Biological Conservation 152 (2012) 136–144

Contents lists available at SciVerse ScienceDirect

Biological Conservation

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

Conservation of amphibians in Borneo: Relative value of secondary tropical forest and non-forest habitats

Graeme R. Gillespie [a,*], Eddie Ahmad [b], Berjaya Elahan [b], Alice Evans [c], Marc Ancrenaz [b,e], Benoit Goossens [c,d], Michael P. Scroggie [f]

[a] Department of Zoology, University of Melbourne, Parkville, Victoria 3052, Australia
[b] Kinabatangan Orang-utan Conservation Programme, c/o Sabah Wildlife Department, Sandakan, Sabah, Malaysia
[c] Organisms and Environment Division, School of Biosciences, Cardiff University, Cardiff, United Kingdom
[d] Danau Girang Field Centre, c/o Sabah Wildlife Department, Kota Kinabalu, Sabah, Malaysia
[e] North of England Zoological Society, Honorary Conservation Fellow, Chester, United Kingdom
[f] Arthur Rylah Institute for Environmental Research, Department of Sustainability and Environment, P.O. Box 137, Heidelberg, Victoria 3084, Australia

ARTICLE INFO

Article history:
Received 24 August 2011
Received in revised form 22 March 2012
Accepted 24 March 2012
Available online 23 June 2012

Keywords:
Amphibian
Rainforest
Southeast Asia
Oil palm
Conservation
Deforestation

ABSTRACT

The impact of degradation of Southeast Asian rainforests and conversion to oil palm plantations on amphibians is unknown. To assess the relative value of secondary forests, oil palm plantations and other non-forest habitats for amphibian conservation, we evaluated amphibian species richness and assemblage composition in secondary lowland forests, compared with oil palm plantations and other non-forest habitats, along the Lower Kinabatangan River, eastern Sabah, Malaysia. Secondary forests retained a large proportion of amphibian species known from lowland primary rainforests. Species richness was higher in secondary forest habitats compared to oil palm plantations and other non-forest habitats. Secondary forests retained a much higher proportion of endemic species than non-forest habitats. We found strong differentiation between the frog assemblages in forest, non-forest and plantation sites. Oil palm plantations retained no microhylid species, few arboreal species and were dominated by habitat generalist and human commensal species. Our findings suggest that, despite a history of disturbance and degradation, remnant secondary forests may play an important role in conserving lowland amphibian diversity. In contrast, oil palm plantations have comparatively low conservation value for amphibians. Our study highlights the value of setting aside adequate areas of representative forest habitats within agricultural landscapes in order to conserve biodiversity, even when those remnants have a history of prior disturbance.

1. Introduction

Ongoing global destruction of tropical forests is a major contributor to biodiversity loss (Wright and Muller-Landau, 2006; Sodhi et al., 2010). Among tropical regions, Southeast Asia currently has one of the highest rates of deforestation (Sodhi and Brook, 2006; Miettinen et al., 2011). Commensurate with this landscape change has been the rapid expansion of secondary forests with varying levels of degradation from selective and commercial logging, and expansion of agriculture, in particular oil palm plantations (McMorrow and Talip, 2001; Fitzherbert et al., 2008). The impacts of these large-scale land use changes on biodiversity are not fully understood, and may further accelerate extinction rates (Sodhi et al., 2010).

In many tropical regions protected areas are inadequate for sustained, broad-based biodiversity conservation (Giam et al., 2011; Mora and Sale, 2011). Conservation of many tropical forest species is increasingly dependent upon human modified habitats, such as production forests, degraded forests and agricultural landscapes (Gardner et al., 2007a,b; Koh and Gardner, 2010; Clough et al., 2011). However, understanding of the conservation value of altered and degraded forests and plantations remains poor for most organisms (Dunn, 2004; Barlow et al., 2007; Gardner et al., 2007a; Sodhi et al., 2010). Whilst evidence exists that some biota persist in modified tropical forests (e.g. Lawton et al., 1998; Medellin and Equihua, 1998; Dunn, 2004; Quintero and Roslin, 2005), there is a lack of consensus regarding the impacts of forest change due to the contrasting responses of different groups of organisms and methodological differences (e.g. Hamer and Hill, 2000; Dunn, 2004; Hill and Hamer, 2004; Lugo and Helmer, 2004). This lack of consensus reflects the relative paucity of studies, ecological variation between taxa, regional and site specific spatial and temporal conditional effects, such as time since disturbance, degree and scale of modification, and the availability of remaining primary forest habitats (Barlow et al., 2007; Gardner et al., 2007a).

* Corresponding author. Tel.: +61 429091783.
E-mail address: Graeme.R.Gillespie@gmail.com (G.R. Gillespie).

0006-3207/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biocon.2012.03.023

Amphibians are considered to be one of the most threatened animal groups globally, having suffered unprecedented rates of decline in recent decades (Stuart et al., 2004). Whilst a range of factors are involved, habitat loss is by far the major cause of declines (Stuart et al., 2004; Gardner et al., 2007a; Sodhi et al., 2008; Gillespie et al., 2011). Amphibian species richness and diversity peaks in tropical forests (Vitt and Caldwell, 2001; Wells, 2007); however, few studies have examined the impact of forest alteration on tropical amphibian communities (Heinen, 1992; Vitt and Caldwell, 2001; Ernst and Rödel, 2005, 2008; Ficetola et al., 2007; Gardner et al., 2007a,b; Wanger et al., 2009a). Resilience of tropical forest amphibians to habitat disturbance may be relatively low, due to adverse microclimatic changes, reduced availability of forest debris (logs and litter) for shelter and foraging, and loss of specialized breeding microhabitats (Vitt and Caldwell, 2001; Hillers et al., 2008; Kudavidanage et al., 2011). Persistence of species may depend on retention of sufficient unmodified habitat (Gillespie et al., 2005; Gardner et al., 2007a; Hillers et al., 2008; Wanger et al., 2009b), as the relatively low dispersal capabilities of amphibians may limit their capacity for recolonisation of disturbed areas (Ficetola et al., 2007). Conversely amphibians may have higher rates of persistence in small habitat fragments compared with other vertebrates due to their small home-range sizes and potentially high local population densities (Vitt and Caldwell, 2001; Rodríguez-Mendoza and Pineda, 2010).

The lowlands of Southeast Asia have been grossly altered in recent decades by timber harvesting and conversion to agriculture, in particular oil palm plantations (McMorrow and Talip, 2001; Sodhi et al., 2010; Miettinen et al., 2011). To date no studies have been undertaken to evaluate impacts on amphibian communities (Barlow et al., 2007; Sodhi et al., 2010). In many lowland regions the only forested areas remaining are secondary or highly degraded (Giam et al., 2011), and often small and fragmented (McMorrow and Talip, 2001; Barlow et al., 2007). Large areas of degraded forests are being converted to oil palm plantations (Koh and Wilcove, 2008a); however, these remnant forests are potentially important reservoirs of biodiversity (Edwards et al., 2010; Giam et al., 2011). To assess the value of secondary forest for amphibian conservation, and the impact of forest clearance and conversion to oil palm plantations, we evaluated amphibian species richness and assemblage composition in secondary lowland forests, compared with nearby oil palm plantations and other non-forest habitats, in eastern Sabah, Malaysia.

2. Methods

This study was undertaken in the Lower Kinabatangan River floodplain in eastern Sabah, Malaysia (Fig. 1). The area is mostly flat and low (10–20 m asl), poorly drained and subject to periodic flooding, and is classified as extreme lowland forest (Azmi, 1998). Recent alluvium and finely textured, nutrient-rich deposits occur near the river while gleyic luvisols occur in poorly drained places (Haile and Wong, 1965). There are several low mudstone hills at *ca.* 40–50 m asl and several karstified limestone outcrops at *ca.* 100 asl (Azmi, 1998). Due to their poor accessibility, some of these outcrops support the only remnants of primary rainforest in the landscape.

The area is characterized by a warm, wet and humid tropical climate, with mean monthly temperatures ranging between 21 °C and 34 °C. Floods mainly occur between November and March during the west monsoon (Sooryanarayama, 1995) but may also occur in April and May (M. Ancrenaz, pers. obs.). Annual precipitation is approximately 2600–3300 mm (Malaysian Meteorological Services Department, cited in Ancrenaz et al., 2004).

With the exception of some steep limestone outcrops, the entire area was intensively logged, both commercially and illegally, between the 1960s and 1995. Most of the area was subsequently cleared for oil palm plantations (Azmi, 1998). Remnant secondary forest persists along the Lower Kinabatangan River, comprising a

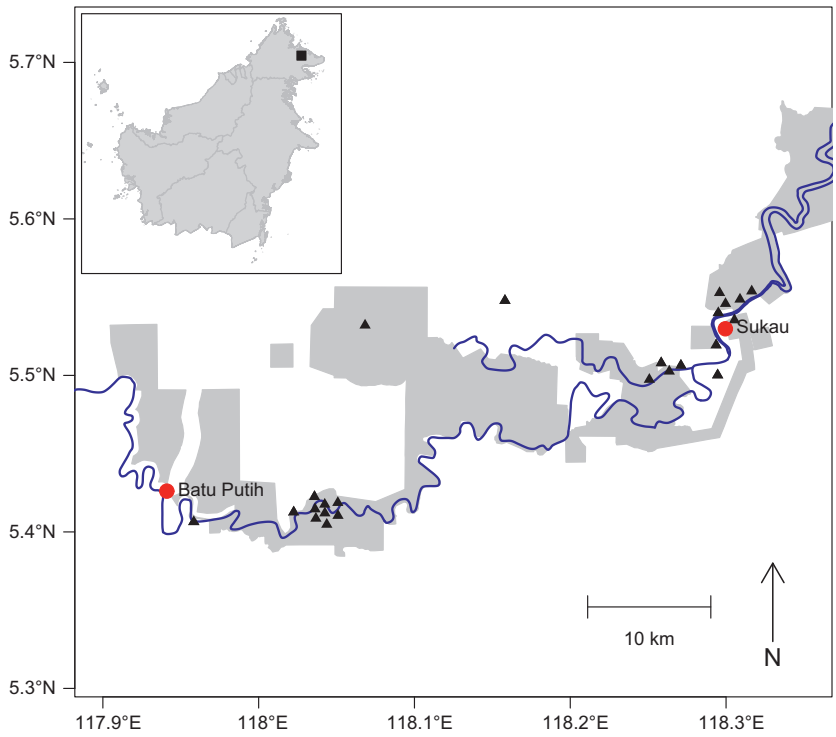

Fig. 1. The Lower Kinabatangan River, eastern Sabah, Malaysia, with its position on the island of Borneo (inset). Shaded areas indicate protected forest areas of the Lower Kinabatangan Wildlife Sanctuary. Surrounding unshaded areas are predominantly oil palm plantations with some degraded forest patches. Black dotes indicate sampling transects.