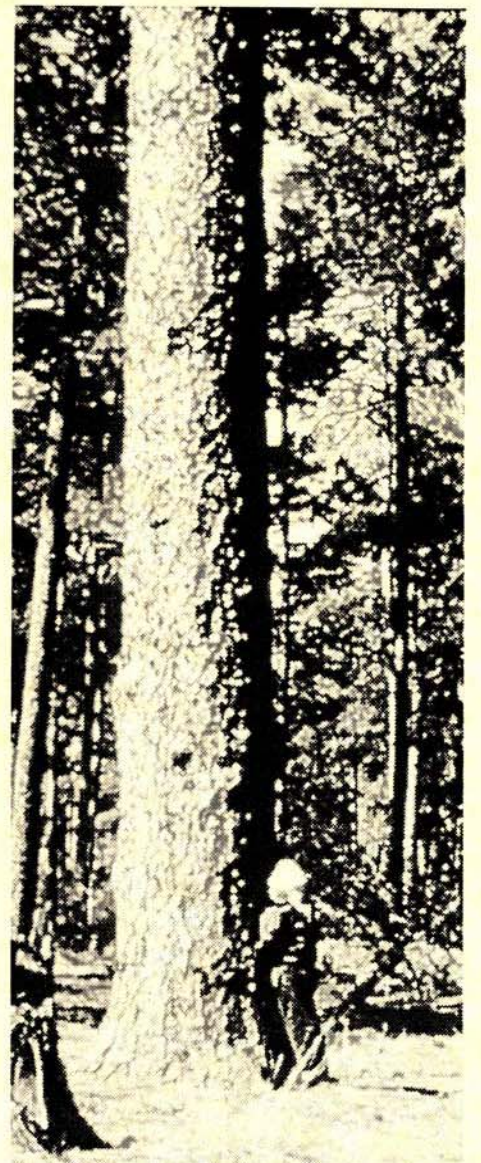


PROCEEDINGS

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Longleaf Pine - Wiregrass Ecosystem Responses to Flooding

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ABSTRACT - High precipitation throughout southwestern Georgia associated with Tropical Storm Alberto (July 1994) resulted in extensive flooding within the Flint River watershed. Flooding varied in extent, intensity, and duration along stream and river valley segments. Effects of the disturbance were evident at scales ranging from populations (e.g., plant and animal mortality) to the landscape (e.g., water quality, remotely sensed spectral changes in vegetation condition and biomass, etc.).

INTRODUCTION

Hurricanes and tropical storms, like other large natural disturbances, play an important role in regulating ecosystem structure and function, as well as affecting diverse plant and animal populations and communities (Michener *et al.*, in press). Longleaf pine-wiregrass ecosystem structure and function are regulated by the complex interaction of disturbances and gradients in resource availability. At the xeric end of the gradient, for example, droughts are thought to be an important factor causing mortality of young trees and herbaceous vegetation. Excess water, such as infrequent flooding associated with tropical weather systems, may also be important. Wahlenberg (1946) suggested that grass stage longleaf pine (*Pinus palustris*) seedlings are sensitive to inundation if the apical meristem is submerged. Similarly, wiregrass (*Aristida stricta*) may be sensitive to flooding when the aerial portion is inundated (Parrot, 1967). Beyond these observations, little information is available regarding the susceptibility of longleaf pine and wiregrass to flooding.

In the southeastern Coastal Plain, floods and wind storms may result in substantial wood inputs to streams. Coarse wood debris (CWD) is an important structural and functional component of streams draining forested areas. CWD generally accumulates on flood plains or as snags on the lateral edges of stream channels and is often the most productive habitat for aquatic invertebrates (e.g., Benke *et al.*, 1985). The rate of wood input is influenced by age structure of riparian forests, tree mortality, riparian geomorphology, and the timing of disturbances (floods, wind storms, debris avalanches).

Tropical Storm Alberto presented an opportunity to assess the role of flooding as a disturbance in affecting longleaf pine-wiregrass ecosystem structure and function. In this paper, we summarize observations related to (1) landscape patterns and processes; (2) longleaf pine and wiregrass mortality; and (3) coarse wood debris input and retention in flooded stream reaches.

Study Area

Ichauway is a 115 km² ecological reserve located in southwest Georgia along the Flint River at its confluence with Ichawaynochaway Creek. The site includes over 22 km of the Ichawaynochaway Creek and over 19 km of the Flint River. Undisturbed terrestrial habitats in the study area are dominated by longleaf pine and wiregrass, the dominant ground cover species.

The riparian zone for both Ichawaynochaway Creek and the Flint River consists of seasonally flooded hardwood hammocks (unconstrained reaches) and longleaf pine-dominated upland terraces (constrained reaches) (Goebel *et al.*, in press). Flood tolerant species are confined to hammocks or steep banks adjacent to terraces. 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 riparian areas.

Materials and Methods

Tropical Storm Alberto remained relatively stationary over southwestern Georgia for an extended period (July 2-7, 1994), and resulted in extremely high precipitation throughout the Ichawaynochaway Creek (2,600 km²) and Flint River (21,000 km²) watersheds (over 53 cm of rain were recorded in some portions of the Flint River watershed). Flood discharges in tributaries and mainstems of the Flint River exceeded 100-year flood discharges along most stream reaches (Stamey, 1995). Flood waters inundated riparian habitats, as well as agricultural fields, pine plantations, and upland habitats adjacent to streams and rivers.

Remote sensing, field surveys during and after flooding (including Global Positioning System surveys; GPS), and Geographic Information Systems (GIS)-based analyses were utilized to characterize the relative impact of flooding within the study area. SPOT-XS (multispectral) images for October 5, 1990 (pre-flood) and September 28, 1994 (post-flood) were utilized to assess vegetation responses to flooding. Procedures used for image rectification, normalization, and accuracy assessment, as well as GIS data used in analyses have been described elsewhere (Houhoulis and Michener, 1996; Michener and Houhoulis, in press). Differences in Normalized Difference Vegetation Index values (NDVI; a measure correlated with vegetation biomass and condition) observed prior to and following the flood (image differencing) were used in an unsupervised classification (NDVI-ID). In the resulting image data set, values that are negative or close to zero indicate areas where NDVI increased in 1994 or remained relatively unchanged, whereas positive values represent areas exhibiting a decrease in NDVI in 1994. A +1 SD (>9 DN) was selected as the 'change' threshold value.

Maximum water levels, surveyed at >350 locations along Ichawaynochaway Creek and the Flint River, were used to derive a flood boundary map and create 1.52 m contour intervals above bankfull conditions to characterize the magnitude of flooding. One hundred and thirty-nine sites (approximately 650 m² per site) containing wiregrass and longleaf pine seedlings and saplings were surveyed throughout the flooded area to quantify vegetation damage. Height of living, recovering, and top-killed trees, valley floor landform, and elevation of all plots with respect to the high water mark during the flood were determined (Michener *et al.*, 1995; B. Palik, unpublished manuscript). Each site contained three randomly chosen plots where ground cover mortality was assessed using a 1 m² quadrat divided into a 10 X 10 grid (10 cm intervals). Presence of bare ground, detritus, and wiregrass condition (top-kill, live, or recovering) were recorded at all points and data from the three plots were averaged and converted into percentages.

Following the recession of flood waters, riparian areas of Ichawaynochaway Creek were surveyed for tree mortality (i.e. those trees uprooted or downed by floodwaters). Replicate (3) reaches (400-900 m in length) in seasonally flooded hardwood hammocks and longleaf pine dominated upland bluffs were surveyed.

RESULTS and DISCUSSION

Approximately 21 km² of upland communities were flooded at Ichauway. Flooding varied in extent, intensity (depth, current velocity), and duration along stream and river channels. Based on soil characteristics, xeric communities were disproportionately affected by the flooding. For example, Bigbee, Kershaw, and Lakeland soils experienced four times more flooding 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 communities.

Relatively sparse overstory canopy coupled with a dense ground cover community primarily dominated by a single species (wiregrass) characterized the study area and facilitated change detection analyses. NDVI-ID proved to be an effective technique for discriminating vegetation responses to flooding. NDVI values in the non-flooded area approximated those observed in 1990, whereas those in the flooded area exhibited a 10 DN decrease. These findings indicate that ground cover vegetation exhibits marked spectral and ecological (mortality, stress, etc.) responses to flooding which can be detected as a decrease in NDVI.

Topkill for both longleaf pine and wiregrass generally occurred where flooding was most intense (both in duration and depth). Flood impacts, however, varied significantly among valley floor landforms. Seedlings and saplings with apical meristems above high water generally survived. Small grass-stage longleaf pine seedlings appeared to have a greater probability of resprouting after initial top kill, than submerged seedlings that had initiated height growth (Michener *et al.*, 1995; B. Palik, unpublished data).

Significant tree mortality occurred in riparian areas adjacent to Ichawaynochaway Creek. Mortality was higher in upland bluff riparian habitats than hardwood hammocks. Higher mortality may be due to constrained stream channel morphology in bluff riparian zones, which results in higher current velocities during floods. Mortality during flooding reflected the abundance of tree species in riparian habitats. Bluff zones are generally dominated by oaks (*Quercus* spp.) and cedar (*Juniperus virginiana*), and those species comprised a majority of trees downed by flooding. Mortality in hammocks was more variable, although oaks and cedars were the most commonly downed species.

CONCLUSIONS

Although catastrophic flooding is infrequent in the Coastal Plain, the long-term dynamics of longleaf pine populations may be influenced by floods, given the 300-400 yr potential life span of the species. Flooding induces mortality of wiregrass and longleaf pine seedlings and saplings if the entire aerial portion of the plant is submerged for a critical period. Because of the large area affected and the relatively sparse canopy, vegetation effects were discernible at the landscape scale based on change detection analysis of SPOT XS data.

Results of this study coupled with ongoing fire, fossorial herbivore, and related studies will likely force us to reassess the "disturbance paradigm" in longleaf pine ecosystems. Effective ecosystem restoration and management efforts will ultimately require a better understanding of the role of climatic and hydrological events, fossorial herbivores, fire, and the interactions among the various disturbances in regulating soil, nutrient, and vegetation patterns and processes. Floods, for example, may promote recruitment of propagules into unvegetated areas; enhance primary productivity, nutrient input, and regeneration; and support the development of ecotones in flood-affected areas. Floods may also, however, have a disproportionately negative impact on biodiversity and certain species, populations, and communities. Ideally, the potential for catastrophic flooding and other extreme events should be explicitly incorporated into reserve and riparian corridor planning and design.

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