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Ecohydrological Processes and Sustainable Floodplain Management

Application of the ecohydrological concept for sustainable development of tropical floodplains: the case of the upper Paraná River basin

Angelo A. Agostinho[1], Luiz C. Gomes[1], Fernando M. Pelicice[1], Edvard E. Souza-Filho[2], Eduardo A. Tomanik[3]

[1]Universidade Estadual de Maringá - Nupelia-DBI-CCB
Av. Colombo, 5790 - 87020-900 Maringá – PR – Brazil
agostinhoaa@gmail.com, lcgomes@nupelia.uem.br, fmpelicice@gmail.com
[2]Universidade Estadual de Maringá – Dept. Geografia-CCH
edvardmarilia@wnet.com.br
[3]Universidade Estadual de Maringá – Dept. Psicologia-CCH
eatomanik@gmail.com

Abstract

The degradation of natural resources in the upper Paraná River's floodplain remnant has been caused by local use of land, and by alterations in the flood regime promoted by more than 100 large reservoirs located upstream from the plain. This destruction appeared irreversible 15 years ago, although the area has been partly rehabilitated through the construction of three large conservation units that encompass the entire remnant. These units, which imposed different levels of restrictions on soil use, have resulted in clear benefits to terrestrial components. However, aquatic ecosystem function is still harmed by artificial regulation of discharge. This regulation reduces biological diversity and the resources traditionally exploited by indigenous people. In this paper, we examined the conditions of the upper Paraná River basin in detail, and we discussed the application of the ecohydrology concept to promote sustainable development in this region.

Key words: Flood control, biodiversity, reservoir, hydroecology, flood and fisheries

1. Introduction

Brazil has one of the biggest river networks on the planet, which drains an area of over 8 500 000 km^2. This large surface area, coupled with variations in the features of the landscape (hydrology, physiography, and geomorphology), results in a great heterogeneity of freshwater ecosystems with a profusion of distinct habitats. Brazil's aquatic biodiversity is among world's most diverse (Agostinho *et al*. 2005), and is directly correlated with the abundance of habitat rivers in the biomes of South America.

The aquatic ecosystems of Brazil and South America are becoming more difficult to maintain, especially in floodplain regions (Gopal *et al.* 2000; Junk 2002). Population growth in the last century has led to an expansion in agriculture, an increase in urban population, and a proliferation of industry. These events have occurred in all large basins, but with a higher intensity in basins located in the south and southeast of Brazil. Population growth

has directly impacted these regions through eutrophication, contamination with pesticides and industrial residues, drainage of water bodies, accumulation of sand, removal of vegetation in the basin and near rivers (riparian), introduction of alien species, and overexploitation of natural resources. Additionally, the natural hydrosedimentological dynamics of floodplains have been profoundly altered by the construction of dams (Agostinho *et al*. 2007a). Natural dynamics in pristine rivers include seasonal but predictable variations in river discharge, modifications in the degree of hydrological connectivity, and the periodic exchange of matter, energy, and nutrients among environments (Junk *et al*. 1989; Neiff 1990; Thomaz *et al*. 2007). These dynamics are responsible for the proper function of floodplains: to maintain productive dynamics, nutrient cycling, and biological structure.

Damming alters several physical, chemical, and biological properties of rivers and their associated floodplains (Petts 1984; Tundisi, Matsumura-Tundisi 2003; Agostinho *et al.* 2004a), but one of the most conspicuous negative impacts is the decline in populations of migratory fish species (Agostinho *et al*. 2007b). These species require certain types of habitats and particular hydrological conditions to complete their life cycle (for example, tributaries, "várzeas", and lotic stretches). The construction of dams may obstruct access to some essential habitats, or even alter environmental conditions that determine reproductive success (Agostinho *et al*. 2003). As a result, recruitment of juveniles to dammed stretches may be seriously affected, and may sometimes cause a population to run the risk of extinction.

The relationship between dam construction and migratory fish species conservation has been debated by researchers for decades. In addition to a vital ecological role in the function of freshwater systems (Freeman *et al*. 2003; Taylor *et al.* 2006), migratory species are quite large in size. They are therefore economically important, and supply wages for several families in all river basins of Brazil (Bayley, Petrere Jr. 1989; Petrere Jr. 1996; Godinho, Godinho 2003; Okada *et al.* 2005; Agostinho *et al.* 2007b). The economic loss caused by the effect of dams on migratory species has motivated a series of management actions including stocking, fishery control, and fish passage construction to restore and/or conserve migratory fish populations in the environments influenced by reservoirs. Intense efforts have been applied to the management of these resources, especially during the last 50 years. However, there are no indications that these actions have yielded satisfactory results, as demonstrated by the depletion of the most important fish stocks in the higher stretches of the upper Paraná River (Agostinho *et al.* 2004b; Pelicice, Agostinho 2008). Consequently, negative impacts of damming still persist, as do those related to other components and processes that occur in floodplains. There is a pressing need for alternative approaches to rehabilitate the natural dynamics of these ecosystems, preferably one that is less reductionist and fragmented.

The ecohydrological approach assumes a strict interdependence between hydrological and ecological processes. This approach represents an interesting alternative in the management of aquatic resources due to its holistic perspective in treating ecosystems. In ecohydrology, successful maintenance of aquatic resources depends on actions that restore natural ecological and evolutionary processes that are dependent on regional hydrological dynamics (Zalewski 2000). Thus, the restoration of spatiotemporal hydrosedimentological dynamics at the basin level is fundamental in this approach: river, floodplain, adjacent landscape, and biota are viewed as a completely integrated system (Ward 1998; Ward *et al.* 2002). Based on a deep knowledge of the dynamics that underlie natural rhythms, ecohydrology aims to increase the capacity of systems in reabsorbing environmental impacts, by using properties of the ecosystem itself as management tools (e.g., rehabilitation of natural hydrological pulses, heterogeneity of habitats, and riparian vegetation; Zalewski *et al.* 1997; Zalewski 2002). It is expected that this approach promotes sustainable human development by preserving functions and services provided by aquatic ecosystems.

In this paper, we considered the use of ecohydrology as a framework for solving environmental problems of floodplains influenced by large dams, given the intrinsic value of wetland rehabilitation and river natural dynamics (Poff *et al.* 1997; Buijse *et al.* 2002). To achieve our goals, we used the upper Paraná River basin as a template. This basin has an enormous number of large dams, but still represents a single floodplain remnant. While this stretch is intensely influenced by the operation of several dams located upstream, it still plays a relevant role in maintaining biodiversity and fishing stocks in the region (Agostinho *et al.* 2007a). Specifically, we discussed how ecohydrology may contribute to the maintenance and restoration of the floodplain remnant of the upper Paraná River, in the context of multiple usages, serious conflicts in the use of resources, and a long history of environmental actions based on reductionist management.

2. Flood regime and floodplain processes

The upper Paraná floodplain was originally a 500 km stretch on the western margin of the Paraná River, between the municipalities of Três