THE IMPACTS OF FLOODING STRESS AND DISTURBANCE ON SEEDLING SURVIVAL IN THE VARZEA OF THE LOWER BRAZILIAN AMAZON

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INTRODUCTION

Frontier expansion and land - use change in the Amazon has stimulated extensive ecological research in the area of tropical forest succession. Succession is the sequential replacement of one plant community by another, the process of which can be affected by natural and human disturbances in the landscape. Tree seedlings colonizing such disturbed landscapes are particularly vulnerable to disturbance and thus represent a narrow bottleneck for tree species to survive and contribute to future forest diversity. Despite the importance of understanding how seedling communities respond to disturbance in Amazonian forests, relatively little is understood regarding this stage of reproduction in tropical tree life history. This study addresses how seedling communities respond to livestock disturbance and flooding stress in a critical but rarely studied ecosystem: the floodplain forests of the Amazon Basin (várzea).

Surprisingly little attention has been paid to the impact of land transformations have on aquatic and wetland ecosystems and their resources, which support a majority of the Amazon population. The Amazon River and its adjacent floodplains form the largest and most diverse freshwater system on the globe. Productive and diverse floodplains occupy approximately 300,000 km2, and serve important ecological and economic roles for fisheries, agriculture, and timber and firewood harvesting. A leading threat to the conservation and management of these valuable wetland resources is the negative impact livestock have on plant communities. The most recent major cycle of land - use transformation in the region is the conversion of floodplains to cattle pasture (McGrath *et al.*, 1999). Intense livestock activity clears the forest understory and compacts soil, such that regeneration of forest species is severely reduced (Sheikh 2002). While floodplain forests are resilient to the natural disturbances of flooding and native wildlife, the intensification of cattle ranching on the floodplain could degrade floodplain forests.

My doctoral research investigates how cattle disturbances and flooding stress affect seedling communities in successional floodplain forests. While much is known regarding the impact of single disturbance events on forest structure and species composition (e.g., hurricanes, logging activity), there is a need for investigation of how disturbance and stresses that act together to influence succession (Chazdon 2003). Through forest inventories and seedling planting experiments in the Lower Amazon River floodplain, I investigate changes in biodiversity and the composition of seedling communities. By conducting this research in rural Amazon fishing communities and conducting interviews on local forest use and history, I also incorporate floodplain residents as participants in the research. By integrating ecological research with local knowledge on floodplain forest change over time, I am developing an interdisciplinary thesis that will contribute knowledge to both tropical forest ecology and local management and conservation.

OBJECTIVES

The objective of this research is to understand the effects of flooding stress and physical disturbance on seedling growth and survival in várzea forests of the Lower Amazon region of Brazil. The study also provides baseline data on the regenerative capacity of key tree species that sustain fruit - eating fish populations.

MATERIAL AND METHODS

This study was conducted in the floodplain forests of Santarém, Pará, Brazil ($02^0$25'S, $54^0$42'W). The floodplains of the region are characterized by a mosaic of natural grasslands, forested levees, dense stands of *aningal*, agricultural clearings, and lakes, the expanse of which is affected by the annual flood regime. Flood waters of the Amazon River in the region peak on average in mid - May, rising 7 - 8 m and extending 20 - 50 km from the main channel. The Santarém region lies within the Transverse Dry Corridor of the Amazon Basin, with a rainfall of 1800 - 2000 mm/yr and 5 consecutive dry months per year (Sombroek 2001), exceptionally dry periods for the Amazon. Forests are generally 20 - 80 years old, replacing abandoned jute plantations or cacao and rubber tree planted forests. The floodplain today

is populated by residents (*ribeirinhos*) that practice such land - use activities as fishing, farming, and cattle ranching (Smith *et al.*, 1995). Forests selected for this study had low cattle impact and were located three separate, stable levees of 100 - 150 m wide along an interior *paraná* of the Amazon River on local landholder properties that are often used as communal fishing grounds for fruit - eating fish.

The goal of this experimental study is to test how physical damage (stem breakage) to seedlings, flood depth, and light affect seedling growth and survivorship. Based on previous research, the mechanisms by which livestock disturbance affects seedling growth and survival are identified as soil compaction, trampling, and mortality of canopy trees which opens light gaps for grass colonization (Sheikh 2002). Physical damage by trampling is likely to be a main limiting factor of seedling growth and survival in the first year of growth. I tested the hypothesis that damage reduces seedling growth rates and survival. This experiment was initiated in May of 2007, when seeds were collected and raised to seedlings in greenhouses. Seedlings of ten species were planted in plots of 5x5 m in three floodplain forests (Figure 1). Half of the seedlings were subjected to a damage treatment where stems were cut and removed at 5 cm aboveground to test their ability to sprout. I monitored their growth and survival over one year, which included a dry and flooded season.

Statistical Analyses: The effects of damage and flooding on seedling survival within and among ten study species were tested with ANCOVAs. Relationships between survival, other environmental variables, and time were then assessed in three steps using survival analyses, ordination, and logistic and linear regression models.

RESULTS AND DISCUSSION

Damage decreases survival and growth rates across all species, varying in size of effect. Flooding duration did not significantly affect survival function of seedlings, except the common pioneer tree Cordia tetrandra. As such, flood duration in this study is not significant in explaining the variability in survival among plots over one year. Dry season mortality suggests that survival is affected by water availability to seedlings during peak dry seasons, however measurements of soil water content (SWC) to not corroborate, most likely due to the poor correlation between SWC and actual soil water availability in 2:1 clays characteristic of these floodplains (cite). Although seedlings were observed to wilt, senesce leaves, and dessicate during the dry season, soil water content in the top 10 cm of soil still showed relatively high values of 21 - 36% water in December at the end of the dry period. Seedling growth rates correlate negatively with flooding duration, which may be a result of increased stress on seedlings or simply less time in aerobic soils to acquire carbon for growth.

The effect of low rainfall in the dry season severely decreased survival among damaged seedlings. However, undamaged seedlings showed a gradual decrease in survival over the 5 - month dry period, with high survival above 80%. Damaged seedlings suffered high mortality rates during the driest month of the year and displayed symptoms of desiccation (e.g., wilting, dry stems). Although local rainfall explains survival rates, there was no significant relationship found between average seedling mortality and soil moisture for either treatment ($F=0.23$, $p=0.64$ and $F=0.06$, $p=0.81$, respectively). In all multiple regression analyses, canopy gap light remains the single most significant ($p < 0.05$) environmental factor explaining variation in mortality within and among species. Growth and resprouting among seedlings is also correlated with canopy light availability across many species, particularly phanerocotylar and early successional species. All species showed decreased survival following damage except for *Coccoloba ovata*, a highly flood tolerant species, which showed higher survival among damaged seedlings. Trends among species suggest a growth - survival trade - off such that species with rapid growth rates have lower survival rates. No significant relationships were found with such variables as soil bulk density, percent sand or clay particle size, elevation, leaf herbivory and soil moisture. The results comparing the effects of the dry vs. flooded season variables should yield interesting insight into the factors that explain first year seedling population dynamics on the floodplain.

The potential interactive effects of stress and disturbance on plant communities are prominent in riparian communities. A stress by its definition sensu Grime (1979) limits plant growth. As seen here, flood stress limited plant growth for all nine species that survived the flood season, but it is unknown whether or not the seedlings experienced reduced growth rates due to the physical stress of flooding on carbohydrate reserves and plant tissues, or if growth rates were reduced simply due to the reduced time exposed to anaerobic soils (a.k.a. a smaller window of growth). Many studies show that plants allocate substantial carbohydrate reserves towards anaerobic respiration (Ferreira *et al.*, 2009), root growth (to increase reserves and replace rotten tissues), and formation of aerenchyma, lenticels, or aerial roots. Allocation to such tissues would decrease reserves available for shoot growth or foliar development, and as such would impose a stress on above ground height extension. One experiment shows seedlings compensating for time lost during submergence and reach similar heights of un - submerged seedlings in the weeks following release from anaerobic conditions (Parolin 2001); however this was not found here in the 4 - 8 weeks after which seedlings were released from inundation.

CONCLUSION

This research addresses major threats in forested wetlands worldwide and in the Amazon today, including the effects of flood and drought stress on forest regeneration, the mechanisms by which cattle ranching affect forest succession and regeneration, and the interactive effects of flood stress and disturbance on seedling communities. Damaged seedlings suffered particularly high mortality during the peak of the dry season, suggesting that floodplain regeneration is susceptible to drought. While wetlands and rainforests are generally perceived as ecosystems with abundant water, this study shows that the effects of dry seasons and droughts to understand seedling community dynamics in tropical wet-

lands must be considered. The integration riverside community residents as research participants have enriched my understanding of floodplain forest history and local use and value. In turn, the research is applicable to local environmental problem - solving with regards to várzea forest and results are available for educational purposes and management of their natural resources.

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