EFFECTS OF FLOODING ON THE LONGLEAF PINE-WIREGRASS ECOSYSTEM

William K. Michener[1], Elizabeth R. Blood[1], Stephen W. Golladay[2], L. Katherine Kirkman[2], Robert J. Mitchell[1], and Brian J. Palik[2]

AUTHORS: [1]Associate Scientist, [2]Assistant Scientist, Joseph W. Jones Ecological Research Center, Route 2, Box 2324, Newton, GA 31770.
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Abstract. Flood waters associated with Tropical Storm Alberto inundated 21 km^2 of uplands at Ichauway, a 115 km^2 ecological reserve located in southwestern Georgia. At the landscape scale, sink holes were formed, landslides and erosion occurred along riverine bluffs and terraces, and sediment deposition occurred along all riparian corridors. Xeric habitats, dominated by longleaf pine-wiregrass and scrub-shrub, were disproportionately affected by flooding on an area basis. Longleaf pine seedlings and saplings with apical meristems above high water always survived. Mortality of submerged longleaf pine and wiregrass was positively related to flooding depth and duration. Treefall in bluff riparian zones and hardwood hammocks reflected species composition within the two habitats although oaks and southern red cedar were the most commonly downed trees in both habitats. Higher treefall was observed in bluff riparian zones and may be related to constrained stream channel geomorphology. Although infrequent, flooding appears to be important in governing the structure and function of the longleaf pine-wiregrass ecosystem and, along with other disturbances, should be explicitly incorporated into reserve and riparian corridor planning and design.

INTRODUCTION

Research in the longleaf pine (*Pinus palustris*) - wiregrass (*Aristida stricta*) ecosystem has focused primarily on patterns of longleaf pine demography, species diversity, and natural history, rather than on the processes, especially disturbances, that drive and maintain viable ecosystems. Although high plant diversity and functional attributes of this ecosystem have been related to frequent and recurring fires, the role of other disturbances, particularly extreme events such as flooding, has been ignored.

Tropical Storm Alberto presented a unique opportunity to assess the role of flooding as a disturbance in regulating longleaf pine-wiregrass ecosystem structure and function. The storm had minimal impact on the Florida Panhandle upon landfall. However, it traveled into southwestern Georgia, remained relatively stationary for an extended period, and resulted in extremely high precipitation throughout the Ichawaynochaway Creek (2,600 km^2) and Flint River (21,000 km^2) watersheds. Over 53 cm of rain were recorded in portions of the Flint River watershed. Rainfall in the two watersheds resulted in record flooding.

Ecological Response to Disturbances

Longleaf pine-wiregrass community structure and function are regulated by the complex interaction of disturbances and gradients in resource availability. Frequent fire is a major disturbance occurring throughout the ecosystem to which plants within the community have evolved. Longleaf pine-wiregrass savannas range from xeric sandhills to wet-mesic or seasonally saturated sites where slash pine (*P. elliottii*) replaces longleaf pine as the dominant canopy species. Where savannas approach perennial stream channels, pine uplands are replaced by riparian cypress (*Taxodium spp.*)/hardwood communities. Soil resource availability varies considerably across this gradient.

At the xeric end of the gradient, lack of water (i.e. drought) has been thought to be an important factor causing mortality of young trees and herbaceous vegetation. However, excess water may also be important. Wahlenberg (1946) suggests that grass stage longleaf pine seedlings are sensitive to inundation if the apical meristem is submerged. Similarly, wiregrass is affected when the aerial portion is inundated (Parrot, 1967). Beyond these observations, little information is available regarding the responses of longleaf pine and wiregrass to flooding.

In the southeastern Coastal Plain, floods and wind storms may result in substantial wood inputs to streams. The source of wood debris in streams is tree mortality within adjacent riparian forests. Rate of wood input is influenced by forest age structure, riparian geomorphology, and the timing of disturbances (floods, wind storms, debris avalanches).

Research Objectives

In this paper, we summarize observations made during and after the flood and discuss the long-term implications of flooding in relation to (1) landscape patterns and processes; (2) longleaf pine and wiregrass mortality; and (3) coarse wood debris input to flooded streams. Two specific hypotheses are addressed: (1) the susceptibility of wiregrass and longleaf pine to flooding is controlled by the topographic position of plants on the landscape (which determines the depth and duration of flooding), and, in the case of longleaf pine, the height of trees (i.e., if the apical meristem remains exposed); and (2) reach geomorphology (i.e. constrained versus unconstrained) influences tree mortality during large floods. Results are synthesized as a conceptual model that relates catastrophic flooding to other climatic, human, and soil disturbances. Implications for future research and resource management are also discussed.

Study Area

Ichauway is located in southwest Georgia, 45 km southwest of Albany. The site, a 115 km^2 ecological reserve located along the Flint River at the confluence with Ichawaynochaway Creek, contains one of the most extensive, unbroken tracts of longleaf pine forest and wiregrass understory remaining in the United States. Ichauway includes over 22 km of the Ichawaynochaway Creek, and over 19 km of the Flint River. The Flint River, a brownwater stream, originates in the Georgia Piedmont region (Figure 1), whereas the Ichawaynochaway Creek originates in an extensive wetland complex near Dawson, Georgia. The latter flows southward approximately 100 km before discharging into the Flint River. The riparian zone for both Ichawaynochaway Creek and the Flint River consists of two principal geomorphic components, seasonally flooded hardwood hammocks (unconstrained reaches) and longleaf pine-dominated upland terraces (constrained reaches). Generally, flow in Ichawaynochaway Creek and the Flint River is low and stable from early summer through autumn. Winter and early spring storms often result in bankfull discharges and inundation of low-lying riparian areas.

METHODS

Aerial photography, field surveys during and after flooding (including Global Positioning System surveys), and Geographic Information Systems (GIS)-based analyses were utilized to characterize flooding in the diverse communities existing along the xeric to hydric gradient that encompasses the longleaf pine-wiregrass ecosystem.

Four months after inundation, wiregrass and longleaf pine mortality were assessed in a naturally-occurring stand on a xeric sandhill site; longleaf pine mortality was also assessed in a nearby six year old longleaf mesic site pine plantation (providing a more uniform distribution of trees) (Figure 1; A, B). Both sites were variably affected by flooding due to topographic heterogeneity. Water depths ranged from a few centimeters to more than three meters and flooding duration ranged from less than one day up to two weeks. Three transects were established at both sites traversing a range of landscape positions. For wiregrass, 0.25 m^2 plots were systematically located along the transect and wiregrass condition [dead, recovering (new tillers had initiated since the flood), or minimally damaged] was determined for each plot. Longleaf pine mortality was quantified in plots stratified by damage classes in stands of saplings that experienced heavy (all seedlings dead), intermediate (some living seedlings), and light (little to no damage) damage. One plot (640 m^2) was established in each of the three damage classes along each transect. Height of living and dead trees and elevation of plots with respect to high water were determined.

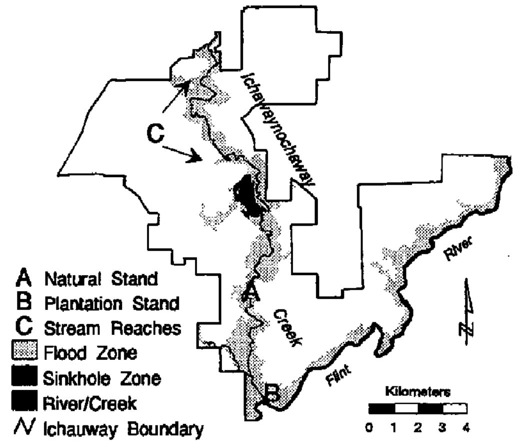

Figure 1. Extent of flooding within the study area.

Following flood water recession, riparian areas of Ichawaynochaway Creek were surveyed for tree-fall (i.e. those trees uprooted or downed by floodwaters) along three replicate reaches (400-900 m in length) in seasonally flooded hardwood hammocks and longleaf pine-dominated upland bluffs (Figure 1; C).

RESULTS AND DISCUSSION

Approximately 21 km^2 of upland communities were flooded at Ichauway (Figure 1). Flooding varied in extent, intensity (depth, current velocity), and duration along stream and river channels. Twenty sink holes (elliptical in shape and ranging from 2.6 to 21.3 m in maximum length and from 0.8 to 3.1 m in depth) were formed in an area comprised of Suffolk soils (mesic, well-drained, moderately permeable soils characteristic of stream terraces; Figure 1). Landslides and extensive erosion were observed along terraces and bluffs bordering the Flint River, but not along Ichawaynochaway Creek. Extensive localized sediment deposition occurred along all riparian corridors. Variability in erosion and sediment deposition is likely related to landform and topographic position, as well as the length of time that a site experienced high flow velocities.

Based on soil characteristics, xeric communities were disproportionately affected by the flooding. For example, Bigbee, Kershaw, and Lakeland soils (predominantly located along riparian corridors) experienced four times more flooding on an area basis than would be expected if these xeric soils were randomly distributed throughout the study area. Flooded xeric soils were dominated by longleaf pine-wiregrass and shrub-scrub habitats.

Mortality of longleaf pine seedlings and saplings and

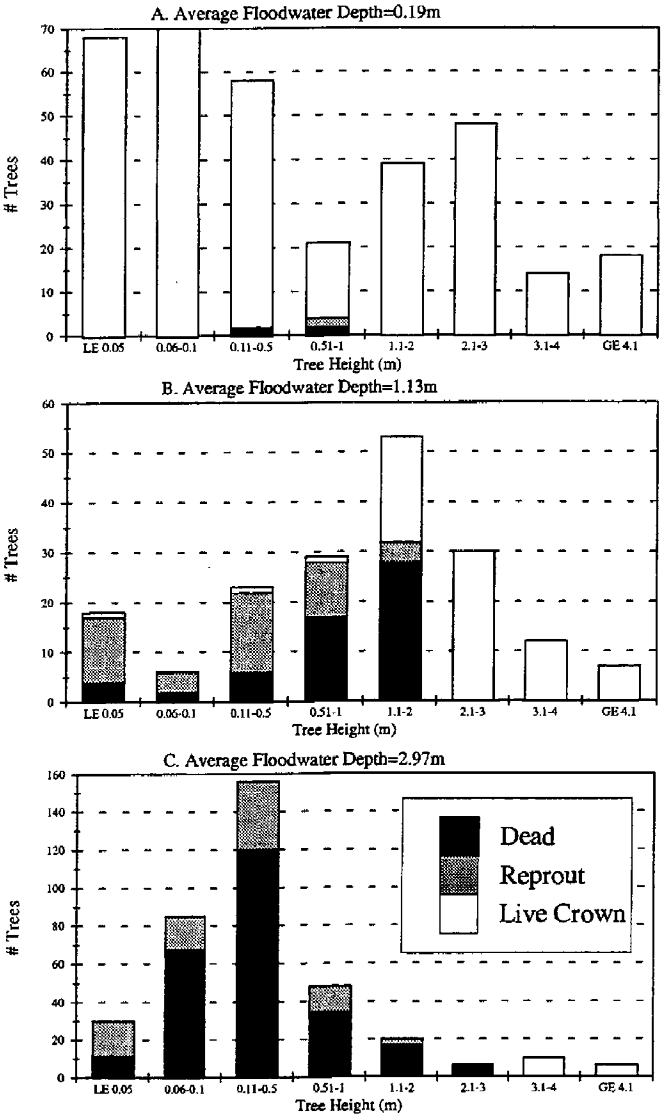

Figure 2. Longleaf pine seedling survivorship.

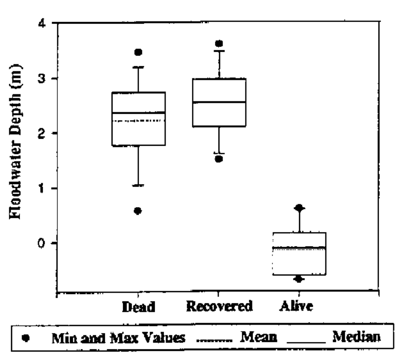

Figure 3. Wiregrass condition and flood height.

wiregrass occurred where flooding was greatest (both in duration and depth; Figures 2 and 3). At flooding depths of 0.5 m or less, wiregrass was minimally affected. As hypothesized, longleaf pine mortality increased as depth and duration of flooding increased (Figure 2, C). However, seedlings and saplings with apical meristems above high water always survived. Submerged small grass-stage seedlings appeared to have a greater probability of resprouting after initial top kill, than submerged seedlings that had initiated height growth.

Significant tree-fall occurred in riparian areas adjacent to Ichawaynochaway Creek. Tree-fall was higher in upland bluff riparian habitats than hardwood hammocks, averaging 17.2 (standard error range -- 7.0-42.4) and 8.5 (standard error range -- 6.5-11.3) trees per kilometer of stream bank, respectively. Higher tree-fall may be due to constrained stream channel morphology in bluff riparian zones, which results in greater current velocities during floods. Tree-fall due to flooding reflected the composition of tree species in riparian habitats. Bluff zones are generally dominated by oaks (*Quercus* spp.) and southern red cedar (*Juniperus virginiana*), and those species comprised a majority of trees downed by flooding (Table 1). In hammocks a higher diversity of tree species was affected, although oaks and cedars were again the most commonly downed species.

Table 1. Species Composition (%) of Trees Uprooted in Ichawaynochaway Creek

	Bluff	Hammock
Quercus spp.	47	19
Juniperus virginiana	28	29
Betula nigra	16	12
Other species	9	40

CONCLUSIONS

Disturbances are typically characterized in relation to their frequency, extent, and intensity. Thus, catastrophic flooding may be related to other climatic, management, and faunal disturbances (Figure 4). In the longleaf pine-wiregrass ecosystem, catastrophic flooding represents one extreme of the disturbance continuum.

Mortality of wiregrass and longleaf pine associated with infrequent catastrophic floods may significantly influence the structure of xeric sandhill communities that are associated with riverine systems. Groundlayer vegetation structure and composition will likely be altered if wiregrass is slow to recover from flood damage. Removal of this pyrogenic dominant will affect competitive relationships and subsequently alter localized fire regimes. Similarly, longleaf pine mortality may have a lasting effect on stand structure. Xeric sites, in particular, have poor seedling survival due to low soil moisture holding capacity. Thus, a pulse of mortality may exceed recruitment of new seedlings even over long time periods. Alternatively, seed regeneration of longleaf pine is dependent on the presence of bare mineral soil free from significant competition. Typically, surface fires in late spring and summer create favorable seedbed conditions prior to seedfall in November and December. Thus, flooding of longleaf pine ecosystems in the lower Coastal Plain, resulting in exposed mineral seedbeds and vegetation mortality, may provide an additional regeneration pathway. While catastrophic flooding is infrequent, longleaf pine population dynamics may be influenced by flood-facilitated regeneration, given the 300-400 year life span of the species.

Little information is available on how various groups of plants or species respond to infrequent perturbations such as flooding. Data collected during this study indicate that flooding induces mortality of dominant perennial plants if the entire aerial portion of the plant is submerged for a critical period. Thus, mortality is concentrated in seedlings or plants of low stature and increases with greater flood depth and duration. The long-term community response will likely vary in relation to amount of soil disturbance (including scouring to mineral layer), litter deposition (affecting nutrient and water availability), flood-vectored seed bank inputs and removals, and wiregrass standing dead litter (which may serve to reduce or prevent recruitment).

Coarse wood debris (CWD) is an important structural and functional component of streams draining forested areas. In the Coastal Plain, wood inputs are low and CWD generally accumulates on floodplains or as snags on the lateral edges of stream channels. Wood is often the most productive habitat for aquatic invertebrates (Benke et al., 1985). Little is known about the dynamics of wood in Coastal Plain streams, however, wood decomposes slowly and resists downstream displacement. This study suggests channel geomorphology interacting with high flows may regulate wood inputs. Thus, infrequent broad-scale disturbances (like catastrophic flooding) may be extremely important in maintaining the availability of wood habitat in Coastal Plain streams.

RECOMMENDATIONS

Increased research attention should focus on the role of infrequent, broad-scale, and "unusual" (i.e. flooding of xeric longleaf pine habitats) disturbances. Results of the present ongoing study will likely force us to reassess the "disturbance paradigm" in longleaf pine ecosystems. For example, floods may have a positive influence on ecosystem structure and function by promoting recruitment of propagules into unvegetated areas; enhancing primary productivity, nutrient input, and regeneration; and supporting development of ecotones in flood-affected areas. In contrast, other effects may be viewed negatively, including the disproportionate impact on biodiversity and certain species, populations, and communities.

The disturbance model presented in this paper has numerous implications for future research and resource management activities. Effective ecosystem restoration and management efforts will require a better scientific

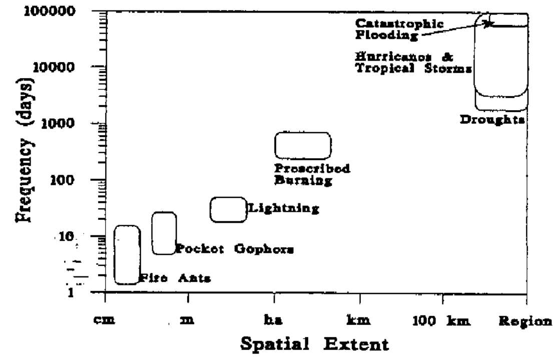

Figure 4. Conceptual model relating catastrophic flooding to other ecosystem disturbances.

understanding of the role of climatic and hydrological events, fossorial herbivores, fire, and the interactions among various disturbances in regulating soil, nutrient, and vegetation patterns and processes. Restoration of species diversity and other multiple use resource management objectives may require that we incorporate the entire suite of disturbances into planning and management efforts. For example, protection strategies for high plant biodiversity and the endangered and threatened species that are associated with xeric longleaf pine-wiregrass communities will require that we explicitly incorporate the potential for catastrophic flooding and other extreme events into reserve and riparian corridor planning and design. Thus, reserve boundaries should extend outside disturbance-prone areas and riparian corridors should periodically incorporate buffer zones that are not subject to flooding.

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