

A QUANTITATIVE ASSESSMENT OF THE STRUCTURE AND FUNCTIONS OF A MATURE BOTTOMLAND HARDWOOD COMMUNITY: THE IATT CREEK ECOSYSTEM SITE¹

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Abstract—We report our efforts, initiated in 1995, to quantify ecological processes and functions in a relatively undisturbed, mature hardwood forest. The 320-ha site is located in central Louisiana on the upper reaches of Iatt Creek, an anastomosing minor stream bottom. The forest is a mature sweetgum (*Liquidambar styraciflua* L.)-cherrybark oak (*Quercus pagoda* Raf.) dominated community with over 70 woody plant species present. Soils are Typic Glossaqualfs. Flooding is flashy, occurring primarily in the dormant season. Initial analyses indicate major overstory species groups do respond to elevational differences within the bottom. Aboveground net primary productivity (NPP) averages 14200 kg per ha per year. Fine litterfall transfers average 8520 kg per ha per year with 63 percent as leaf fall. In contrast to an adjacent pine upland, leaf litter decomposition, as measured by mass loss, was initially greater in the bottomland, but in the second year there was little difference between sites. Pure sweetgum and red oak subgenera (*Erythrobalanus*) decomposed significantly faster than pine needles in both environments. A diverse avian and aquatic population is evident.

INTRODUCTION

The currently estimated 12.5 million ha of forest wetlands in the Southern United States represent less than one-half the original area designated as forested wetlands. Their decline, the growing awareness of their importance, and the efforts to replant or restore wetland (bottomland) forests have increased pressure to understand the structure and functions unique to these communities.

In the early 1990's the Southern Forested Wetlands Initiative was formed. Agencies active in the initiative are the USDA Forest Service, the U.S. Geological Survey, and the U.S. Army Corps of Engineers. In managing, maintaining, or restoring ecosystems the initial need is to identify important functions that characterize undisturbed or stable communities or landscapes. Therefore, an initial objective of the initiative, has been to quantify the physical, chemical, and biological functions of mature bottomland forest communities (Harms and Stanturf 1994).

To address this objective, in 1995, three research areas were established: Iatt Creek in central Louisiana, Coosawatchie River in South Carolina and Cache River in Arkansas. The Coosawatchie River and Cache River study areas are on major alluvial bottoms, and the Iatt Creek study area is on a minor alluvial bottom. The Center for Forested Wetlands in Charleston, SC and the Center for Bottomland Hardwood Research in Stoneville, MS are responsible for the Coosawatchie River and Iatt Creek research study areas, respectively. The U.S. Geological Survey and the U.S. Army Corps of Engineers are responsible for the Cache River study area.

The site types were chosen based on their extent across the South and their probable exposure to management treatments. Selection of specific study areas was based on condition, age, and stability of communities and the area's size and hydrology. Heavily harvested forest communities and dam controlled streams have been avoided. Study

areas have at least 300 ha, and nonresearch management activities must be minimal for at least the next 10 years.

A minor alluvial bottom has been selected because the majority of the bottomland hardwood forests remaining in the South are within minor alluvial bottoms (Hodges 1998). Moreover, these bottoms are expected to face some of the highest management pressures. Minor alluvial bottoms primarily differ from those of major streams in two respects: flood characteristics and the influence of immediately surrounding uplands.

Based on published research, gaps are evident in our understanding of the basic processes and components within bottomland forests. These gaps are especially evident for minor bottoms. In this paper we describe the Iatt Creek Study Area and present some of the preliminary results of this study. In this study area, 11 studies are currently ongoing. This report focuses on initial analysis of the vegetative community, aboveground Net Primary Productivity (NPP), litterfall transfers, rates of litterfall decomposition, and observations from avian and aquatic studies.

METHODS

Study Area Description

The Iatt Creek Study Area is on the upper reaches of Iatt Creek, on the Winn Ranger District of the Kisatchie National Forest (KNF) located in central Louisiana (31° 43' 30" N; 92° 38' W). The site is a braided stream bottom dominated by Iatt Creek but laced with secondary streams flowing into and parallel with the primary stream. The approximately 195-km² watershed upstream from the research area is primarily forest and pasture. The approximately 320-ha study area varies in width from 550 to 1000 m and has an overall length of 5000 m. The dominant soil series is Guyton, Typic Glossaqualfs. Climate is in the humid temperate domain, subtropical division (Bailey 1998) with a normal annual temperature of 18.1 °C and normal annual precipitation of 1470 mm (Owenby and Ezell 1992).

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Study Area Infrastructure

To provide the information and the organization needed for multiple studies; closed base, perimeter, and transect line surveys were made. Permanent stakes were installed at 61-m intervals on all survey lines and where lines crossed streams. Seven transect lines were located parallel to each other at 500-m intervals (fig. 1). In these surveys the location and elevation of each stake were determined. A separate point grid at 250-m x 250-m intervals was established for the avian study. The starting points of all surveys were randomly selected. Two meteorological stations were established, one in the forested bottom and the other in an adjacent clearcut opening.

Geographic Information System (GIS) coverages of Iatt Creek are provided by the KNF. Coverages include soils, topographic, vegetation and land use, roads, land ownership, and aerial photographs. Geographic Positioning System (GPS) and elevational surveys were used to greatly refine the coverages especially location and extent of sloughs, stream channels, and other features within the study area (fig. 1).

Vegetation Dynamics—Ordination

Study design and installation—Beginning at a random starting point, 47 ordination plots were established at systematically located points 122 m apart on the seven transect lines. The plots were 0.1 ha (20 m x 50 m), and were subdivided into ten 10-m x 10-m subplots to facilitate data collection and analysis.

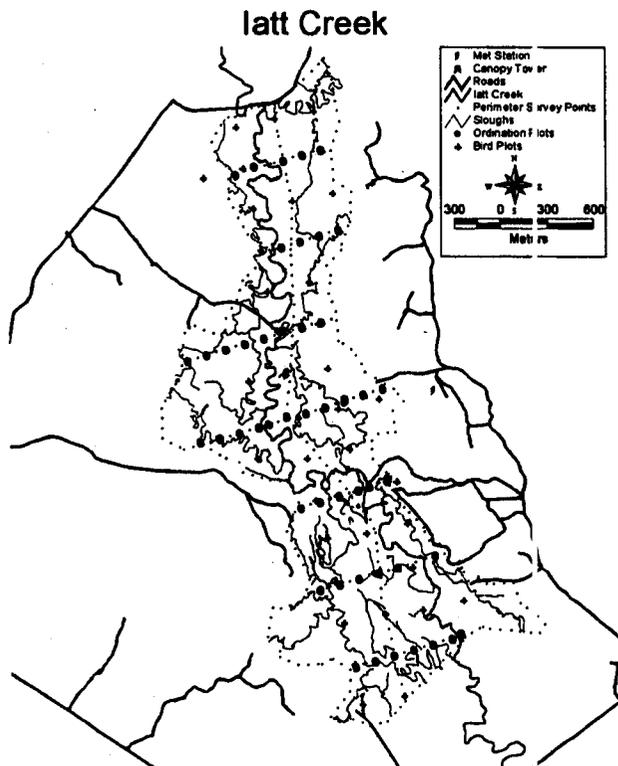


Figure 1—The Iatt Creek Study Area, Winn Ranger District, Kisatchie National Forest.

Overstory and midstory plants in each plot were inventoried, and species and diameter at breast height (d.b.h.) for each stem ≥ 7.6 cm d.b.h. were recorded for each 0.01-ha subplot. Elevation above sea level of each subplot corner and maximum elevation of the soil surface at the base of each of the measured trees were calculated.

Sapling and low shrub/herbaceous layers were also measured. In the sapling layer, the d.b.h. and species of every tree > 2.5 -cm and < 7.6 -cm d.b.h. were determined. On each subplot all trees < 2.5 -cm d.b.h. and > 1.4 -m in height were counted by species and two d.b.h. size classes: ≤ 2.5 cm and ≥ 1 cm and < 1 cm. To measure the low shrub (height < 1.4 m) and herbaceous layer, ten 1-m² sample plots were randomly located within each 0.1-ha plot. For each sample plot, percent cover by plant species was calculated.

Data summary and analysis—Initial analysis efforts focused on tree layer (> 7.6 -cm d.b.h.) composition and species dominance. Basal area (BA, m² per plot), density, and importance value were calculated for each species. These variables were summarized by species for all trees, for all dominant and codominant trees, and for all intermediate and suppressed trees. Data for each tree species were aggregated into five data sets: the full data set representing all 10 subplots of each ordination plot, two non-overlapping 0.04-ha square plots (S1 and S2), and two non-overlapping 0.04-ha rectangular plots (L1 and L2). The S and L subplots are composites of the smaller 0.01-ha subplots initially established as the subdivisions of the 0.1-ha study plots. Data were summarized into total BA and total density by plot and subplot for each species, and into importance values for each species on each plot and subplot. Importance value was calculated as (species relative BA as proportion of total BA on plot) + (species relative density as proportion of total density on plot) + (species relative frequency as proportion of 10 (or 4) subplots on which the species occurred). Environmental variables for each of these data sets include the elevation, to the nearest 0.1 m, of all the trees and all the plot corners that belong to that data set.

Analysis of this data set is ongoing and a complete discussion of approach is beyond the scope of this paper. For this paper, data analyses were conducted using SAS (Anonymous 1988), CANOCO (Ter Braak 1988), and TWINSpan (Hill 1979). We used SAS for data manipulations and for hypothesis testing. We used CANOCO to conduct a detrended correspondence analysis of the species BA values and TWINSpan to conduct a two-way analysis of species and plots to produce a hypothesis of plot and species groupings for visual and nonparametric analysis.

Aboveground Net Primary Productivity

Annual aboveground NPP per unit area is calculated as the sum of annual net biomass increment and detritus production or litterfall (leaf and branch) (Binkley and Arthur 1993, Waring and Schlesinger 1985).

Initial cluster analyses indicated that sweetgum (*Liquidambar styraciflua*) and sweetgum-cherrybark oak (*Quercus pagoda*) are the two dominant communities in the bottom, accounting for 70 percent of the 47 ordination plots (Gardiner and others 1996). From these dominant communities, 10 ordination plots were randomly selected for

estimation of NPP. The tree, sapling, and herbaceous vegetation layers were defined like those in the ordination study.

Biomass increment is the increase in plant biomass produced during the measurement period. It is estimated as the annual change in standing woody biomass plus mortality. For each tree in the tree layer within each plot, d.b.h. was measured annually and height in alternate years beginning in the winter of 1995-96. Using published biomass equations aboveground biomass was estimated for each tree and summed on a per area basis for each year (Magonigal and others 1997, Schlaegel 1984).

Similarly, beginning in 1996 all saplings have been identified and measured annually (basal diameter and height). Sapling biomass also has been estimated by using published equations (Williams and McClenahan 1984).

Mortality occurring between measurements is not measured as biomass in the second measurement year. Therefore, the mass of the mortality occurring between measurements is added to the change in living biomass between years to provide a valid estimate of biomass increment. Adding the biomass of tree(s) that died during the measurement period to the change in aboveground tree biomass increases the biomass increment of dead tree(s) to zero for the measurement period (Binkley and Arthur 1993).

To measure aboveground herbaceous production within each productivity plot, 10 points were randomly selected and sampled in August 1996 at the peak of standing biomass. All low vegetation was collected from a 1-m² plot at each sample point. Vegetation was separated into grasses, sedges, broadleaf, current growth of woody perennials (< 1.4 m), vines, ferns, and other materials. All vegetation, except woody perennials, was clipped at ground level, sorted by categories in the field, and placed in paper bags. For woody perennials, leaves and current year's twig growth were collected. All materials were oven-dried at 70 °C with mass reported on an oven-dried weight basis.

Litterfall—Annual Detritus Production

Fine litterfall—Litterfall was measured using litter traps—open mesh baskets supported about 1.5 m above the ground by poles. Within each of the ten 0.1-ha plots used to estimate aboveground NPP, five litter traps were randomly placed. Collections were made monthly. Contents were sorted into leaf tissue, fruits and flowers, bark and fine wood (< 1 cm diameter), and other; oven-dried (70 °C), and weighed.

Coarse branchfall—Five 50-m² subplots (5 m x 10 m) were randomly located within each of the ten 0.1-ha study plots. Initially, all coarse woody branchfall (wood > 1 cm in diameter) was marked or removed from each sample subplot. Since 1996, coarse branchfall has been collected on a quarterly basis and processed in a manner similar to fine litterfall.

Interaction of litter species and forest community in decomposition processes—Litter decomposition and nutrient mineralization reflect the leaf litter composition and micro-environment in which they occur. The objective of this study was to evaluate the influence of leaf litter species and community type on leaf litter decomposition and nutrient

mineralization. The mass loss rates of three litter species or species groups were evaluated in Iatt Creek's bottomland hardwood community and the adjacent upland pine community. Nutrient analyses are in process.

This study used the litterbag method to follow mass and nutrient loss over time. In this method, mesh bags, filled with a known mass of litter, are placed in the study environment. Changes over time are determined by periodically collecting and weighing a subset of litterbags. In this study the litterbag was a flat nylon net bag, 20 cm x 30 cm, Delta (15.9-kg test), with 1-mm mesh openings. The litterbags were filled with 20 g of the leaf litter, sewn shut, and placed on the surface of the existing forest floor. Bags were individually numbered and secured in place with wire pins.

The three litter species were sweetgum, red oak subgenera (*Erythrobalanus*) and loblolly pine (*Pinus taeda* L.). Litter materials were freshly fallen senescent leaves collected within the study communities and sorted by species or species group.

Within each community, five permanent plots were randomly selected. The five bottomland hardwood plots were selected from the 10 plots used in determining NPP, and the five pine plots were selected from a pool of nine 0.1-ha pine plots in the adjacent upland.

On each plot, three sets of 14 litterbags were randomly placed for each of the three species of litter. At approximately bimonthly intervals over the next 2.5 years, collections of three litterbags for each species were made from each of the 10 plots. A total of 1,260 litterbags were installed and collected.

Collected samples were returned to the laboratory in individual paper bags, cleaned of foreign materials and soil (as practical), oven-dried (70 °C), and weighed. Because mineral contamination was significant and variable, a subsample from each collected bag was then ashed at 450 °C for 4 hours in a muffle furnace to allow reporting of mass loss on an ash-free basis.

Avian and Aquatic Populations

Avian surveys were conducted by means of 10-minute point counts in winter and summer at all study area grid points (Hamel and others 1996). Aquatic populations were surveyed by using standard electro-shocking and netting techniques in the case of fish and hand probing of habitat in the case of fresh water mussels. Results are reported on a per unit effort basis.

RESULTS AND DISCUSSION

The mature hardwood forest is tall, multi-sized, and dominated by large diameter sweetgum, cherrybark oak, and water oak (*Quercus nigra* L.). Some 73 species appear in the woody vegetation layers. The age of the co-dominant/dominant trees (mean height 33 m) is 66 to 75 years at 0.6-m above soil surface. Total tree age may be from 5 to over 20 years greater. Basal area averages 35 m² per ha with a mean stand density of 462 stems per ha \geq 7.6 cm d.b.h.; 1,037 stems per ha \geq 2.5 cm d.b.h.; and 1,610 stems per ha < 2.5 cm d.b.h. Quadratic mean diameter of all trees \geq 7.6 cm d.b.h. is 30.4 cm with a quadratic mean diameter of 20.5 cm for all trees \geq 2.5 cm d.b.h.

Ordination—Vegetation Dynamics

Figure 2 presents an example of initial ordination analyses. The CANOCO and TWINSpan programs were applied to data on BA of all trees on a 10-m x 40-m subset of the full vegetation sample plots. The analysis produced a combined ordination of plots and species to a six-level hierarchy. Analysis of the elevations of the plot corners from the groups of plots distinguished in the ordination revealed a very great variability of species occurrence at the latt Creek site. Analysis of variance of elevations indicated that significant differences existed among mean elevations of plots at all six levels of the hierarchy (R^2 for level 6 = 0.504, where $F_{(15, 462 \text{ df})} = 30.71$, $P = 0.0001$). However, the differences among means were distinct and ordered in sequence by elevation for only the two highest levels of the hierarchy (R^2 for level 2 = 0.326, $F_{(2, 465 \text{ df})} = 112.44$, $P = 0.0001$). A simultaneous plot of the species and plots indicated a substantial variation among species in the minor stream bottom. Because the variation in elevation within plots is relatively large compared to the variation in elevation across the entire study site, efforts to distinguish gradients defined by elevation will be difficult.

Aboveground Net Primary Productivity

Initial estimates of aboveground NPP show that the single dominant component is fine litterfall (leaf production) which accounts for about 60 percent of the total NPP as follows:

Component	kg per ha per year
Tree layer wood biomass increment	3,880
Sapling layer wood biomass increment	30
Fine litterfall	8,520
Coarse Branchfall	1,530
Herbaceous annual production	160
Total aboveground NPP	14,120

Wood increment accounts for about 28 percent of total NPP with coarse branchfall accounting for about 11 percent. Both sapling biomass increment and herbaceous understory production appear relatively minimal.

The distribution of productivity reflects the maturity of the forest and the multi-layered nature of the forest vegetation. Due to mesic conditions, the study area supports a large leaf surface area. The large diameter branchfall reflects natural pruning associated with a mature, closed canopy forest. The aboveground NPP is high but within the range reported for southeastern wetland forests (Megonigal and others 1997). The NPP is among the highest for the world's forests outside the tropics. The relationship and responsiveness of annual aboveground NPP to yearly and across site variation in site parameters is being investigated.

Litterfall

Consideration of seasonal litterfall patterns is beyond the scope of this report. Based upon 3 years of data, mean total litterfall is 8520 kg per ha per year with leaves accounting for 63 percent, fruiting structures and seeds 15 percent, fine wood 12 percent, and other fines 9 percent. Total fine litterfall is near the upper limit of the litterfall range (1380 - 8550 kg per ha per year) reported by Megonigal and others (1997) for an array of southeastern wetland forests. Indeed, the latt Creek litterfall is among the highest reported in world forests (Bray and Gorham 1964, Meentemeyer and others 1982, Vogt and others 1986) as a group, exceeded only by tropical rainforests.

Fine Litterfall Decomposition Rates

We compared the rates of mass loss for senescent leaf tissue from cherrybark oak, sweetgum, and loblolly pine in the bottomland and adjacent uplands (table 1). Changes in mass remaining were fit to the negative exponential model of Jenny and others (1949). Rates of decompositions are reported as k values (table 1). In forests, k values commonly range from 0.01 in boreal coniferous to 1 or 1.2 in temperate deciduous forests and as high as 4 to 6 in tropical rainforests.

After 13 months, litter in the pine community exhibited lower k values than in the bottomland (table 1). Within both communities the k values for pine litter are lower than those for deciduous litter. Moreover, within the pine community, sweetgum mass loss is somewhat greater than for red oak leaves while in the hardwood community, the k values are almost identical for the two deciduous broadleaf species.

After 27 months, the k values show a lack of significant differences between communities; the primary difference being the much slower rate of decomposition for the pine needles. As expected, mass loss rates for pine needles were significantly lower than those for deciduous broadleaf species. The impact of substrate quality differences between pine and deciduous broadleaf species has been frequently noted (Heal and others 1997, Swift and other 1979). Decomposition constants for the deciduous broadleaf

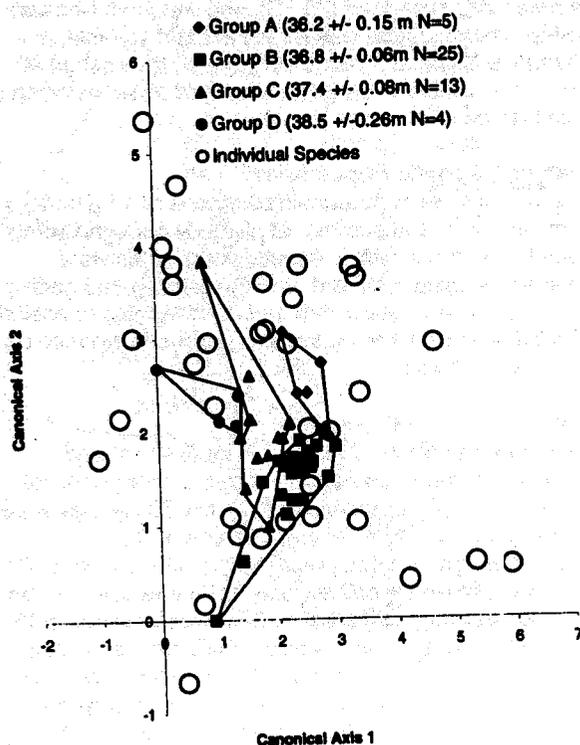


Figure 2—Initial Canonical analysis plot of one data subset from the overstory (> 7.6 cm d.b.h.) vegetation data set.

Table 1—Jenny k values for two sites and three leaf species, where percentage remaining = e^{-kt} (t = time in years) (Jenny and others 1949)

Leaf species	Bottomland hardwoods	Upland p ne
-- k values based on initial 13 months --		
Loblolly pine	0.43	0.28
Red oak	.77	.58
Sweetgum	.76	.63
-- k values based on entire 27 months --		
Loblolly pine	.51	.44
Red oak	.76	.76
Sweetgum	.77	.78

species are within the range of wetland forests. For forested wetlands, our k values for single deciduous species are lower than the 1.01 reported by Lockaby and Walbridge (1998) and the 0.83 by Conner and Day (1991) in a natural forested wetland. However, they are slightly higher than the 0.667 reported by Day (1982). Regardless of variation, the k values for the dominant deciduous broadleaf species are indicative of a forest with a high rate of decomposition and nutrient mineralization (Swift and others 1979).

Wildlife Populations

Avian populations—Repeated winter and summer counts revealed more than 75 bird species. Of these species, 23 were Neotropical migrants and 17 were North temperate or short distance migrants. These surveys continue.

Aquatic populations—In September 1997, the fishes and freshwater mussels were quantitatively surveyed at two sites along the Iatt Creek mainstem and at four sites in the floodplain (e.g., beaver-dammed tributaries, overflow depressions). One mainstem site was located at the northern boundary and the second in the southern section of the study area. The mainstem of Iatt Creek yielded a total of 21 fish species, and the shallower floodplain habitats yielded from 6 to 16 fish species. With few exceptions, the fish fauna found in the isolated pools on the floodplain represented a subset of the fauna in the mainstem. Further analysis of catch-per-unit-effort and relative abundances of fishes may provide additional information on the composition of the fauna between mainstem sites and between mainstem and floodplain sites.

The main stream sites yielded six total freshwater mussel species, but no freshwater mussels were found in the floodplain habitats. Freshwater mussels were most common in the shallow riffles and pools at the mainstem site on the northern boundary where catch per unit effort was 80 mussels-per-person-hour searched. In the middle section, catch per unit effort was lower (24 mussels-per-person-hour searched); however, all six freshwater mussel species were present at both mainstem sites.

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