from the edge) distances. Each site was visited multiple times and approximately 4–8 transects were sampled per visit. Each individual transect was only sampled once so that a maximum number of microhabitats within each fragment could be sampled. We demarcated each transect with mason line and then waited at least one hour before initiating surveys. The starting point for each transect was a random point along the forest-palmito or forest-pasture edge; spacing between transects was random (with a minimum spacing of 5 m). As we sampled, we moved perpendicularly from the edge into the forest or pasture/palmito. Where trails, gravel roads, live fences, and other anthropogenic modifications intersected forest or agricultural plots, we sampled across or through these features, considering them part of the human-impacted environment.

We used distance- and time-constrained visual encounter surveys (von May et al., 2010) to sample our transects, which extended 50 m in length, 2 m in width, and 3 m in height. A single observer sampled each transect by walking slowly along it for 25 min and collecting, identifying and releasing (away from the transect, to avoid recapture) all reptiles and amphibians encountered. Like von May et al. (2010), we regularly disturbed the substrate to stimulate animal movement and reduce differences in species detectability. The time needed for capture and identification was excluded from the 25 min constraint. Transect lines were marked every 5 m so that we could record the approximate distance of each captured animal from the forest edge. We determined the species identity of each animal with a field guide (Guyer and Donnelly, 2005) and obtained photographic evidence for later identification as necessary.

2.3. Microhabitat measurements

We collected vegetation and water-availability data for each site. We gathered vegetation cover data by using PVC quadrats placed at random points 50 m and 100 m into each habitat type and at the forest-matrix edge. For each quadrat, we estimated (to the nearest 10%) the proportional cover of each vegetation type: forbs, grass, litter, palmito plant, soil, water or woody vegetation. We approximated understory density by taking visual obstruction measurements with a Robel pole placed 50 m and 100 m into each habitat type, as well as at the edge (Robel et al., 1970). Each time we placed the pole in a new location, we walked 10 m in all four cardinal directions from the pole and recorded the number of rings visible from that point. Additionally, we recorded the presence or absence of water along each transect.

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