

**EDGE EFFECT FROM CONTINUOUS FOREST
AND FRAGMENT FOREST ON THE LARVAL PERFORMANCE OF
AN AQUATIC ANURAN TADPOLE AND PREDATOR-PREY
INTERACTION IN CENTRAL AMAZONIAN**

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RESUMO

Efeito de borda de floresta contínua e fragmento de floresta sobre a performance larval de um girino anuro e interação predador-presa na Amazônia Central

Nós examinamos como a interação predador-presa de uma larva de anuro é influenciada pela proximidade da borda de floresta contínua e de fragmentos de floresta tropical primária de terra-firme. Os resultados mostraram que a proximidade da borda de floresta contínua e de fragmentos florestais não afetou a sobrevivência e o desenvolvimento de *Osteocephalus taurinus* com e sem predadores, indicando que nem as mudanças no hábitat nem os predadores causaram o padrão observado na performance larval. Em uma análise gráfica, ambos parâmetros apresentaram números suavemente mais altos em floresta contínua.

Palavras chave: Performance larval, girino, manipulação experimental, anfíbio

ABSTRACT

We examine how the predator-prey interaction of aquatic anuran larva is influenced by proximity of edge from continuous forest and fragments of primary tropical terra-firme forest. Results showed that the proximity of edge of these habitats did not affect survival and larval development of *Osteocephalus taurinus* with and without predators, indicating that neither the habitat changes nor the predators caused the observed pattern in larval fitness. In a graphic analysis both parameters showed lightly higher numbers in continuous forest.

Keywords: Performance larval, tadpole, experimental manipulation, amphibian

INTRODUCTION

Larval anuran assemblages have been used as a model of predator-prey systems and this system has provided considerable experimental evidence for the role of competition and predation in natural communities (Heyer et al., 1975; Morin, 1986; Magnusson & Hero, 1991; Bridges, 2002).

Experimental manipulations using artificial ponds have investigated the ecological interactions that influence the distribution and abundance of larval anuran assemblages in temperate regions (Morin, 1983; Morin et al., 1983, 1985; Alford & Wilbur, 1985; Wilbur & Alford, 1985; Petranka et al., 1994) and tropical ones (Gascon, 1992 a,b). In the

central Amazonian region, field experiments demonstrated that predators significantly reduced tadpole survival, and aeshnid naiads were the most voracious predators, followed by libellulid naiads and *Distyctid* beetle (Gascon, 1992 a).

In tropical aquatic habitats, some studies show that odonate naiads and fishes are very effective predators of tadpoles (Heyer et al., 1975; Gascon, 1989, 1992 a; Hero, 1990; Magnusson & Hero, 1991; Azevedo-Ramos et al., 1999). Predation and competition are considered the principal ecological factors influencing the community of the Brazilian Amazon rainforest tadpoles (Hero, 1990; Gascon, 1992 a; Oliveira, 1996). However, to our knowledge, few studies have investigated the edge effects of

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fragments and continuous forest on the ecological interactions in this region. We know one study in a fragmented dry subtropical forest in northwestern Argentina where it was observed that pollination and seed production of the plant community declined with increasing fragmentation, reflecting impacts of the habitat change on plant-animal interactions (Aizen & Feinsinger, 1994). Moreover, we nothing do not know within the aquatic larval anuran environment. Effects of fragmentation on adult frogs are the studies more recent (see Tocher et al., 1997).

In this paper, we examine how the predator-prey interactions of aquatic animals are influenced by environmental changes of the proximity of edge from primary tropical terra-firme forest and forest fragments. The goals were to test whether the proximity to the edge to affect some parameters of larval performance (survival and development) and the predator-prey interaction of aquatic animals in controlled experiments. We asked whether there are differences in performance parameters and predator-prey interaction in relation to the proximity of edge of 1ha and 10ha fragments and continuous forest. We tested one tadpole species (*Osteocephalus taurinus*), and two voracious known predators of tadpoles such as aeshnid and libellulid naiads (Gascon, 1989; 1992 a, b, 1995b).

MATERIAL AND METHODS

This work was carried out in Brazil's National Institute for Amazon Research- Biological Dynamics of Forest Fragment Project (INPA- BDFFP) reserves 80 km north of Manaus (2° 30' S; 5° 60' W) (Lovejoy et al., 1986; Lovejoy & Bierregaard, 1990). This study was done during two sampling years. The first sampling year was from March to July 1995. The second year was from November 1995 to June 1996. The forest is typical terra-firme forest (not subject to periodic flooding), with an annual precipitation of 2200 mm. The canopy height is smaller than 40m and palms dominate the understory (Scariot, 1996).

Enclosure ponds were distributed in fragmented forest and continuous forest habitats. These artificial ponds (2,0 X 1,50m) are formed by excavation of the soil (12cm deep), using plastic canvas and covered by 10 cm of soil and litter. Ponds were covered totally with a nylon net to prevent the entrance of new organisms. The ponds were colonized for the same number of *O. taurinus* eggs and aeshnid and libellulid naiads in the three kinds

of habitats (1 and 10 ha fragments and continuous forest).

Five ponds were constructed in continuous forest (distant 1000m from edge), one pond in each of four fragments of 1ha (4 ponds – distant 100m from edge), and one pond in each of three fragments of 10 ha (3 ponds – distant 350m from edge). Only thousand eggs of the frog *Osteocephalus taurinus* were placed handle in experiment 1 (see below). Thousand eggs of *O. taurinus* and three individuals of both predators, aeshnid and libellulid dragonfly larvae, were placed by hand in two and three experiments (see below). *Osteocephalus taurinus* is usually the first species to breed and to colonize a newly filled pool (Gascon, 1992b). This is a species that reproduces throughout the year with peak activity during the rainy season (Gascon, 1989). This species was chosen for colonization because it is the most common anuran and because it egg-laying is easily localizable (Gascon, 1991). The larval phase of *O. taurinus* is approximately 30 days in natural conditions. For this reason, the number of tadpoles in artificial ponds was accounted after 30 days colonization when the species is completing the metamorphosis. The predatory dragonfly larvae used in the experiments are very effective predators of tadpoles in terra-firme ponds (Gascon, 1992a). We chose the prey (number of frog eggs) and the predator (number of individuals of dragonfly larvae) combinations based on previous work (Gascon, 1991; 1992a).

Three experiments were performed. Each experiment was used in the ponds of fragments and continuous forest during the same time. In this way, it was given the same treatment in the twelve ponds of the habitats in each time. When there were the entrance of others organisms, the experiment was repeated. The first experiment consisted to introduce only eggs of *O. taurinus* in artificial ponds in fragmented forest and continuous forest habitats. This experiment was designed to test the difference in survival and development of *O. taurinus* tadpoles between the habitat types 1ha, 10ha and continuous forest in relation to the edge effect. To accomplish this, 1000 *O. taurinus* eggs were placed in each enclosure pond (replicate) of each habitat (12 ponds). In the two subsequent experiments we tested whether there are differences in predator-prey interactions as a function of the different edge proximities of habitats. In these experiments, 1000 eggs of *O. taurinus* were placed with three

individuals of libellulid naiads (experiment 2) or with three individuals of aeshnid naiads (experiment 3) per pond of each habitat. The first experiment lasted 60 days, with monitoring of tadpole performance (survival and development) at 30 and 60 days. Experimental manipulations of this work showed that the species completed larval development in 60 days during the first experiment. It was maybe due the absent of predators in artificial ponds.

In experiment 1, the tadpoles were collected with a dip-netted and were placed in basins. After it was obtained the total number of survivals and tadpoles in fourth stage, in 30 and 60 colonization days in the ponds monitored. In this way it was possible to observe the tadpole development in controlled experiment without predator and to compare between the habitats. In the end of 60 days all the ponds were cleaned. In experiments 2 and 3 with predators the tadpole development was observed only after 30 days.

All the comparisons were done in function to test the differences among the habitats of 1ha, 10ha and continuous forest in relation to the proximity edge. The individual ponds were considered replicates but have one pond for each fragment and several fragments in each class size. We used Kruskal-Wallis analyses of variance (Siegel, 1975) to test for differences in survival and median developmental stage for tadpole species in each experiment. The analyses were done using the

SYSTAT statistical program (Wilkinson, 1990). We calculated tadpole survival by counting the total number of survivor tadpoles in each pond and each experiment. Larval development was determined by the total number of stage four tadpoles in the end of each experiment.

RESULTS

Survival and development of *O. taurinus* tadpoles were not significantly different between the three types of habitats, neither there was a difference of prey-predator interaction by the proximity edge of habitats (Table 1).

The first experiment, which lasted 60 days, consisted of placing *Osteocephalus taurinus* eggs in the artificial enclosure ponds. The results of 30 days of colonization showed that the survival (median \pm 1 standardized error) of tadpoles did not vary between fragments. The number of tadpoles in the fourth stage (mean \pm 1 standardized error) was lightly bigger in continuous forest (Figure 1b). The 60 days of development results showed the same pattern as for the 30 days of colonization (mean \pm 1 standardized error) (Figure 2b).

In the second experiment, which consisted of placing *Osteocephalus taurinus* eggs with three libellulid individuals, the number of surviving tadpoles and the number of juveniles (mean \pm 1 standardized error) did not differ among fragments

Table 1. Kruskal-Wallis analyses of variance and associated values of *P* of *Osteocephalus taurinus*, for the three experiments. Analyses tested differences in number of survivors and juveniles among the different habitats (fragments and continuous forest).

Survival	Number of recruits
Experiment 1 (no predator - 30 days)	
(K-W = 4.503; GL = 2; P= 0.105)	(K-W = 2.439; GL = 2; P= 0.295)
Experiment 1 (no predator - 60 days)	
(K-W = 2.908; GL = 2; P= 0.234)	(K-W = 1.296; GL = 2; P= 0.523)
Experiment 2 (presence of libellulid naiads)	
(K-W = 0.960; GL = 2; P= 0.619)	(K-W = 2.875; GL = 2; P= 0.238)
Experiment 3 (presence of aeshnid naiads)	
(K-W = 0.574; GL = 2; P= 0.751)	(K-W = 0.600; GL = 2; P= 0.741)

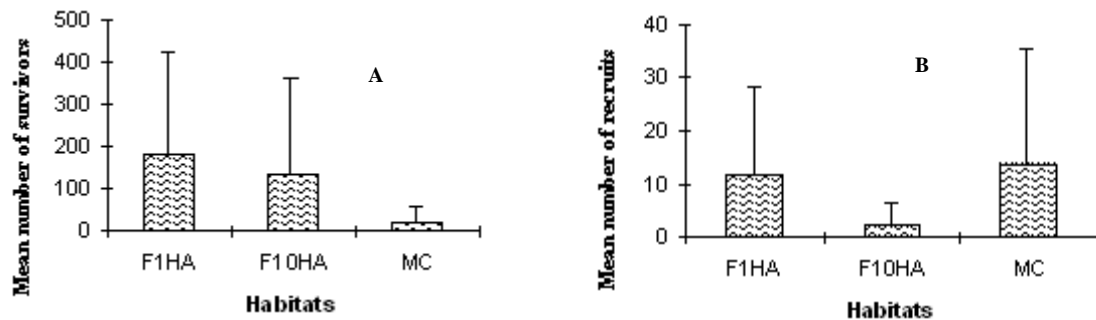


Figure 1. Experiment 1 (30 days), regarding the number of survivors (A) (mean ± 1 standardized error) and the number of recruits (B) (mean ± 1 standardized error) in artificial enclosure ponds among different habitats.

(Figures 3a, b). The tadpole survival of *O. taurinus* was greater in continuous forest. No surviving tadpoles reached stage four at 30 days in this habitat.

In the third experiment, which consisted of placing *Osteocephalus taurinus* eggs with aeshnid individuals, the number of survivor tadpoles and the number of juveniles (mean ± 1 standardized error) was lightly greater in continuous forest, but there is no statistical difference in the results among the fragments (Figures 4a, b).

DISCUSSION

Results showed that the proximity of edge from fragments and continuous forest did not affect survival and the larval development with and without the presence of predator. In the central Amazonian region, the forest fragmentation positively (Rylands & Keuroghlian, 1988; Tocher et al., 1997) and negatively affected (Klein, 1989; Lovejoy et al., 1986;

Bierregaard & Stouffer, 1997) animal population parameters on the Biological Dynamics Forest Fragments Project reserves.

Odonate larvae seem to be the main predators responsible for the regulation of *O. taurinus* tadpole populations (Oliveira, 1996). These larvae were considered the most effective predators in terra-firme ponds, which are common in the habitats of continuous forest in the Brazilian Amazonian region (Gascon, 1992 a). In an experimental study, the odonate larvae were considered the most voracious predators because they ate significantly more *O. taurinus* larvae in different size classes than fish (Gascon, 1989).

The present work contributes to how ecological interactions can be affected by environmental change such as edge proximity of fragmented habitats and primary habitat. Predator-prey interactions and larval performance were not significantly different among the habitats, but few

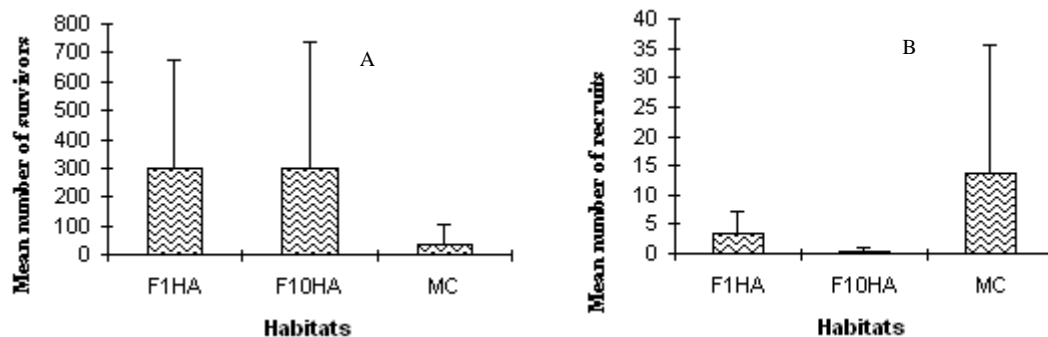


Figure 2. Experiment 1 (60 days), regarding the number of survivors (A) (mean ± 1 standardized error) and the number of recruits (B) (mean ± 1 standardized error) in artificial enclosure ponds among the different habitats.

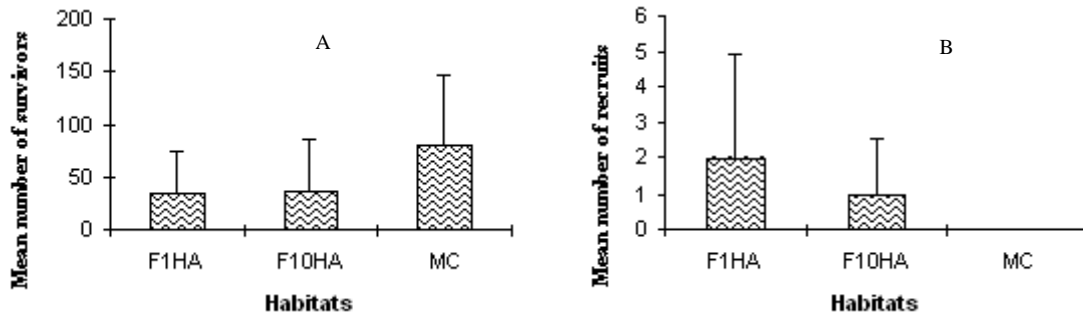


Figure 3. Experiment 2 (1000 frog eggs + 3 libellulids), regarding the number of survivors (A) (mean \pm 1 standardized error) and the number of recruits (B) (mean \pm 1 standardized error) in artificial enclosure ponds between the different habitats.

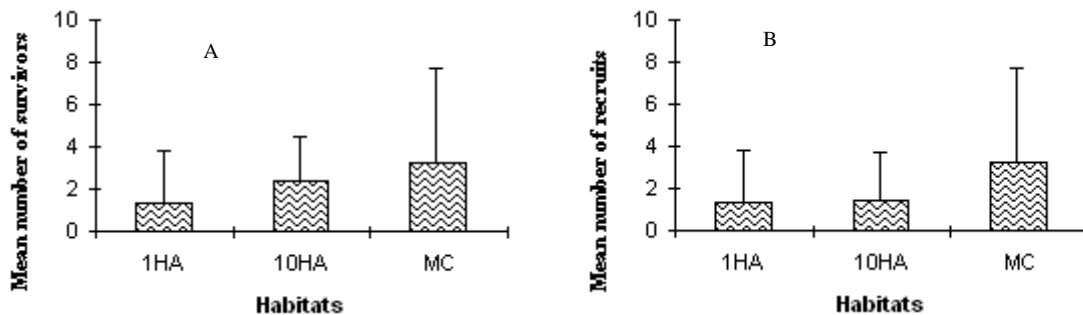


Figure 4. Experiment 3 (1000 frog eggs + 3 aeshinids), regarding the number of survivors (A) (mean \pm 1 standardized error) and the number of recruits (B) (mean \pm 1 standardized error) in artificial enclosure ponds between the different habitats.

higher in continuous forest in a graphic analysis. The development of tadpoles was not significantly different between the habitats with or without the presence of predator. However, the survival and development tadpoles were higher in continuous forest than fragments.

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