Perspectives of hydrological disturbance as the driving force of Brazilian semiarid stream ecosystems.

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ABSTRACT: Perspectives of hydrological disturbance as the driving force of Brazilian semiarid stream ecosystems. Existing conceptual approaches on hydrological disturbance applied to aquatic ecosystems provide a relevant insight into the understanding of Brazilian semiarid streams functions. Succession is an appropriate tool for investigating the response of ecosystems to hydrological disturbance. Recent research developed in intermittent streams of Brazil suggested that hydrological disturbance is the primary force for the operation of these ecosystems. A series of perspectives rising from recent studies are thereby proposed: 1. Low and medium floods occurring within a wet period may diminish the density of some aquatic communities; 2 Organisms more resistant to disturbance by flood might not serve as indicators of some disturbance events; 3. The succession pattern at the start of a wet period seems to be highly related to drought magnitude in the previous dry period; 4. Different frequencies of disturbance may induce very different successional patterns; 5. More complex communities may be more stable than less complex ones.

Key-words: intermittent streams, hydrological disturbance, succession, theoretical perspective, semiarid region, Northeast Brazil

RESUMO: Perspectivas da perturbação hidrológica como força organizadora para os rios do Semi-árido Brasileiro. As abordagens de perturbação hidrológica desenvolvidas em ecossistemas aquáticos proporcionam importantes idéias para o conhecimento do funcionamento de rios intermitentes do Semi-árido Brasileiro. A sucessão de comunidades aquáticas é uma ferramenta apropriada para analisar a resposta do ecossistema frente às perturbações hidrológicas. Trabalhos recentes realizados nos rios intermitentes do Semi-Árido Brasileiro sugerem a perturbação hidrológica como a força primária na organização destes ecossistemas. Uma série de perspectivas derivadas de recentes estudos é proposta: 1. Cheias de baixa e média magnitude ocorrendo no período úmido podem diminuir a densidade de comunidades aquáticas; 2. Organismos resistentes às perturbações hidrológicas podem não servir para identificar alguns eventos perturbadores; 3. A sucessão ecológica no início de um período úmido parece estar altamente relacionada com a magnitude da seca anterior ao período úmido; 4. Diferentes freqüências de perturbações podem induzir a diferentes modelos de sucessão; 5. Comunidades mais complexas podem ser mais estáveis que comunidades menos complexas.

Palavras-Chave: riachos intermitentes, perturbação hidrológica, sucessão, perspectivas teóricas, região semi-árida, Nordeste Brasileiro.

Introduction

The essential characteristic of Brazilian semiarid region is the low amount of rainfall and the narrow temperature oscillation. This peculiar climatic rhythm results from the proximity to the Equatorial Zone and from a complex pattern of atmospheric circulation. This general trend can vary greatly in space within the extensive semiarid region (1.000.000 km^2), where dry periods extend between 1 and 11 months per year. The geographic variability resulting from rainfall patterns, altitude, relief and continentality contributes to increase the landscape diversity in the Brazilian semiarid region. Episodes of torrential and violent storms are frequent in summer-autumn in many parts of the region.

Most Brazilian semiarid aquatic ecosystems are intermittent; the duration of wet period varies between 1-11months. The little relevance of aquifers in the region limits the importance of groundwater in the function of aquatic ecosystems (IBGE, 1977). Brazilian semiarid rivers flow into the Atlantic Ocean, at least occasionally in the course of a year. For this reason intense salinization does not occur in these ecosystems (Ab'Saber, 1994/95). Brazilian semiarid streams were classified by Santos (1962) in terms of their climatic features. The main characteristic of Brazilian semiarid streams is the lack of surface flow along an annual cycle, with a sharp and unpredictable alternation of wet and dry periods. In this context, it is significant that the most typical lotic systems of this region are characterized by low, irregular and extreme flows, with a high spatial and temporal variability of flood conditions.

Information concerning the climate, vegetation, fauna, and human activities is available for many ecological processes in Brazilian semiarid region. Much less is known on the effects of hydrological disturbance on the functioning of Brazilian semiarid streams. Research in this direction should include the analysis of community responses to disturbance by flash floods and droughts. Studies on succession of aquatic communities are appropriate tools for investigating the response of ecosystems to hydrological disturbances. We will analyze here succession *sensu* Picket (1976), as the changes observed in an ecological community following disturbance. The main objective of this paper is to analyze the importance of hydrological disturbance on the functioning of intermittent streams, using case studies from the semiarid region of Brazil. Conceptual perspectives are proposed on the temporal analysis of hydrological change as the primary forces in the operation of these ecosystems.

The concept of hydrological disturbance

The concept of disturbance as a discrete event defined in terms of attributes such as frequency, intensity, duration and predictability (Pickett & White, 1985) is useful to analyze the effects of hydrological variation on the functioning of intermittent streams. Research on disturbance has been especially active since Souza (1984) defined disturbance in his work on intertidal systems. Resh et al. (1988) changed the definition proposed by Pickett & White (1985) to include only the events that are beyond the predictability threshold, since organisms are adapted to seasonal disturbance. Poff (1992) regarded four limitations in Resh et al.'s assertion that disturbances are necessarily unpredictable (hydrological statistics, biological adaptation, predictability, and ecological and evolutionary mechanisms).

On the other hand, the concept of hydrological disturbance is related to the idea of ecosystem stability (Margalef, 1968; Webster et al.., 1975; Sutherland, 1990). Resistance (the degree to which a variable remains unchanged during and after disturbance) and resilience (rate of recovery after disturbance) are measurable features of stability which have been used to characterize both ecosystem and population responses (Webster et al. 1975, Grimm & Fisher 1989). The diverse meanings of stability and complexity generated a strong controversy between different authors (Pimm, 1994). Theoreticians have considered stability from a mathematical point of view (i.e. systems are either stable or not). On the other hand, the term stability has been discussed at different levels of ecological organization – populations, community, or ecosystems - (Pimm, 1984). Complexity has been taken into different meanings to express the number of species, the degree of interspecific connectance, and the relative abundance of a species in the community. Bonner (1988) defined complexity by the number of cell types found in an organism. These definitions provide theoretical basis for semiarid stream ecology, including the Brazilian semiarid streams. However, the lack of studies that analyze the response of different aquatic communities to the single hydrological disturbance event motivates field studies to elaborate conceptual approaches and theoretical perspectives related to the stream functioning.

Flood and drought are the most important hydrological disturbances in intermittent streams. Disturbance should be characterized by their attributes (i.e. magnitude and frequency). The concept of disturbance is controversial in aquatic ecosystems (Benke et al. 2000). While flooding in low gradient rivers has an important ecological interaction between the river channel and its associated floodplain (Junk et al. 1989), floods are catastrophic events in streams (Resh et al., 1988). Floods are usually pulses, especially in constrained rivers. In lowland unconstrained floodplain rivers, these pulse events may have an extensive duration. Flood and drought modify the structure and function of streams in deserts (Fisher & Grimm, 1988; Grimm & Fisher, 1989) and Mediterranean regions (Giudicelli et al., 1985; Maltchik et al., 1994; Ortega et al., 1991; Vidal-Abarca et al., 1992).

Brazilian semiarid streams are characterized by extremes of flood and drought (Maltchik, 1996, 1999). These extreme events are important disturbing agents and influence the succession of algae (Maltchik et al. 1999), macrophytes (Maltchik & Pedro 2001), macroinvertebrates (Maltchik & Silva-Filho 2000; Silva-Filho & Maltchik 2000), fishes (Medeiros & Maltchik 1999, 2000, 2001) and the human population associated to stream ecosystems (Maltchik 2000). These studies, performed in the Brazilian semiarid region, support that a specific research framework for intermittent streams may be useful and provide a relevant perspective for semiarid stream ecology. The basis of this proposal should be that the key processes to bear in mind are the characteristics of hydrological disturbance through time.

Theoretical perspectives

The analysis of the dependence of the pattern of ecosystem organization on flood magnitude, together with its timing, would be the first aspect to be considered. Flood may exert positive or negative effects on the stream structure, depending on its magnitude (Tab.I).

Table I. Variation of macroinvertebrate biomass in Avelós stream during 1996 related to the flood magnitude. The floods of low magnitude influenced in a different way the macroinvertebrate biomass in the Avelós stream. The floods of 0.1 $m^3.s^{-1}$ and 0.3 $m^3.s^{-1}$ increased the biomass of macroinvertebrate, while the flood of 0.5 $m^3.s^{-1}$ (April 29) decreased it. On the other hand, the flood of high magnitude (1.1 $m^3.s^{-1}$ - March 11) caused an accentuated decline in the macroinvertebrate biomass.

Flood magnitude ($m^3.s^{-1}$)	Macroinvertebrate Biomass (%)
0.1	+ 9.58
0.3	+ 1,244.0
0.5	-3.57
1.1	-97.37

Low and medium floods occurring within a wet period may diminish the density of aquatic community (Fig. 1). However, high magnitude floods may temporarily eliminate the occurrence of a specific population in a stream reach (Fig. 1). Organisms more resistant to disturbance by flood could not serve to identify some of those disturbance events (Fig. 2).

The background of environmental conditions that the stream ecosystems present at the start of a wet period seems to be highly specific to drought magnitude in the preceding dry period (Fig. 3). Different disturbance frequencies may induce very different patterns in the ecosystem behavior due to the life cycles and persistence strategies and adaptation of organisms (Fig. 1). These patterns become more complex when other features of disturbance vary as well, depending on the combination of disturbance events at the long term.

Stability against disturbance caused by floods and drought is different between communities and between ecosystems. Each community or population presents a resistance threshold to disturbance by flood and drought, which can vary among annual cycles and stream orders. More complex communities *sensu* Bonner (1988) may be more stable than less complex ones (Fig. 4).

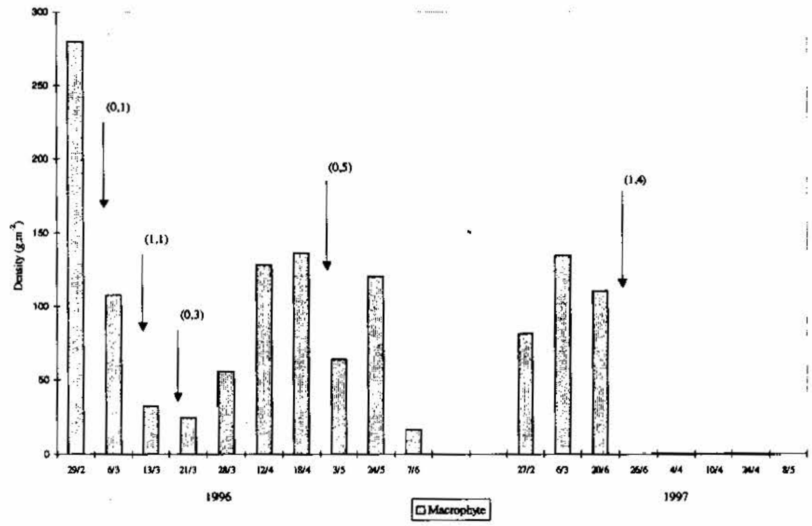

Figure 1: Density of *Najas marina* in the Avelós stream during two annuals cycles (1996-97) (Maltchik & Pedro, 2001). The attributes of flood (magnitude and frequency) determined different succession pattern of the macrophyte during successive hydrological cycles. The macrophyte biomass decreased after all five floods. Post flood biomass was 47-75% of pre-flooding when discharges were lower or equal to 0.5 $m^3.s^{-1}$, and 0-30% when discharges were higher than 1.0 $m^3.s^{-1}$. Successive floods delayed the onset of the re-establishment by *Najas marina*. Macrophyte resilience was negatively related to magnitude of floods. After floods of low and intermediate magnitude, three weeks were necessary to re-establish 48 and 88% of biomass lost, and after the high magnitude flood, six months were necessary to start the re-establishment by *Najas marina*. Arrow = flood occurrence. () = Stream discharge - $m^3.s^{-1}$.

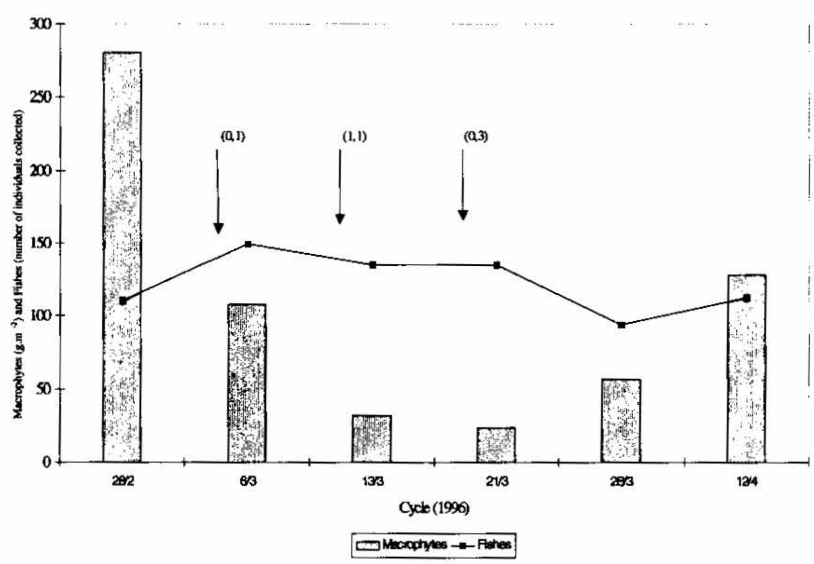

Figure 2: Density of macrophytes (Maltchik & Pedro 2001) and fishes in the Avelós stream during an annual cycle (1996). Flood may exert different influences in the structure of the stream ecosystem. While fish community was resistant to disturbance by flood of low magnitude (0.1 $m^3.s^{-1}$) in Avelós stream during 1996, the population of *Najas marina* was not resistant. . Arrow = flood occurrence. () = Stream discharge - $m^3.s^{-1}$.

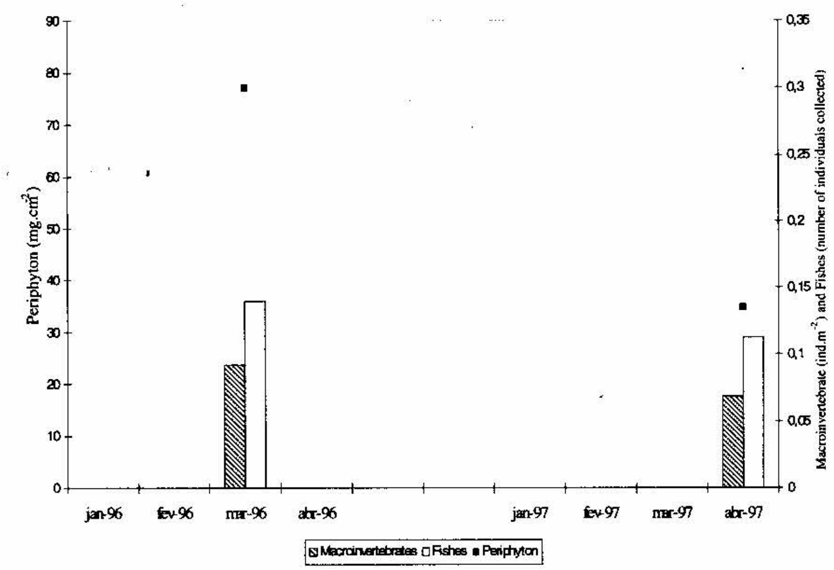

Figure 3: Density of periphyton, macroinvertebrates and fishes at the beginning of two annuals cycles (1996 and 1997) in the Avelós stream. When the start of the wet period was delayed within the annual cycle, the lowest values of these variables were recorded.

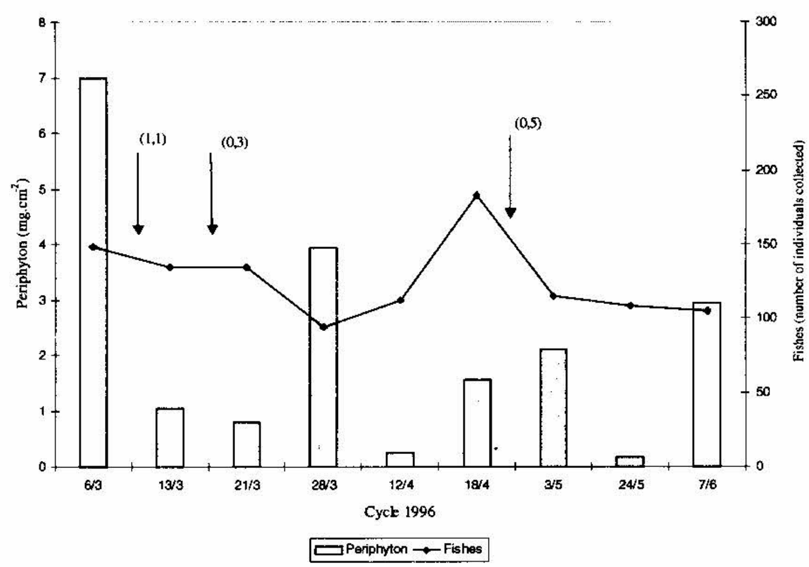

Figure 4: Density of periphyton and fishes in the Avelós stream during 1996. Periphyton density was more variable in time than fish community within the annual cycle. We defined complexity by the number of cell types found in an organism (Bonner, 1988). Arrow = flood occurrence and () = stream discharge in $m^3.s^{-1}$.

The homeostatic potential of intermittent stream ecosystems at a large scale is undervalued because they are highly fluctuating and because contribution of microbes, seed-banks, and refuges are rarely taken into account when assessing biodiversity of intermittent streams. Estimating these relationships will provide the basis for long term research on stream function.

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