Biological Conservation 220 (2018) 37–49

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Edge effects of oil palm plantations on tropical anuran communities in Borneo

Sarah A. Scriven[a,b,1], Graeme R. Gillespie[c,d,*,1], Samsir Laimun[e], Benoît Goossens[a,e,f,g]

[a] Organisms and Environment Division, Cardiff School of Biosciences, Cardiff University, Cardiff, United Kingdom
[b] Department of Biology, University of York, York YO10 5DD, UK
[c] School of Biosciences, University of Melbourne, Parkville, Victoria, Australia
[d] Department of Environment and Natural Resources, Palmerston, Northern Territory, Australia
[e] Danau Girang Field Centre, c/o Sabah Wildlife Department, Kota Kinabalu, Sabah, Malaysia
[f] Sabah Wildlife Department, Kota Kinabalu, Sabah, Malaysia
[g] Sustainable Places Research Institute, Cardiff University, Cardiff, United Kingdom

A R T I C L E I N F O

Keywords:
Amphibians
Habitat fragmentation
Oil palm agriculture
Rainforest
Deforestation
Southeast Asia

A B S T R A C T

The expansion of industrial agriculture (oil palm) has significantly reduced lowland tropical diversity through direct loss or alteration of habitat, leading to habitat fragmentation and edge effects. Edge effects can have serious impacts on species diversity and community dynamics. To assess the effect of oil palm plantation edges on anuran communities in Sabah, Malaysian Borneo, we surveyed anuran species and measured structural habitat and landscape parameters at 74 sites spread across forest and plantation habitats along the Kinabatangan River. We then evaluated how anuran species richness and assemblage composition varied in relation to these environmental parameters. Relative species richness was higher at forest sites, compared to oil palm plantation sites. Plantation sites were dominated by wide-ranging terrestrial species, and assemblage composition varied mostly in relation to standing surface water. Forest habitats supported both more endemic and arboreal species. Variability on anuran assemblage composition in forest habitats was greatest in relation to distance to forest edge followed by canopy density, which was also partially correlated with forest edge distance. Moreover, anuran species richness in forest habitats declined as proximity to the forest-plantation interface increased, and as canopy density decreased. Our study provides further evidence that oil palm plantations provide little conservation benefit to anurans. Furthermore, oil palm plantations appear to have adverse pervasive impacts on amphibian diversity considerable distances into adjacent forest areas. These findings suggest that in order for small patches or narrow corridors of retained forest in landscapes managed for oil palm to maintain biodiversity values in the long term, their sizes and widths need to adequately account for the considerable influence of edge effects.

1. Introduction

Conversion of tropical forests to intensive plantation forestry or agriculture has negative impacts on biodiversity, and oil palm plantations are no exception (Fitzherbert et al., 2007, 2008; Danielsen et al., 2008; Foster et al., 2011). Direct negative effects (e.g., a decline in species richness, or changes in community composition) of oil palm plantation establishment on tropical forest biodiversity have been documented for a range of biota, including mammals (Danielsen and Heegaard, 1995; Maddox et al., 2007; Bernard et al., 2009), birds (Peh et al., 2006; Azhar et al., 2011), amphibians (Gillespie et al., 2012; Faruk et al., 2013) lizards (Glor et al., 2001; Gallmetzer and Schulze, 2015), various insect groups (Chung et al., 2000; Davis and Philips, 2005; Koh and Wilcove, 2008; Brühl and Eltz, 2010; Fayle et al., 2010) and other invertebrates (Hassall et al., 2006), and plants (Danielsen et al., 2008).

In addition to the direct effects of habitat loss and alteration from conversion of rainforests to plantations, there are a range of indirect and pervasive effects on biodiversity that may manifest themselves over time. These include downstream effects of hydrological and nutrient changes in waterways and catchments (Dudgeon et al., 2006), as well as habitat fragmentation and edge effects on adjacent remaining forest areas (Fitzherbert et al., 2007, 2008; Danielsen et al., 2008). Habitat loss and fragmentation are likely to exacerbate the impacts of

* Corresponding author at: School of Biosciences, University of Melbourne, Parkville, Victoria, Australia.
E-mail addresses: sarah.scriven@york.ac.uk (S.A. Scriven), Graeme.Gillespie@nt.gov.au (G.R. Gillespie), goossensbr@cardiff.ac.uk (B. Goossens).
[1] These authors contributed to the work equally.

https://doi.org/10.1016/j.biocon.2018.02.006
Received 12 April 2017; Received in revised form 24 January 2018; Accepted 5 February 2018
0006-3207/

anthropogenic climate change on tropical species (Nowakowski et al., 2017), and may also result in genetic erosion, leading to a reduction in breeding populations (e.g., see Goossens et al., 2005). Edge effects may also have a number of ecological consequences, including microhabitat alterations resulting from changes in temperature, humidity, wind or light penetration (Laurance et al., 2002; Fischer and Lindenmayer, 2007; Broadbent et al., 2008); invasive species, that may cause habitat disturbance (Ickes et al., 2005), competition, predation (Rajaratnam et al., 2007), or introduction of disease (Arroyo-Rodríguez and Dias, 2010); and increased human access for resource extraction, such as hunting, timber harvesting and other resource extraction (McMorrow and Talip, 2001; Fitzherbert et al., 2008).

Detrimental edge effects in tropical forests from roads, agriculture and silvicultural plantations have been documented for various biota, including mammals (Lidicker, 1999; Goosem, 2000), birds (Watson et al., 2004; Moradi et al., 2009), invertebrates (Didham et al., 1996) and plants (Hoang et al., 2010). However, evidence of major adverse forest edge effects on amphibians and reptiles is more ambiguous (Gardner et al., 2007a), with a number of studies finding either no effect (Gascon, 1993; Biek et al., 2002; Toral et al., 2002), a weak effect (Demaynadier and Hunter, 1995), or species-specific effects with no overall change in richness (Schlaepfer and Gavin, 2001; Lehtinen et al., 2003). To date, few studies have examined edge effects on tropical forests from oil palm plantations (Fitzherbert et al., 2008; Yaap et al., 2010; Lucey and Hill, 2012). Understanding these pervasive effects is important for the conservation of biodiversity in remnant forest patches that have high conservation value, many of which occur in highly fragmented landscapes.

The expansion of oil palm plantations has significantly reduced lowland tropical amphibian diversity through direct loss or alteration of habitat (Gillespie et al., 2012; Faruk et al., 2013; Gallmetzer and Schulze, 2015). Oil palm plantations have lower amphibian species richness, more disturbance-tolerant species and less endemic species (Gillespie et al., 2012; Faruk et al., 2013; Gallmetzer and Schulze, 2015; Konopik et al., 2015). These differences in richness and changes to community composition in oil palm plantations compared to forest habitats are underpinned by marked differences in both habitat structure and microclimate characteristics. Oil palm plantations lack microhabitats important for many forest amphibian species and are subject to a greater microclimatic flux (Chung et al., 2000; Peh et al., 2006; Luskin and Potts, 2011; Gillespie et al., 2012). Important microhabitats for amphibian reproduction, foraging and shelter may be absent or limited within plantations, excluding many forest-dwelling species. However, quantification of impacts of forest conversion to oil palm plantations on amphibian communities is limited.

Forest amphibian communities persisting in forests within close proximity to plantations are also potentially highly vulnerable to pervasive edge effects, such as changes in abiotic conditions (see Urbina-Cardona et al., 2006; Dixo and Martins, 2008). The reproductive strategies of many rainforest amphibians are potentially highly sensitive to microclimatic and microhabitat perturbations (Heatwole and Taylor, 1987; Wells, 2007; Bickford et al., 2010). Oil palm plantations are typically colonized by highly dispersive anuran species with more generalized ecological requirements (Gillespie et al., 2012; Faruk et al., 2013), which may in turn penetrate adjacent forests and compete with, or predate on, forest species. Elevated population densities of other species, such as leopard cat (*Prionailurus bengalensis*) and bearded pig (*Sus barbatus*), may increase predation on anurans or cause habitat alterations near forest edges (Peters, 2000; Ickes et al., 2005). Given that pervasive edge effects may permeate substantial distances into adjacent forest habitats for some taxa (e.g., Broadbent et al., 2008), it is likely that such effects may detrimentally affect forest amphibian communities residing in these fragmented landscapes. Oil-palm induced edge effects and their influence on tropical amphibian communities have received little attention, and so there is currently limited understanding of how species richness and diversity change in relation to plantation edge proximity.

We evaluated the influence of forest/oil palm plantation edges on anuran diversity by collecting empirical data on anuran species richness and assemblage composition from 74 sites located within lowland rainforest and adjacent oil palm plantations in Malaysian Borneo. Using a repeated sampling design, we collected data from both edge and interior habitats (~20 m and 100–500 m from the forest/plantation interface, respectively) within secondary forest and established plantations. We then examined differences in anuran species richness and assemblage composition between oil palm plantations and adjacent forest in relation to a number of site-specific structural habitat parameters and local-landscape parameters, including the distances from forest/plantation interfaces. Based on findings from previous studies that have compared amphibian species richness and community composition between oil palm plantations and forest habitats (see Gillespie et al., 2012; Faruk et al., 2013), we hypothesized that: (i) forest sites would support more species than plantation sites, and (ii) plantation sites would support distinct communities of anurans compared to forest habitats, mostly comprising of generalist, widespread (i.e., non-endemic) terrestrial species. Some rainforest species are known to be detrimentally affected by agricultural edges (Urbina-Cardona et al., 2006; Schneider-Maunoury et al., 2016), and anuran communities in particular may be sensitive to changes in habitat structure that result from oil-palm induced edges (Gillespie et al., 2015). Hence, we also hypothesized that: (iii) species richness would increase in forest habitats with increasing distance from the forest/plantation interface; and (iv) both structural habitat and local-landscape parameters (i.e., proximity to the forest-plantation interface) would strongly influence anuran community composition and species richness within both habitat types.

2. Methods

2.1. Study area

Fieldwork was conducted along the Kinabatangan River in northeast Borneo, within the Malaysian state of Sabah (5°10′–5°50′N; 117°40′–118°30′E) (Fig. 1). The climate is warm, wet and humid with mean monthly temperatures throughout the year ranging from 21 to 34 °C. Mean annual precipitation is usually between 2600 and 3600 mm and there are seasonal floods between November and March (Sooryanarayama, 1995), which can extend through to May (Gillespie et al., 2012). A large portion of the Kinabatangan floodplain is classified as extreme lowland forest and is flat, low (10–20 m a.s.l.) and poorly drained (Azmi, 1998). Due to logging between the mid 1950s and early 1990s, the lowland forest of the Kinabatangan floodplain is almost exclusively regenerating secondary forest (McMorrow and Talip, 2001).

Over the past two decades much of the remaining lowland forest of the Kinabatangan floodplain has been converted to oil palm plantations (Abram et al., 2014). These alterations have left only remnant patches of forest, scattered amongst a matrix of vast oil palm monocultures, along with several small villages, and other agricultural lands (Gillespie et al., 2012; Abram et al., 2014). These forest patches form a partially fragmented corridor, extending from the coastal mangrove swamps for approximately 70 km upstream to the dry-land foot hill forests (Gillespie et al., 2012). This corridor includes the 27,960 ha Lower Kinabatangan Wildlife Sanctuary (LKWS), gazetted in 2005 (Abram et al., 2014), 10,000 ha of private and state forests and 15,000 ha of Virgin Jungle Reserves (VJRs) (Ancrenaz et al., 2004).

2.2. Site selection and local-landscape parameters

We established 39 transects, each 120 m long, in secondary forest in LKWS and adjacent forest areas, and 35 transects of the same length in oil palm plantations. Transects were spread over a reach of approximately 100 km of the Kinabatangan floodplain and surrounding oil