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Impact of oil palm agriculture on understory amphibians and reptiles: A Mesoamerican perspective

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ABSTRACT

Oil palm plantations expand rapidly in tropical regions, including the Neotropics. This study, quantifies the impact on the herpetofauna of the Pacific lowlands of Costa Rica. Amphibians and reptiles were sampled along transects in forest interior (FI), at forest margins (FM) and in oil palm plantations (OP). While no significant difference in species richness was found between FI and FM, OP were characterized by a strongly impoverished fauna. Total species richness of amphibians and reptiles was reduced to 45.3% and 49.8% compared to FI, respectively. Species assemblages in OP differed from forest habitats and were characterized by disturbance-tolerant species and a severe loss of endemic species. In amphibians, functional diversity declined dramatically towards OP indicating a decrease of their ecological function. The almost complete absence of leaf litter, understory vegetation and woody debris and the more open canopy may be responsible for the depauperate herpetofauna in OP. Enhancing understory vegetation could help making plantations a less hostile environment for some species. Still, those management measures might not be enough to promote forest specialists. Therefore, to maintain a diverse herpetofauna in tropical human-modified landscapes, the protection of any forested habitats such as secondary forests and strips of gallery forests is essential.

1. Introduction

Loss and fragmentation of tropical rainforests are widely recognized as major driving forces of global biodiversity decline (Brooks et al., 2002; Gallant et al., 2007; Sala et al., 2000; Sodhi et al., 2008). During the last decades across the tropics more than half of the new cropland came primarily on the expense of tropical forests (Gibbs et al., 2010) and often resulted in large-scale landscape homogenization (Koellner and Scholz, 2008). This development poses a serious threat for tropical biodiversity as such habitats lack the complexity previous habitats provided (Fitzherbert et al., 2008). The following decrease in many narrowly distributed species, coupled with an increase in a small number of cosmopolitan species, also leads to an increasing homogenization of the biota (McKinney and Lockwood, 1999).

Huge parts of those expanding croplands are oil palm (*Elaeis guineensis*) plantations (OP) (Koh, 2007), currently representing the largest perennial cropland in the tropics (Meijaard and Sheil, 2013; Sheil et al., 2009). Typically, OP are monocultures characterized by an extremely reduced species richness and shifts in community composition towards disturbance tolerant species (Aratrakorn et al., 2006; Azhar et al., 2011; Brühl and Eltz, 2010; Edwards et al., 2010; Fayle et al., 2010; Koh and Wilcove, 2008) and a strongly declined functional diversity (Edwards et al., 2013a,b; Konopik et al., 2014).

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Having suffered unprecedented rates of decline in recent decades, amphibians and reptiles are among the most threatened animal groups globally (Gibbons et al., 2000; Stuart et al., 2004). However, few studies have examined the impact of forest alteration on tropical herpetofaunal communities (Gardner et al., 2007; Vitt and Caldwell, 2001; Wanger et al., 2010, 2009). Even less studies have quantified the impact of conversion to OP (Faruk et al., 2013; Gillespie et al., 2012; Gilroy et al., 2014; Glor et al., 2001) all indicating depauperate communities primarily dominated by common habitat generalists of little conservation concern.

In the last decades, OP have also been rapidly expanding in the Neotropics, where they already covered about 860,000 ha in 2012 (FAO, 2014). A first Neotropical study on Colombian OP reports smaller biodiversity declines compared to studies from Southeast Asia, particularly for herpetofauna (Gilroy et al., 2014). Those results however might have underestimated the actual biodiversity loss as the herpetofauna was sampled only in remnant forests like riparian forest strips or isolated forest fragments. Hence, the forest community was probably already impoverished. In Mesoamerica, Costa Rica has one of the largest areas of OP (635 km^2 in 2012; FAO, 2014). This is the first study trying to quantify the impact of oil palm cultivation on amphibians and reptiles of Mesoamerican lowland rainforests. In contrast to the study by Gilroy et al. (2014), our sampled forest sites did not represent forest remnants but large blocks of remaining lowland rainforest. We particularly addressed the following hypotheses:

(1) OP are characterized by a dramatically decreased structural complexity compared to forest habitats resulting in a reduced canopy cover and a decline of available microhabitats (e.g. leaf litter, deadwood) (Faruk et al., 2013; Gillespie et al., 2012; Konopik et al., 2014). These changes most likely transfer into a decrease of species richness. To rule out additional negative effects on the herpetofauna caused by isolation of plantations from the forest source areas, we only sampled amphibians and reptiles at OP sites located adjacent to the forest margin.

(2) The forest edge itself may represent an important transition zone already filtering the number of true forest interior species available for colonizing adjacent plantations. A certain fraction of the forest interior herpetofauna is not capable of tolerating the microclimatic conditions characteristic of forest edges. On the other hand, species from the adjacent matrix of land-use systems are able to penetrate forest edge habitats (Urbina-Cardona et al., 2006).

(3) We expect that environmental filtering from forest sites towards OP is reducing functional diversity of amphibian and reptile communities, as demonstrated for other taxa (Edwards et al., 2013a,b). We used several functional diversity measures (functional richness, functional evenness, functional divergence and functional dispersion; Laliberté and Legendre, 2010, Mouchet et al., 2010 and Villéger et al., 2008) to quantify changes in ecological functions of the herpetofauna from forest interior towards forest margin and OP.

(4) As reported for amphibians from Southeast Asia (Faruk et al., 2013; Gillespie et al., 2012) and lizards from the Caribbean region (Glor et al., 2001), we expect that OP in the Neotropics are also characterized by a species composition distinct from forest habitats.

(5) Most likely species assemblages shift from forest specialists depending on specific microhabitats in forest habitats towards common and disturbance tolerant species in OP as documented for other regions (Gillespie et al., 2012) and other taxonomic groups (birds: Edwards et al., 2013a; dung beetles: Edwards et al., 2013b).

(6) Range-restricted forest species of high conservation relevance should be particularly prone to habitat disturbance and hence largely absent in OP as demonstrated by studies on lizards (Glor et al., 2001) and birds (Edwards et al., 2013a).

2. Methods

2.1. Study area and study sites

This study was carried out in proximity of the Tropical Research Station La Gamba on the Pacific slope of southwestern Costa Rica (Fig. 1). Beside the remaining large block of primary forest (located in the Piedras Blancas National Park) and a variety of old-growth secondary forests (almost 80 years old), the forest margin zone next to the village of La Gamba is an agro-mosaic increasingly dominated by OP (Höbinger et al., 2012; for details on vegetation: Weissenhofer and Huber, 2008).

We selected five replicate sites in each of the three following habitat types (Fig. 1): forest interior (FI), forest margin (FM) and oil palm plantation (OP) (Appendix Table A.1). A vegetation map of the study area (Weissenhofer and Huber, 2008) was used for a first evaluation of potential study sites, which were finally selected after a subsequent visit. FI sites are pristine or old-growth secondary forests situated at least 200 m away from the nearest forest edge. All FM sites are adjacent to strongly human-dominated habitats (e.g. fallows, pastures, gardens, oil palm plantations). OP sites had an area of 10–50 ha and were situated adjacent to forest margins. All study sites were selected to be at least 300 m apart from each other.

2.2. Sampling of amphibians and reptiles

Fieldwork was conducted during the rainy season between 03 July and 27 September 2013, when activity of terrestrial amphibians and reptiles is particularly high (Marques et al., 2000; Veith et al., 2004). At each sampling site all visually detected reptiles and amphibians were recorded along two 100 m transects running parallel in a distance of 10 m. While at FI and OP sites the pairs of transects were orientated randomly, at FM sites they were situated parallel to the always clearly defined forest edge. Each transect census lasted up to 2 man-hours to complete. Some surveys at OP sites were