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Are riparian forest reserves sources of invertebrate biodiversity spillover and associated ecosystem functions in oil palm landscapes?

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ABSTRACT

The world's forested landscapes are increasingly fragmented. The effects of fragmentation on community composition have received more attention than the effects on ecological processes, particularly in the tropics. The extent to which populations from forest fragments move (spillover) into surrounding agricultural areas is of particular interest. This process can retain connectivity between populations and alter the rate of beneficial or detrimental ecological functions. We tested whether riparian forest fragments (riparian reserves), are sources of two functionally important invertebrate groups (dung beetles and scavenging ants) within oil palm plantations in Malaysia. We also assessed whether forest fragments enhance rates of associated ecosystem functions (dung and bait removal). We found that oil palm sites with and without adjacent riparian reserves had similar overall beetle and ant communities and functional rates. However, dung beetle species richness, abundance and diversity declined with distance from a riparian reserve, providing evidence for a weak spillover effect. In addition, dung beetle community metrics within a riparian reserve predicted corresponding values in adjacent oil palm areas. These relationships did not hold for dung removal, ant community metrics or bait removal. Taken together, our results indicate that although riparian reserves are an important habitat in their own right, under the conditions in which we sampled they have a limited role as sources of functionally important invertebrates. Crucially, our results suggest that contiguous habitat corridors are important for maintaining connectivity of invertebrate populations, as forest dependent species may not easily be able to disperse through the agricultural matrix.

1. Introduction

Across the tropics, agricultural expansion and intensification are driving forest conversion and fragmentation (Gibbs et al., 2010). As forest fragments become an increasingly common feature of our landscapes, we need to understand which communities and functions they support, and how they interact with the surrounding landscape. Understanding the ecology of forest fragments is especially important in the species-rich tropics given the high productivity of these areas and the negative impacts of human-dominated land uses on a wide range of tropical species (Newbold et al., 2014). Palm oil production is a major industry across the tropics, especially in Southeast Asia, and plantations are expanding in Africa and the Neotropics (Butler and Laurance, 2010; Wich et al., 2014). This expansion is of concern as the conversion of native habitats to oil palm causes declines in many taxa (Savilaakso et al., 2014) and ecosystem functions (Barnes et al., 2014b).

Although existing evidence suggests that forest fragments in oil palm do not conserve biodiversity as well as continuous forest areas, they can support more bird species (Edwards et al., 2010), dung beetle species (Gray et al., 2014) and ant species (Gray et al., 2015) than nearby oil palm areas. Forest fragments provide resources for vertebrates such as the common palm civet (Nakashima et al., 2013) and large (>300 ha) forest fragments in oil palm landscapes can support diverse bat assemblages (Struebig et al., 2008). However, the degree to which forest fragments act as sources for functionally important species in oil palm plantations is less well known.

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Spillover is the movement of individuals from a "source" or "target" habitat to a "recipient" or "non-target" habitat (Brudvig et al., 2009; Rand et al., 2006). The term spillover has been used to refer to the increase in fish densities around marine protected areas (Roberts et al., 2001), the movement of species from forest into neighbouring agroforestry plantations (Tscharntke et al., 2011), and the flow of chemicals from areas of intense agriculture into less disturbed habitats (Didham et al., 2015). Here, we are concerned with the spillover, or movement, of biodiversity from forest fragments into areas planted with oil palm. The dispersal of individuals across an agricultural matrix can affect species' survival in habitat remnants (Ewers and Didham, 2006) and the delivery of valuable ecosystem services such as pollination or pest-control (e.g. Karp et al., 2013; Ricketts, 2004). In oil palm plantations, spillover of communities from forest has been documented for butterflies (Lucey and Hill, 2012), ants (Lucey et al., 2014) and orchid bees (Livingston et al., 2013). However, few studies have assessed how forest fragments influence ecological processes in oil palm; recent evidence suggests that forest has little effect on the activity of herbivorous pests (Gray and Lewis, 2014) or on oil palm yield (Edwards et al., 2014).

Here, we quantify the extent of spillover from riparian reserves (strips of forest protected alongside rivers) into surrounding oil palm plantations in Sabah, Malaysian Borneo. Riparian reserves are protected because they improve water quality and reduce flood risk (McDermott et al., 2010), but they also provide habitat for forest-dependent species (Marczak et al., 2010). In Sabah, 20 m of natural vegetation must be retained either side of any river more than 3 m in width (Sabah water resources enactment, 1998). We surveyed two key insect groups (dung beetles and ground-foraging scavenging ants) and the ecological processes they support (dung and animal necromass removal respectively). These two processes are important because they potentially impact soil properties and plant growth (Frouz and Jilkova, 2008; Nichols et al., 2008). If ants and dung beetles are moving from riparian reserves into adjacent oil palm, this may be because dung or animal necromass resources are not being used by the species able to persist permanently in the oil palm, and so the spillover effect could result in an increase in important ecological functions.

We addressed the following questions:

1. Does the diversity, species richness, abundance, community composition or function of dung beetles and scavenging ants differ between oil palm with and without an adjacent riparian reserve?
2. Does the biodiversity and ecosystem function of these taxa in oil palm change with increasing distance from the riparian reserve boundary?
3. Does the biodiversity and ecosystem function of these taxa in riparian reserves predict biodiversity and ecosystem function in adjacent oil palm?

2. Methods

2.1. Study sites

Study sites were located adjacent to rivers (5–10 m width) in South Eastern Sabah, Malaysian Borneo (117.5°N, 4.6°E). The landscape is a mosaic of twice-logged lowland dipterocarp rainforest, acacia, and oil palm plantations (planted between 1998 and 2011). The sites also form part of the Stability of Altered Forest Ecosystems project (see Ewers et al. (2011) and www.safeproject.net for further details).

We collected data from 14 sites adjacent to rivers: seven in areas of continuous oil palm and seven in areas of oil palm with a riparian reserve (Fig. 1). At each site, we set up a sampling grid of 12 points, consisting of four transects perpendicular to the river. Transects were 100 m apart, with sampling points at 0 m, 50 m and 100 m from the high water line. At sites with a riparian reserve, sampling points fell both within the riparian reserve and in the oil palm adjacent to it. Due to variation in the width of the riparian reserves (mean 49 m, standard deviation = 30 m, referring to forest width on one side of the river), the number of sampling points falling outside the riparian reserve varied slightly between sites. All sites were separated by at least 1.5 km, and all riparian reserve sites were at least 1 km from the nearest continuous logged forest boundary.

2.2. Data collection

Data on dung beetle communities and function were collected between February and July 2011 (12 sampling points at each of 14 sites, giving 168 sampling points in total). Data on ant communities and function were collected between April and July 2011 (nine of the 12 sampling points per site, across 13 sites, giving 117 sampling points in total). Logistical difficulties prevented us collecting ant data from one of the oil palm sites (top left in Fig. 1). The months during which

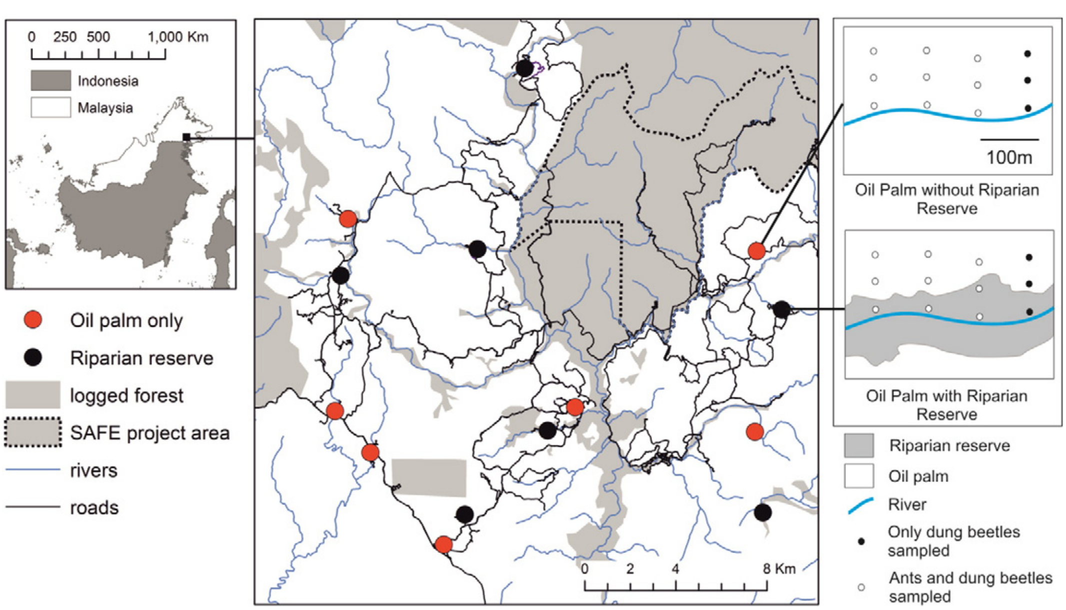

Fig. 1. Map of study sites within Sabah, Malaysian Borneo, and an example layout of sampling points at sites with a riparian reserve (black circles) and without a riparian reserve (red circles).