Ecological Indicators 82 (2017) 478–483

Contents lists available at ScienceDirect

Ecological Indicators

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

Original Articles

Influence of oil palm monoculture on the taxonomic and functional composition of aquatic insect communities in eastern Brazilian Amazonia

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ARTICLE INFO

Keywords:
Land use
Freshwater
Ephemeroptera
Plecoptera
Trichoptera
Functional traits

ABSTRACT

Large scale palm oil plantations for the production of vegetable oil are among the most harmful agricultural activities to biodiversity, especially given their rapid expansion, worldwide. Many cases of species loss have already been recorded in Asian countries, although research is still incipient in the Amazon basin, and the environmental impacts of these monocultures on freshwater ecosystems in the Neotropical region are still poorly understood. The present study evaluated the effects of oil palm plantations on the physical structure of stream habitats and the resulting changes in the taxonomic and functional composition of aquatic insect communities. A total of 2100 specimens of the orders Ephemeroptera, Plecoptera and Trichoptera were collected during the present study, representing 40 genera and 16 families. The hypothesis tested was that the taxonomic and functional diversity of the orders Ephemeroptera, Plecoptera and Trichoptera (Insecta) decreases in streams surrounded by oil palm plantations in comparison with those embedded in forested areas. In the plantation streams, the taxonomic richness and composition, and the functional richness are modified significantly. Functional composition appeared unaltered despite reduced canopy cover associated with oil palm streams. These effects emphasize the importance of the riparian vegetation for the protection of the aquatic communities found in oil palm plantations. The maintenance of the riparian vegetation may mitigate the impacts of plantations, contributing to the conservation of insect communities and associated biodiversity.

1. Introduction

The exotic species Elaeis guineensis Jacq. (common name: oil palm) has recently become one of the most cultivated equatorial crops (Koh, 2008). Brazil is one of the world's top producers of oil palm due to the favorable conditions for this monoculture (e.g., high temperature and rainfall, low soil pH) in the Amazon rainforest (Muller and Alves, 1997; Butler, 2011). Yet, oil palm expansion in Amazon may increase the impact of habitat loss and fragmentation on biodiversity (Butler, 2011; Foster et al., 2011).

There is compelling evidence of the loss of taxonomic and functional diversity in the bird and amphibian assemblages associated with oil palm plantations in eastern Amazonia (Lees et al., 2015; Almeida et al., 2016; Correa et al., 2015). However, there is little consensus on the nature of the impact of oil palm plantations on the region's aquatic ecosystems. For example, while Cunha et al. (2015), recorded a decrease in heteropteran species richness, Shimano and Juen (2016) found no clear evidence of any change in the species composition of ephemeropterans. While some studies have addressed the impact of oil palm on the taxonomic composition of specific groups of organisms, there has yet to be any systematic analysis of the impact on the functioning of stream ecosystems. Complementary approaches, such as functional diversity, especially if compared with taxonomic composition, may reveal distinct community patterns, and provide a better understanding of the relationship between the impacts of oil palm plantations and aquatic biodiversity.

The larvae of the orders Ephemeroptera, Plecoptera, and Trichoptera (EPT) are widely used as ecological indicators due to their

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http://dx.doi.org/10.1016/j.ecolind.2017.07.006
Received 23 November 2016; Received in revised form 9 June 2017; Accepted 3 July 2017
Available online 21 July 2017
1470-160X/

sensitivity to environmental changes in aquatic habitats, in particular at the micro-habitat level (Lake, 2000; Péru and Dolédec, 2010; Luiza-Andrade et al., 2017). Functional redundancy, which determines the resilience of a community to environmental variation (Petchey and Gaston, 2002), may also be altered by the impact of human activities. Communities with a high degree of functional redundancy, for example, are potentially more tolerant of variation in the environment (Petchey and Gaston, 2002).

The present study compares the functional and taxonomic responses of the Ephemeroptera, Plecoptera, and Trichoptera found in streams located within forested areas and oil palm plantations in eastern Amazonia. The study analyzed two complementary questions: (1) do the species richness and the taxonomic and functional composition of the EPT vary systematically between forest and plantation streams? (2) Which specific functional traits are related to the environmental variables found in both types of stream? The taxonomic and functional diversity is expected to be reduced in plantation areas in comparison with the forest, given that the oil palm monocultures tend to reduce environmental heterogeneity, the number of habitat types, and resource availability.

2. Material and methods

2.1. Study area and sampling design

The present study was conducted in the Agropalma Agroindustrial Complex, in the municipalities of Tailândia, Acará and Moju, in northeastern Pará state, northern Brazil. The study area comprises 107,000 ha, of which 39,000 ha are covered with oil palm plantations and 64,000 ha with forest reserve (Agropalma, 2015). The predominant vegetation type of the region is Tropical Rainforest. The area is the largest forest remnant of the Belém Center of Endemism. The climate corresponds to Köppen's *Af* type (Peel et al., 2007), i.e., tropical humid, with an average temperature of 26 °C and relative humidity of 85% (Fig. 1).

Sampling was conducted in second and third order streams of the basin of the Acará River (Strahler, 1957), only in dry season, in November and December 2012, and July and August 2013. The restriction of sampling to the dry season was due to the fact that benthic macroinvertebrates are more abundant during this period (Bispo et al., 2001; Diniz-Filho et al., 1998), and that samples are thus more representative of the community structure (Brasil et al., 2016). A total of 21 streams were sampled, eight in native forest and 13 in oil palm plantation (Fig. 1). One 150 m transect was established in each stream, and was divided into 10 15 m stretches, each subdivided into three 5 m segments. The first two segments of each stretch were sampled, while the third segment was used to gain access to the subsequent stretch. A total of 20 samples were thus collected in each stream.

Based on the recommendations of Shimano and Juen (2016), the study focused on the larvae of the orders Ephemeroptera, Plecoptera, and Trichoptera. The specimens collected were fixed and stored in 85% ethanol, and identified to the genus level using the identification keys of Lecci and Froehlich (2007), Pes et al. (2014), and Domínguez et al. (2006), consultations with experts, and comparisons with material deposited in the Zoological Collection of the Federal University of Pará.

2.2. Environmental variables

Environmental variables were measured in each of the 10 stretches of stream, following Peck et al. (2006). This protocol evaluates various components of the physical structure of the stream, such as the channel morphology, substrate flow type, quantity of woody debris in the stream, the structure of the riparian vegetation, the availability of shelter for the aquatic biota, and human pressures. Physical and chemical variables of the water were also measured, that is, the temperature (°C), turbidity (NTU), dissolved oxygen (mg/L), conductivity (μS/cm), total dissolved solids (mg/L), and pH at the beginning, middle, and end of each 150 m transect using a Horiba® multi-parameter probe. Following Cunha et al. (2015) and Juen et al. (2016), variables with a Pearson correlation of $|r| > 0.7$ were excluded from the analyses to avoid problems associated with the collinearity of variables (Table 2).

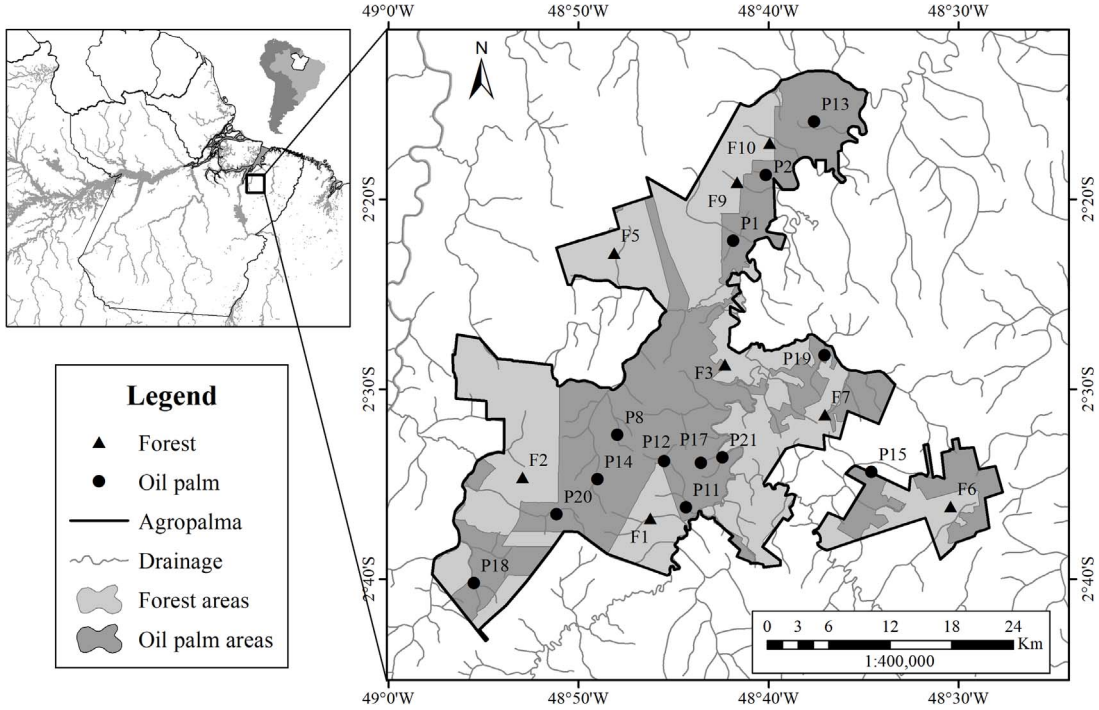

Fig. 1. Distribution of sites in 21 streams distributed in oil palm plantations (circles) and forest fragments (triangles), that were sampled in 2012 and 2013 in Acará, Moju and Tailândia, Pará, northern Brazil.