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Are Odonata communities impacted by conventional or reduced impact logging?

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ABSTRACT

Timber harvest is a prevailing economic activity in Amazonia, which contributes to forest degradation and biodiversity loss. However, Reduced-impact logging has been used to mitigate the loss of environmental integrity and biodiversity, since it has been assumed to be less detrimental than conventional logging practices. The objective of this study was to evaluate if environmental conditions, streams and Odonata communities in reduced-impact logging areas (RIL) are similar to those of unlogged areas (CONTROL), whilst all are modified in conventional logging areas (CL), as a consequence of vegetation removal from the margins of water bodies. Forty-nine streams in areas that differ in timber harvest practices were sampled in eastern Amazonia. As expected, aquatic systems in RIL areas showed environmental conditions and Odonata species composition similar to CONTROL areas while CL streams differed both from CONTROL and RIL. Odonata richness and abundance were not different between CONTROL, RIL and CL treatments, however. Despite the fact that species richness and abundance changes may be masked by the presence of remaining riparian vegetation in CL areas, the use of reduced-impact logging minimizes changes in Odonata species composition and environmental conditions, that remain similar to that of unlogged areas. This is possible due to the planning to reduce environmental impacts in RIL. Unlike RIL, most canopy cover in the proximity of the water bodies (<10 m distance) is lost in CL areas due to logging activities.

1. Introduction

Several unplanned human activities lead to habitat degradation of natural ecosystems (Malhi et al., 2014). In tropical forests, conventional logging (CL) removes vegetation without silvicultural practices to protect biodiversity, also damaging species with no market value, resulting in changes in forest structure and diversity (Davies et al., 2005a,b). On the other hand, wood removed by reduced impact logging might create a habitat with more clearings embedded in the matrix of closed canopy forest or might not lead to a drastic physical degradation of aquatic ecosystems (Nogueira et al., 2016).

In addition, CL produces an increased amount of forest residues (e.g. woody debris, logs), which derive both from logging (Davies et al., 2005a,b) and from logging road construction (Gomi et al., 2006; Kleinschroth et al., 2016). Although forest residues can serve as microhabitats for many species in terrestrial environments, they can form barriers and affect the dynamics of ecosystem functioning (Olsson and Staaf, 1995). It is noteworthy that a higher input of logs in aquatic ecosystems can reduce the morphological complexity of the channel, and consequently, the water flow in streams (Davies et al., 2005a,b). Changes in the physical characteristics of the channel can change species composition of aquatic organisms such as Odonata, which are highly dependent on stream flow conditions (Sanabria and Realpe, 2009; Vilela et al., 2016). The conversion of natural landscape to degraded areas results in loss of leaf

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litter productivity, increased stream temperature (Janisch et al., 2012), potential input of sediment in streams (Fossati et al., 2001; Gomi et al., 2006), with subsequent changes in water quality (Fernandes et al., 2014; Zeni and Casatti, 2014).

Timber demand for civil construction, paper production, and energy sources has had the exponential growth predicted for the Anthropocene period (Steffen et al., 2011). Thus, aquatic ecosystems tend to be threatened by CL because they depend on marginal structures covered by riparian forest for their maintenance and functioning (Bleich et al., 2015). The deployment of reduced-impact logging techniques is an attempt to integrate logging and biodiversity conservation (Roque et al., 2015). This practice is supported by Brazilian law (Law 7.803, De 18 de Julho de 1989), which defines the criteria for logging deployment and functioning near Amazon aquatic ecosystems.

Reduced-impact logging (RIL) is a set of operations in a polycyclic system and includes planning in pre- and post-logging phases, including (primary and secondary) road construction, and maintaining protected buffers along the water systems (Dykstra and Heinrich, 1996). Hence, RIL techniques and practices attempt to maintain the physical environmental characteristics of terrestrial ecosystems and dendritic aquatic systems; therefore, RIL minimizes the effects of logging on aquatic biodiversity, such as vertebrates (Dias et al., 2010) and saproxylic macroinvertebrates (Roque et al., 2015). As many species have specific environmental requirements, they are subject to environmental selective pressures, which cause determining limitations to the local persistence of species (Poff and Ward, 1990).

Despite the advances of RIL techniques, their effects are still unpredictable for groups with high specificity or fidelity to environment quality (Bicknell and Peres, 2010). It is thus important to assess the response of aquatic invertebrate organisms to the effects of RIL in order to determine effective actions to improve management in natural areas. Amazonian aquatic ecosystems have very heterogeneous natural physical characteristics and their responses could be nonlinear to different human activities (Leal et al., 2016). However, these predictions must be tested at larger scales and in the long term to understand their actual effects on biodiversity and on the functional diversity of species (Burivalova et al., 2015).

Insects of the Odonata order have broad distribution and diversity in tropical water systems and are good models to be used in the assessment of the effects of anthropogenic changes in aquatic ecosystems (Carvalho et al., 2013; Oliveira-Junior et al., 2015; Rodrigues et al., 2016) and in priority areas assigned for conservation, which comprise biodiversity hotspots (Simaika et al., 2013). The persistence of adult odonates in aquatic environments of terrestrial landscapes is associated with many factors, including the effects on areas surrounding riparian vegetation (Dolný et al., 2014), bionomic features, e.g. body size (Dutra and De Marco, 2014), selectivity of microhabitats/substrates (Corbet, 1999), and thermoregulatory abilities (May, 1976; De Marco et al., 2015). Combined with these factors, the choice of microhabitats for juvenile development in their aquatic phase also determines habitat selection by adults (Kadoya et al., 2008). Especially in Neotropical regions, the majority of Odonata species are essentially associated with forests, which provide several larval habitats, shaded and sunshine microhabitats, which are unavailable to thermal conformers in open areas (Paulson, 2006).

We assess the effects of CL and RIL attempting to identify which environmental variables of streams (marginal vegetation, channel morphology, and physico-chemical aspects of water) are most important to the community structure of Odonata assemblages. Our hypothesis is that there is changes in Odonata species diversity and composition between pristine forests (hereafter, CONTROL) and CL areas, and marginal vegetation metrics are determining factors in the differences in Odonata adult compositions between treatments. On the other hand, species diversity and composition shall be similar between CONTROL and RIL areas, if logging in RIL is effectively planned to minimize impacts on forest structure as thought. Due to previously planned removal of timber in reduced impact management, it is expected that physical environmental conditions of streams (e.g. riparian vegetation), which affect the Odonata community, remain unchanged by this practice; consequently, biodiversity shall remain unchanged.

2. Material and methods

2.1. Study area

This study was carried out in 49 streams, which comprise the Capim River basin, in the municipality of Paragominas, northeastern Pará State, Brazil (Fig. 1). For its most part, the vegetation in the region is classified as Dense Ombrophilous forest (Almeida et al., 2009). The climate in the region is "*Aw*", according to Köppen's system (Peel et al., 2007); tropical wet, with rainfall of approximately 2000 mm/year and relative air humidity of 80% (Silva et al., 2007).

Sample units were selected to reach greater environmental variation of aquatic systems visited. Some criteria were adopted: minimum geographical distance of 2 km between each stream to preserve their independent sampling and streams from different sub-basins. A total of 12 streams located in CONTROL areas were assessed; these were undisturbed areas, with continuity between the riparian vegetation and the adjacent forest, and absence of human impacts in the surroundings (Oliveira et al., 2008); 26 streams in managed logging areas, where RIL is deployed (Veríssimo et al., 1992); and 11 streams in CL areas. CONTROL and RIL streams are located inside Cikel Brasil Verde Madeiras LTDA complex. This area has been logged since 2001 under FSC (Forest Stewardship Council) certification and polycyclic logging is carried out; an area is only logged again after 30 years of forest regeneration. Sampling units in conventional logging areas are located in properties around Cikel Company and do not belong this company.

Despite the presence of vegetation around aquatic ecosystems in conventional logging areas, it forms a discontinuous reach with the adjacent forest where the number of large trees is lower than in reference areas, which is compatible with the history of logging in the Paragominas region (Veríssimo et al., 1992).

2.2. Sampling design and biological sampling

A 150-meter reach was delimited in each stream, subdivided in 10 sections (15 m), separated by crosscut sections (11), designated by letters from A (downstream) to K (upstream). Subsequently, each section was subdivided in three five-meter segments, and the Odonata order was only sampled in the first two segments, comprising a total of 20 five-meter segments.

Odonata adults were collected using an entomological net between 11 am and 14 pm, a period with the busiest activity (Kutcher and Bried, 2014). A one-hour period was standardized for sampling in each stream. Each individual collected was stored into envelopes of thin paper, following Lencioni's protocol (2005, 2006). To identify the specimens, we used specialized taxonomic keys (Garrison et al., 2006, 2010; Garrison and von Ellenrieder, 2015; Lencioni 2005, 2006; Pessacq, 2014; von Ellenrieder, 2013a). The witness biological material is deposited in the Zoology Collection at the Federal University of Pará, Belém campus - PA, Brazil.