96-050

NONGAME WILDLIFE CONSERVATION FUND

Small Project Proposal FY95 (July 1995-1996)

1. Project Title: Ecosystem function and restoration in the Cache River Bioreserve, Illinois.

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5. I request $1,000 in funding from the Nongame Wildlife Conservation Fund.

6. PROPOSAL CATEGORY *(For Staff Use Only)*

Management	Site Inventories	Education

7. Project Justification:

The ecological integrity of the Cache River ecosystem is threatened by: 1. altered hydrologic setting due to impoundment and channelization, 2. loss of natural habitats due to agricultural activities and timber harvest, 3. sediment deposition in wetlands causing the deterioration of water quality, and, 4. hydrologic and sedimentation scenario incompatible with the restoration and maintenance of cypress swamps. The project proposed here is part of a larger one to examine the effects of sedimentation on cypress swamp vegetation. The money requested here is of specific value as a training opportunity for undergraduate students in the critical areas of restoration and landscape ecology. To date, more than 50 paid and volunteer workers have helped in the work.

8. Project Objectives:

The specific objectives of this study are to determine the length of hydroperiod and sedimentation levels that inhibit plant establishment in cypress swamps including seed germination and seedling establishment.

9. Project Methodology

We hypothesize that plant establishment rarely occurs in the flooded portions of Buttonland Swamp, except at the edge of the high water flood mark in farm field adjacent of the swamp. Lack of sapling recruitment spells the long-term decline of the adult population as natural mortality takes its toll. To test this hypothesis, seed germination and recruitment studies will be conducted to identify the conditions under which the ecosystem can propagate itself.

Seed bank samples will be collected at 20 points along transects within swamp in the Lower Cache River and composited into 1 sample. Subsamples will be subjected to various levels of sedimentation to determine the upper limit of sedimentation impeding germination.

In addition, seedlings will be planted at elevations corresponding to particular water depths for winter flooding in the Crawford Tract of the Nature Conservancy adjacent to Buttonland Swamp in the Lower Cache. Seedling will be subjected to various levels of sedimentation and their subsequent survival

monitored for two years after planting. Using this approach, the limits of water depth and sedimentation to survivorship will be determined for seeds and seedlings of various species in the swamp.

Outcome. The vegetation study will determine the long-term ability of Buttonland Swamp to recruit cypress and other species to sustain the integrity of the swamp by identifying the critical hydroperiod and sedimentation level above which cypress swamp species establishment can not occur. In addition, it will train many undergraduate and graduate student workers and volunteers. The study described will form the basis of recommendations regarding the quantity of water necessary to promote seed dispersal from intact swamps for the natural restoration of cypress swamps in abandoned farmland in the Cache River Region.

10. Project Location

The Cache River area in southern Illinois (Fig. 1) was once an extensive region of cypress and mixed hardwood swamp of approximately 250,000 hectares in the northernmost region of the Gulf Coastal Plain before its extensive alteration for agriculture. Most of the work will be done in the Crawford Tract (property of the Nature Conservancy) adjacent to Buttonland Swamp near Perks, Pulaski County, Illinois (37°17'50"N; 89°03'10"E).

Budget:

11. Illinois Wildlife Preservation Funds Requested:

Labor	$1,000	Travel	$0
Equipment	$0	Commodities	$0
Contractual	$0	Other	$0

SUBTOTAL $1000

12. Funds You Will Provide: SUBTOTAL $3854

13. TOTAL COST OF PROJECT $2000

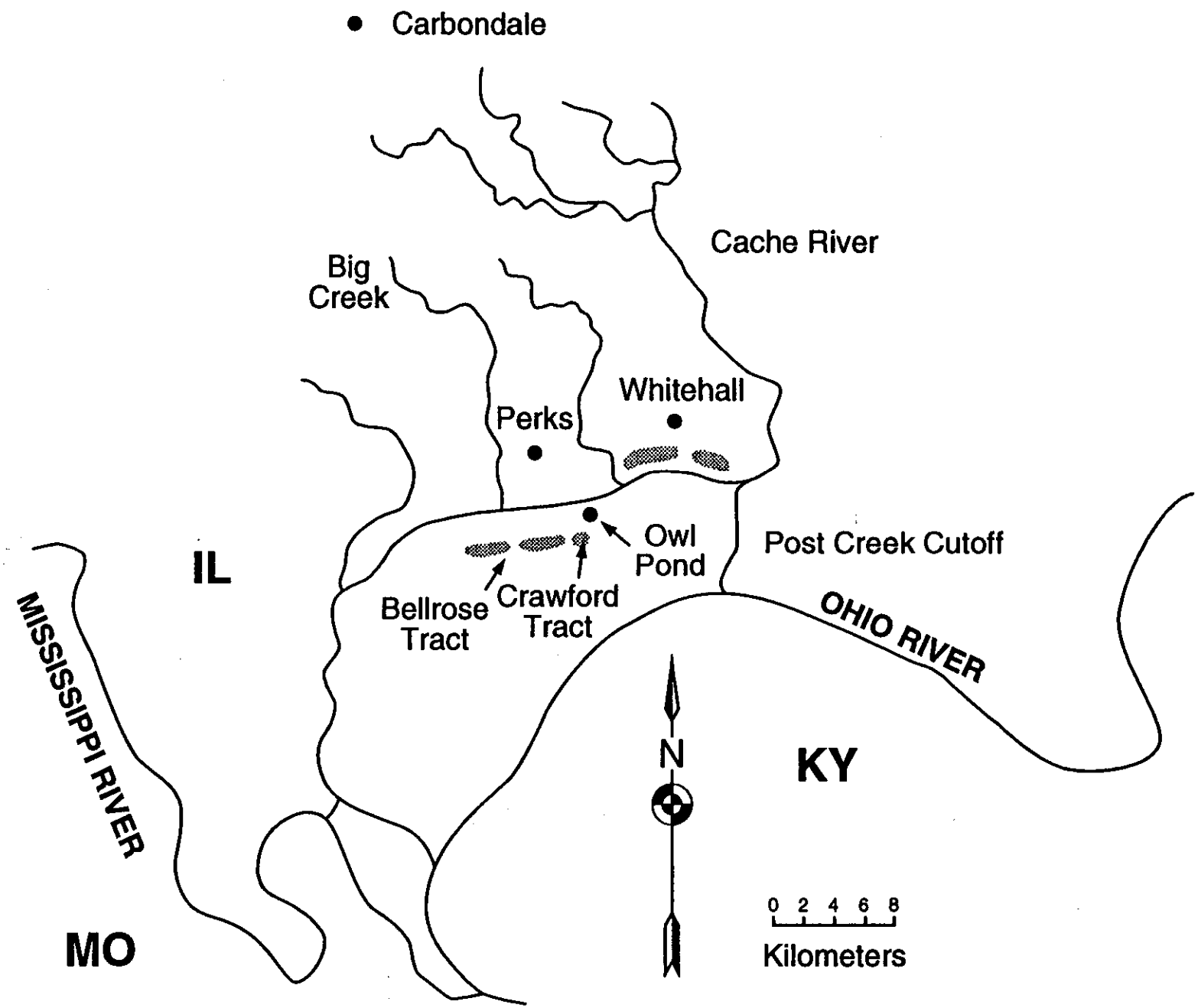
14. Does your project involve endangered or threatened species (x) yes () no collecting protected species () yes (x) no Department of Conservation property () yes (x) no.

15. Attached: Detailed Budget, Map of Project Area (Fig. 1), Detailed Proposal, Short Vitae, Relevant Publications, Training Potential

Year 1

A. Professional Staff	Salary	# Mos.	% time	P/M	Agency	# Mos.	% time	P/M	SIU
1. Beth Middleton	4371.12	0.00	0.00	0.00	0.00	9.00	0.05	0.45	1967.00
Subtotal:				0.00	0.00			0.45	1967.00
B. Other Personnel									
1. Undergraduates					1000.00	0.00	0.00	0.00	0.00
Subtotal:				0.00	1000.00			0.00	0.00
C. Subtotal Personnel					1000.00				1967.00
D. Fringe Benefits for Professional Staff									
1. Retirement/Life @10.69%					0.00				210.00
2. Medical/Dental @$535/per.mo.					0.00				241.00
Subtotal:					0.00				451.00
E. Equipment									
Subtotal:					0.00				0.00
F. Travel									
Subtotal:					0.00				0.00
G. Commodities									
Subtotal:					0.00				0.00
H. Contractual									
Subtotal:					0.00				0.00
I. Direct Costs					1000.00				2418.00
J. Indirect Costs (0% of MTDC)					0.00				1016.00
(Unrecovered Indirect Costs @ 42%)									420.00
K. Total Project Costs					1000.00				3854.00

Figure 1. Map of the Cache River region, Illinois.



95-117 Middleton II 1.0

ECOSYSTEM FUNCTION AND RESTORATION IN THE CACHE RIVER BIORESERVE, ILLINOIS

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ECOSYSTEM FUNCTION AND RESTORATION IN THE CACHE RIVER BIORESERVE, ILLINOIS

PROJECT SUMMARY

The Cache River watershed in southern Illinois contains unique and diverse wetland ecosystems including cypress and tupelo swamps, and over 100 state threatened or endangered plant and animal species. These ecosystems are threatened, however, by modern agricultural practices, hydrologic modifications, habitat fragmentation, sedimentation, wetland drainage, stream channelization and stream incision initiated by the construction of the Post Creek cutoff.

The purpose of this project is threefold: (1) to better understand the interaction between human and natural systems within the Cache River Bioreserve; (2) to use this understanding to evaluate land and water resource management alternatives designed to conserve local biological diversity and foster economic development; (3) to link models of socioeconomic processes with hydrologic models and from there to ecological models of wetland forest dynamics and wildlife habitat. To help accomplish this objective a Spatial Decision Support System (SDSS) will be developed. SDSS integrates geographic information system (GIS) software, simulation models, and knowledgebase models into a system designed to support resource management. This SDSS will then be used to assess managerial strategies important for land and water conservation, such as, keeping cropland out of production after the Conservation Reserve Program (CRP) expires, partial closure of the Post Creek cutoff, and dechannelizing tributary streams.

The research plan for this three year project is designed to be cost-effective by drawing upon past research, and collecting only those new data required to model the system in the context of conservation management. The scientific goal is to more clearly define the interactions between human and natural subsystems in a complex landscape, and more fully account for their contribution to the dynamics of a bioreserve. The conservation goal is to use these understandings to assess specific environmental management alternatives for the Cache River Bioreserve. In doing so, this research integrates all components of the bioreserve, and takes account of the opportunities and limitiations of the ecological, hydrological and socioeconomic subsystems.

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INTRODUCTION

The Cache River watershed encompasses 1,944 km^2 of southern Illinois near the confluence of the Mississippi and Ohio Rivers. The watershed has diverse ecological resources and unique natural communities, including cypress (Taxodium distichum) - tupelo (Nyssa aquatica) swamps and other forested wetlands. At least 100 state threatened or endangered plant and animal species are known within the watershed. The Cache River region also supports unique ecological communities and 10 globally rare or endangered species. For these reasons, the Cache River Bioreserve was created and parts of the Cache River watershed incorporated in the Cypress Creek National Wildlife Refuge.

The ecological integrity of the Cache River ecosystem is threatened by: (1) loss and fragmentation of natural habitats as a result of agricultural activities and timber harvest; (2) dramatically altered hydrologic systems caused by drainage and channelization; (3) sediment deposition in wetlands causing deterioration of water quality and alteration of habitat conditions in Buttonland Swamp; and (4) land use and economic activities that are incompatible with long-term maintenance of ecological functions. Moreover, the predominantly rural 5-county area has an impoverished economy with minimal infrastructure and weak linkages to the surrounding region which make it sensitive to the cost and benefits of habitat restoration and protection in the Cache River region.

State and federal agencies and non-governmental organizations are collaborating in a joint venture to protect and restore ecological resources of the watershed in a manner compatible with the social and economic welfare of the resident human population. Joint venture partners are actively acquiring lands and restoring natural communities within a 237 km^2 riparian corridor surrounding the Lower Cache River (Figure 1).

Research Goals

The research we propose combines field studies to extend ongoing research in the Cache River watershed with synthesis in the context of modeling. Thus, the research is not solely ecologic or hydrologic; nor is it solely socio-economic. The nexus of the work is the interplay of

the subsystems that constitute the Cache River Bioreserve ecosystem, which are all too often studied in isolation leading to either irrelevant or unworkable strategies for ecosystem management. The emphasis of this project is on integration through understanding how each subsystem operates and how it links with the other subsystems in a way that will allow us to address the ecosystem management scenarios outlined below (Figure 2). Furthermore, we are proposing a fundamental break with previous modeling activities (e.g. Williams and Nicks, 1988; He et al., 1993), that have posited land-use scenarios without significant regard to their feasibility in the face of socio-economic and political realities and trends. Considering the realities of the human subsystem is essential where ecologic outcomes depend upon the actions of multiple decision-makers who control both private and public lands, many of whom base their decisions and actions on economic or preference criteria that are not consistent with the goals of integrated watershed management or preservation of the Cache River Bioreserve. Our research considers land-use patterns that are derived from the ability and willingness of land managers to undertake specific conservation-oriented management actions.

This objective to integrate the subsystems appropriately imposes a set of more specific research goals, and a modus operandi among the interdisciplinary research team. The proposed activities of each of the researchers are guided by the overarching objective to integrate our findings. While many of the specifics of this integration will be worked out throughout the research period, some parameters are clear. They include:

(1) the purpose of computer modeling is to express the Cache River Bioreserve in ways that enable the testing of a specific set of management scenarios (while maintaining the generality that would enable their application to the integrated management of other watersheds);

(2) models of the subsystems in the Cache River Bioreserve will be selected for their ability to give outcomes for specific management practices that are derived from management scenarios;

(3) field studies are designed to give information relevant to an understanding of the respective subsystems as components of the bioreserve ecosystem to be modeled.

The tool for integrating the component subsystems will be a Spatial Decision Support

System (SDSS) (after Densham, 1991). SDSS are designed to help decision makers address complex spatial problems (Figure 3). An optimal solution to such problems often does not exist for these problems because all objectives are not quantifiable or even known. SDSS, therefore, encourages the user to explore the bounds of the problem by generating and testing alternative solutions. This SDSS will be designed to assess as accurately as possible how management options will impact the ecology of the Bioreserve and the economy of the watershed. For example, Pearlstine et al. (1985) used a SDSS and a forest dynamics model (FORFLO) to demonstrate how the proposed release of impounded water to the Santee River in South Carolina would result in succession of bottomland hardwoods to cypress-tupelo swamp on that river's broad floodplain, as compared to the treeless mudflats that would result from Army Corps of Engineers' planned release schedule. Our research objectives in the Cache River region are similar and will benefit from their work, but the issues addressed in this project are more complex because, in addition to hydrology, they include the effects of sedimentation, upland land-use patterns and in-stream modifications on ecosystem dynamics. Upland management options focus on the Big Creek and Cypress Creek watersheds which, despite widespread enrollments of highly erodible croplands in the Conservation Reserve Program (CRP), may still deliver high sediment loads to Buttonland Swamp (Demissie 1989; Demissie et al. 1990). Management options include (1) maintaining highly erodible cropland in the CRP or some other easement program after contracts expire in 1996-99, and (2) acquiring farmlands adjacent to Buttonland Swamp for conversion to forested wetland ecosystems. In-stream options include (3) sediment remediation through dredging, constructions of gabions and sedimentation basins, stream-bank stabilization, and partial closure of the Post-Creek cutoff that diverts water from the Lower Cache River and threatens Heron Pond and other forested wetlands by initiating incision of the Upper Cache, and (4) restoration of channelized water flows to naturally meandering stream courses, especially along lower Cypress Creek. Additionally, we will model (5) how ecological conditions will change under current management.

We will expand upon previous work (Beck et al., in press; Gates et al., in press). Beck et

al. (1993) used ecological (erosion, sedimentation, and landscape structure) and economic (personal income, industrial output, employment, and population) criteria to evaluate implementation of large-scale habitat restorations, riparian filter strips, and alternative agricultural practices. Questions were raised regarding sources of sediments currently deposited in swamps (i.e., erosion from uplands vs. stream banks and beds), and storage of previously eroded upland sediments within streams (Davie and Lant, in press). Middleton (in press) further emphasized the importance of restoring naturally fluctuating hydroperiods to maintain productivity and regenerate cypress-tupelo plant communities.

RESEARCH PLAN

The research plan will be conducted over three years in three overlapping segments: (1) process studies of the sub-systems in Figure 2; (2) development of spatially explicit models of these three system components; (3) evaluation of management alternatives (modification of land use, in-stream remediation, restoration of natural stream course). These three segments will be developed concurrently.

PROCESS STUDIES

Hydrology and Sedimentation: Lead Scientist- K. Flanagan

Objectives: (1) Examine the channel and floodplain composition and morphology of Big and Cypress Creeks for the purpose of understanding channel erosion and transport of sediment (suspended and bedload) into Buttonland Swamp; (2) Measure the sediment yield produced by farming operations within the Big Creek and Cypress Creek watershed; (3) Develop alternative methods of erosion control that reduce siltation in Buttonland Swamp by controlling erosion within the tributary streams (Big and Cypress Creeks); and (4) develop and parameterize hydrologic and sediment transport models that will be integrated into the SDSS.

It has been suggested (Demissie et al., 1990) that high sedimentation rates threaten the ecological integrity of the Buttonland Swamp. To mitigate this problem, effective and affordable

methods of silt removal must be developed. However, the development of these methods is difficult because the details of fine-grained sediment transportation, storage, and deposition in stream channels and receiving basins, such as Buttonland Swamp, is poorly understood. This study will focus on the storage and erosion of fine-grained material in Cypress and Big Creeks and will provide information on the timing and controlling factors of stream channel alluviation.

Research on stream systems in southern Illinois indicate that much of the sediment is transported as bedload rather than suspended load (Flanagan, 1993). Knowledge gained from the proposed study expands our understanding of fine-grained bedload transport processes as well as the hydrologic and sedimentation processes that affect Buttonland Swamp, and from this, management alternatives can be developed that help ensure the integrity of the swamp ecosystem. To evaluate the efficacy of management alternatives, predictive models need to be developed to estimate the lag time between the erosion of the surrounding watershed and final depositional events into the wetland. This will be done by studying consistent and dominant variables influencing the timing of channel erosion and sediment sources. Coring of Buttonland Swamp coupled with previous studies (Demissie, 1989; Demissie et al, 1990) will give an indication of sedimentation rates both prior to and after the initiation of intensive agriculture.

Eight stations will be set up along each of the Big and Cypress Creeks and eight to twelve measurements will be taken in a cross sectional profile using standard surveying methods. These measurements (depth, width, shape of channel) will determine any change in the stream bed at each station and indicate a buildup or erosion of the bars (Brassington, 1990). Sediment samples will be collected from both the suspended load and bedload and analyzed for lithology (rock type) and grain size (after Gordon et al., 1992). Clay lithology will be determined on oriented samples with the Scintag Powder Diffractometer. Bedload samples will be studied in hand specimen and under a petrographic microscope to determine sediment sources. Cross-sectional stream profiles and wetland measurements (length, width, and depth) will be obtained monthly or after any large storms. Also, water temperature, water level, and flow velocity will be monitored following standard hydrological field methods (Brassington, 1990). A study of Buttonland Swamp will

involve taking cores and measurements from a field constructed datum line (or reference line) at the same locations as the cypress regeneration sites (Brassington, 1990).

The information obtained will be used to calibrate the hydrologic model of the Cache River watershed. It will summarize times of highest flow and greatest erosion along the stream channels and the controlling parameters under differing seasonal conditions. It will supply basic information needed to; (1) assess bank stabilization efforts and; (2) track the transport of channel material into the floodplain and wetland.

Products: (1) Base information on the storage and erosion of fine-grained material in the Big and Cypress Creeks; (2) Knowledge about the factors controlling stream channel alluviation in the Cache River watershed; (3) Hydrologic and sediment transport models that can be integrated into the SDSS.

Cypress Regeneration: Lead Scientist- B. Middleton

Objectives: (1) Collect primary and secondary data needed to assess current conditions in Buttonland Swamp; (2) Determine the length of hydroperiod and levels of sedimentation that inhibit plant establishment in cypress swamps, with special emphasis on cypress trees; (3) Use vegetation establishment information to parameterize a forest establishment model (e.g. FORFLO) that will be integrated with hydrologic and sedimentation models.

The survival and reproductive strategies of plant and animal communities adapted to wetland ecosystems rely on a dynamic hydrologic regime. At least 40 species in cypress swamps disperse via water (Middleton, submitted). Because of changes made to the Cache River hydrologic system, most of the land adjacent to Buttonland Swamp is no longer inundated during yearly flood events, nor do portions of the existing swamp dry out during the summer. Because most plant species, cypress in particular, cannot establish under water, little recruitment of new individuals occurs in permanently flooded wetlands (DuBarry, 1963). Cypress swamps in the Bioreserve core area have the lowest recorded rate of primary production in the Gulf Coastal

Region, perhaps due to continual inundation (Middleton, in press). In addition, high rates of sedimentation affect the Lower Cache, and it is not known how this affects the growth of ecoclinal populations at the extreme edge of their distribution.

We hypothesize that plant establishment rarely occurs in the flooded portions of Buttonland Swamp, except at the edge of the high water flood mark in farm fields adjacent to the swamp. Lack of sapling recruitment spells the long-term decline of the adult population as natural mortality takes its toll. To test this hypothesis, seed dispersal and germination studies will be conducted to identify the conditions under which the ecosystem can propagate itself.

Seed Germination and Sedimentation: Seed bank samples will be collected at 20 points along transects within swamp in the Lower Cache River and composited into 1 sample. After sieving the soil to remove plant fragments, the soil sample will be divided into 30 subsamples and placed in soil trays. These subsamples will be subjected to sedimentation treatments as follows: 5 trays will be kept moist with no sediment added, 5 trays will be kept moist with 5 cm of sediment added, 5 trays will be kept moist with 10 cm of sediment added, 5 trays will be flooded with no sediment added, 5 trays will be flooded with 5 cm of sediment added, and 5 trays will be flooded with 10 cm of sediment added. Sediment will be made from swamp soil microwaved for 3 minutes to kill seeds. Plants that emerge from the soil in the trays will be identified, tallied, and then pulled to prevent seed contamination.

One hundred seeds each of cypress, tupelo, buttonbush, and pin oak will be placed into 15 trays of potting soil in a greenhouse and subjected to the above treatment. Three sets of 100 seeds of each species will be tested for viability at the beginning of the study with tetrazolium.

Seedling Transplant Studies and Sedimentation: Twenty cypress seedlings will be planted at 10 elevations corresponding to particular water depths for winter flooding in the Crawford Tract of The Nature Conservancy near Perks, Illinois. Of these, 10 seedlings will be subjected to 50 cm of sediment and 10 will not be subjected to sediment. The locations of each planting will be randomly chosen within a 100 m transect. The Crawford Tract, adjacent to Buttonland Swamp has been the subject of an intense seed dispersal study utilizing elevations determined with a

transit. Production of the cypress seedlings will be determined for each seedling using biomass estimates as based on their heights using length/mass regression. Seedling survivorship and biomass will be monitored for 2 years after planting. This study will determine the level of flooding and sedimentation that limit the growth of cypress seedlings.

The results of these experiments will be used in the restoration of cypress swamp communities as well as to calibrate the forest establishment model. In particular, we hypothesize that establishment could occur in certain locations in and near the swamp, particularly at the edge of the high water flood mark in farm fields adjacent to swamps in the Cache River System given a favorable hydrologic regime.

Products: (1) Determination of the long-term ability of Buttonland Swamp to recruit cypress and other species from the seed bank and thus to sustain the integrity of the swamp; (2) Identification of the hydroperiod and levels of sedimentation required for the establishment of cypress and other species; (3) Calibration of the dynamic forest establishment model for linkage with the hydrologic model.

Animal Habitat Relationships: Lead Scientists- R. Gates, B. Burr, and R. Brandon

Objectives: (1) Develop animal community profiles for selected habitats (forested wetlands and swamps, riparian zones, and herbaceous uplands) that occur within the Big and Cypress Creek drainages; (2) Identify habitat conditions and biophysical parameters associated with different faunal assemblages within riparian, wetland, and upland habitats in the Big and Cypress Creek drainages; (3) Develop statistically-based models to predict responses of selected faunal assemblages and/or indicator species to habitat and landscape changes associated with different management scenarios.

Any management practice that alters the existing hydrologic regime will impact certain animal communities. To evaluate alternative management scenarios it is necessary to determine which communities are positively impacted and which communities are deleteriously impacted by such changes. Furthermore, it is necessary to identify the regional impact on recreationally

important species.

Existing data sources will be used to compile taxonomic lists and determine the diversity of vertebrate species that are resident or breed in riparian and wetland communities in the Cache River watershed. Based on knowledge of life histories and habitat requirements, species will be segregated into cross-taxonomic guilds that would be expected to respond similarly to changes in stream physical characteristics, plant communities, and surrounding land-use patterns. Indicator species will be identified that are sensitive to changes in land use and ecological conditions. Relative abundance and distribution of these species will be used as indicators of the ecological integrity of faunal communities in different portions of the study area.

To identify the habitat conditions and biophysical parameters associated with faunal assemblages, a stratified sampling scheme will be developed. This survey will determine the distribution and relative abundance of vertebrate species in representative habitats. Species distributions and relative abundance will be sampled across physical and habitat gradients that occur within streams and riparian zones, and selected wetland and upland habitats. Faunal survey sites in the Lower Cache River that were sampled in an earlier study (Phillippi et al. 1986) will be revisited to determine recent changes in aquatic faunal communities. Field sampling techniques will be similar to those used by Phillippi et al. (1986), Keller et al. (1993), and Mitchell et al. (1993). Physical, spatial, and biological characteristics of sample sites will be measured and related to patterns of distribution and abundance of vertebrate species among habitat types and across biophysical gradients. A partial list of biophysical parameters to be measured include: macroinvertebrate abundance and diversity, stream profile, flow velocity, water temperature and sediment load, stream substrate composition, vegetation composition and landscape structure and connectivity. Multivariate statistical analyses will be used to ordinate faunal composition of stratified sample plots in relation to physical and biological gradients so that changes in faunal communities associated with land and water management scenarios can be modeled.

Using this information, existing habitat suitability index (HSI) models will be adapted, and/or new HSI models will be developed, to match the ecological conditions that prevail in the

Cache River watershed. These models will be based on landscape-level parameters that can be modeled using GIS. Interfacing spatially-based models of habitat quality with GIS will permit analyses of the effects of changes in landscape structure (habitat fragmentation and connectivity) on faunal communities of the Cache River watershed.

Products: (1) Faunal survey for the Lower Cache River. (2) Spatially-explicit habitat suitability index (HSI) models, calibrated for the Lower Cache River and integrated into the SDSS. (3) Evaluation of the effects of management alternatives on animal communities.

Land Use And Regional Economy: Lead Scientists- J. Beaulieu, R. Beck, S. Kraft, C. Lant

Objectives: (1) Collect primary and secondary data that describe the range of farming enterprises and the diversity of farm operations and farm operators, the existing set of agricultural and environmental policies that circumscribe land use decisions on the part of landowners and farm operators, and the structure of the regional economy of the Cache River watershed; (2) Develop a representative farm linear programming model that can capture the diversity of resources and enterprises of the farm operations in the area; (3) Map the agricultural land-use pattern that would emerge in the Cypress Creek and Big Creek watersheds under a variety of USDA policy scenarios as an input into the watershed hydrologic model; and (4) Estimate the net economic impact of management scenarios on the local economy of the Cache River watershed.

Secondary data sources from previous studies (Beck et al., 1993; Kraft and Toohill, 1984; Kraft and Lant, 1992; Esseks et al., 1990), the United States Census Bureau, and state and local agencies will be used to develop representative farm models reflective of the range of farming practices and enterprise types found in the 5-county watershed. Additional data about the variability of farm operations in the watershed will be acquired from a special tabulation of the 1992 Census of Agriculture, which has been performed for the 1987 Census (see Kraft 1993). The data will also be used to specify the range of resources found on farms in the region and the extent to which farmers participate in USDA commodity and conservation (e.g., CRP and

Conservation Compliance) programs.

This linear-programming-based representative farm model will facilitate the simultaneous assessment of a large number of alternative land uses (e.g., crops and livestock) and land-use practices (e.g., tillage and cultivation alternatives) given a diversity of resources, input costs, and product prices (Taylor and Frohberg, 1977; Crowder et al., 1985; Bretas and Haith, 1990; Carter, 1963; Plaxico and Tweeten, 1963). Using biological and physical data from this study, we will develop model constraints encompassing ecological parameters (e.g., levels of soil loss, nutrient flows, size and placement of filter strips) critical to water quality and the ecological integrity of the basin. These constraints will permit us to incorporate ecological factors in whole-farm economic planning. For example, the model could be used to develop a land-use pattern that meets the objective of maximizing farm income, under the constraints of ecological requirements such as (1) annual sediment yield to the Cache River must be less than X tons; (2) the amount of plant nutrients leaving farm fields must be less than X tons; and (3) acreage allocated to filter strips must be greater than X acres. The representative farm models will provide information on the nature and amount of outputs that will be produced and inputs that will be used on different types of farms under different conservation policies or strategies for ecological restoration. The regional economic effects can then be aggregated using the regional input/output model (IMPLAN) (University of Minnesota, 1989) parameterized with farm level data from extant farms and the results of the farm level models. Results from the linear programming model will be used in conjunction with the input/output analysis to assess the impact of optimal programming solutions on the regional economy.

Primary survey data will also be obtained from farm operators and others in the region to assess the relationship between the uses of particular, spatially registered areas of farmland and a range of USDA and environmental policies. Given the existing public polices affecting the use of land and water resources and the possible new policies that might come into existence through the reauthorization of the Clean Water Act, the Endangered Species Act and the 1995 Farm Bill, the surveys will be used to assess the receptiveness of farmers in the watershed to these policies and

the likelihood that such polices might be implemented. A census of the approximately 250 farm operators in the Cypress and Big Creek watersheds who are presently enrolled in USDA programs will be performed to build maps of likely land-use patterns that may emerge under a number of policy frameworks (see Lant and Kraft, 1993; Esseks and Kraft, 1993; Kraft, Lant, and Steinbeck 1993). In particular, the likely future uses of the 52,365 acres of cropland currently enrolled in the CRP will be mapped based on a number of policy scenarios related to the extension of the program. These maps will form the basis upon which the watershed hydrologic model will be parameterized, thus providing a firm link between USDA policy, resulting land-use patterns and hydrologic outcomes.

Regional economic effects of management scenarios have been modeled using input/output analysis (IMPLAN). Results indicated that land-use changes associated with establishing the bioreserve are not inherently detrimental to the local economy (Beck et al., in press). However, some of the regional economic problems (e.g. the shift from an agricultural economy to an agricultural/recreational/wildlife economy) were more readily modeled and better understood than ecological problems primarily because important ecological data were lacking and models were not available to adequately project ecological impacts. The biophysical research described above is designed to provide this kind of information. As such, it will now be possible to more fully evaluate the impact that meeting ecological objectives may have on the regional economy. In addition to IMPLAN, we will use the Small Area Assessment Model (Robinson and Hickman, 1990; Beck et al. 1993). This latter model permits the assessment of how the Cache River watershed is linked to the regional economy.

Products: (1) Primary and secondary data describing the regional socio-economic system; (2) Maps of contingent land-use patterns in the Cypress and Big Creeks that correspond with likely USDA policy scenarios concerning the conservation and commodity programs; (3) Farm level and regional socio-economic models that describe the dynamics of this system and illustrate the impact that conservation efforts within the Cache River Bioreserve may have on the regional economy.

INTEGRATION AND MODELING: Lead Scientists- D. Bennett and D. Sharpe

Objective: (1) Integrate the results of process studies, new and existing process models, and spatial data handling technology to develop a SDSS for the Cache River Bioreserve.

In the context of management of the Cache River Bioreserve, it is necessary to view socioeconomic and biophysical processes as components of the regional ecosystem. The purpose of the process studies discussed above is to provide the insights and data needed to make informed decisions about alternative environmental management scenarios, listed in the Introduction. The role of a spatial decision support system is to facilitate the evaluation of these scenarios (Figure 3). That is, the nature of the questions to be asked, together with an understanding of relevant components of the Cache River Bioreserve as summarized in the SDSS, lead to management recommendations based on predictions of outcomes of selected management activities. The purpose of integration and modeling is to develop and test the SDSS. This involves modeling (or describing) each subsystem and the behavior and linkages among them in the context of computer-based technologies. However, doing this presents certain problems. An ongoing challenge in this study is to develop a conceptual model that solves a number of implementation problems, some of which are discussed below.

(1) Linking biophysical processes with the decision making process. Typically, ecosystem models focus on biophysical processes (Figure 4a). Here we consider the human environment to be part of the ecosystem and search for ecosystem management options that benefit both the human and natural subsystems: we must consider the impact that conservation and restoration objectives have on the regional socioeconomic subsystem (Figure 4b) which may constrain the management options available.

(2) Discrete vs. continuous representation of space. A geographical feature can be represented in the computer as a continuous field (as approximated by a set of grid cells or a triangulated irregular network) or as a set of discrete objects (Goodchild, 1992). Land management activities tend to be implemented at the object level (e.g a farm field), while physical processes operate across a continuous landscape. To capture the connection between human activities and natural processes it

is necessary to integrate field and object spatial data models. One solution to this problem is to extend our spatial model of a field to include the notion of a bounded field. Each spatial object would then contain a bounded field; the continuous landscape would be represented as a set of bounded fields.

(3) Discrete vs. continuous representations of time. Decisions are made at discrete points in time (event based), while physical processes take place continuously at variable rates. To model natural systems it is necessary to approximate the passage of time by discrete increments. This provides a way in which decision events can be integrated into our model. Yet a problem remains. An appropriate time step depends on the process being simulated, its duration, the accuracy required, and response time needed. For example, farm management options are generally made annually, forest dynamics are often simulated using monthly time increments (e.g. JABOWAII) , while the time step in hydrological models (e.g. ANSWERS, AGNPS) may be a minute. When considering the impact that one system has on the other it will be necessary to consider such differences in temporal scale.

(4) Modeling and supporting the decision maker. The behavior of the decision maker can, in part, be captured by linear programming and expert system technology. Note that commercially available GIS software cannot directly model such behavior. In addition, decision makers should be able to interact with SDSS to generate and test alternative management scenarios. Though the utility of GIS as a management tool is well documented, in many instances, GIS software lacks the flexibility and power needed to address such complex issues as the management of the Cache River Bioreserve (Bennett and Armstrong, 1993). By merging expert knowledge, computer modeling and spatial data handling techniques, SDSS provides the analytical power needed to tackle such issues (Densham, 1991). As noted above there are many issues that must be resolved before such a tool can be developed. Part of the research agenda for this project, therefore, is to identify ways in which human and natural systems can be integrated into a single decision support environment. To accomplish this we must identify who the decision makers are, what decisions are made, and the key linkages between impacted subsystems. The development of such decision

support systems requires the development of new computer models, the use of existing technologies (e.g. GRASS, ARC/INFO), and/or the integration and modification of new and existing models (e.g. IMPLAN, ANSWERS, AGNPS, HEC, FORFLO) and technology. The process studies will help identify the critical dynamics extant in the Cache River Bioreserve and this knowledge will be used to select specific process models.

Products: (1) A new approach for the integration of human and natural systems in a SDSS framework that is designed specifically for natural resource management; (2) An integration of ecological, hydrological, and socioeconomic studies into a management tool that will help decision makers evaluate alternative management scenarios for the Cache River Bioreserve; (3) A step toward a new tool for the evaluation and implementation of the bioreserve concept.

EVALUATION OF MANAGEMENT SCENARIOS: Lead Scientists- Research team and TNC Personnel

Objective: Use the resulting management tool to evaluate the management scenarios identified above.

Once the knowledge gained from process studies is integrated into the SDSS environment we will evaluate the impact of selected resource management scenarios (Figure 3). Initial criteria on which these alternatives will be evaluated include their impact on the regenerative capacity of the cypress-tupelo swamp, faunal diversity and on the regional economy; other criteria will surface during discussions with decision makers.

Product: Recommendations concerning the management of the Cache River Bioreserve, base on selected environmental management scenarios.

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Associate Editor, Wetlands, Society of Wetland Scientists, 1993-present.
Visiting Lecturer, Organization of Tropical Studies, Costa Rica. Summer 1993. Course: Tropical Biology.
Postdoctoral Associate, Ducks Unlimited Canada, Winnipeg, Manitoba and Research Unit in Landscape Ecology, Leopold Center, Iowa State University, IA. May 1989 - August 1990. Geographic Information System analysis of vegetation changes in Manitoba, Canada.

HONORS
Who's Who in Science and Technology, 1991-94 & Midwest, 1994.
Fulbright Award to India, G.B. Pant University, Pantnagar, India, Council for International Exchange of Scholars, 1990-91.
Teaching Excellence Award, Iowa State University, 1989.
Phi Beta Delta Honor Society for International Scholars, 1989-93.
Sigma Xi, 1990-94.

RESEARCH FUNDING (past 5 years)
Wetland ecology of northern India (G. B. Pant University).
1. Council for International Exchange of Scholars (Fulbright), Washington, D. C., 1990-1991 ($12,000).

Restoration of southern bottomland hardwood forests along the Cache River, southern Illinois.
2. Office of Research Development and Administration, Southern Illinois University, 1991-1993 ($22,000)
3. Nature Conservancy Chicago Area Office 1991 ($1,000)
4. Robert Munroe, computer equipment 1991-1992 ($500)
5. Gaylord and Dorothy Donnelley 1992 ($2,000)
6. Illinois Department of Conservation 1993 ($1,000).
7. Nature Conservancy, 1993 ($1,500)

The role of flooding in seed dispersal: restoration of cypress swamps in southern Illinois.
8. U.S. Geological Survey via IL Water Resources Center. University of Illinois, Urbana, IL, 1993-1995 ($35,000).

Improvement of plant diversity in coal slurry ponds reclaimed as wetlands through treatment of the seed bank during drawdown.
9. National Mine Land Reclamation Center, Midwest Region, Carbondale, IL 1991-1992 ($30,000).

Leaf decomposition and mineral cycling in mangroves in Belize.
10. Smithsonian Institute Caribbean Coral Reef Ecosystems Program, Washington, D.C., 1993 ($3,000).

Sedimentation and ecosystem function in cypress swamps.

11. D. Bennett, K. Flanagan, R. Gates, S. Kraft, B. Middleton, D. Sharpe, J. Beaulieu, R. Beck, and C. Lant. Cache River Consortium, Ecosystem function and restoration in the Cache River Bioreserve, IL. Nature Conservancy, 1995-98 ($560,000).
12. Ken Thompson, undergraduate student funding, 1995- ($1,000/year).
13. University Women's Professional Development, 1995 ($750).

Ecotones and mangrove swamps at Twin Cays and Punta Ycacos, Belize.

14. D. Whigham, C. Feller, K. McKee, B. Middleton. Smithsonian Institute Caribbean Coral Reef Ecosystems Program, Washington, D.C., 1994-95. ($10,000).

GRANTS AND RESEARCH SUPPORT PENDING

Role of hydroperiod in the spatial distribution and restoration of cypress and tupelo in swamps, Buttonland Swamp, Illinois. National Science Foundation ($309,000).

Middleton, B. A., K. Flanagan, D. Bennett, and S. Kraft. Collaborative wetland research on sustained wetland usage in Central America. IUCN, San Jose, Costa Rica.

B. PUBLICATIONS MOST RELEVANT TO RESEARCH PROPOSED

Middleton, B. A. 1990. Effect of water depth and clipping frequency on the growth and survival of four wetland plant species. *Aquatic Botany* 37: 189-196.

Middleton, B.A., A.G. van der Valk, C.B. Davis, D.H. Mason, and R.L. Williams. 1991. Vegetation dynamics and seed banks of a monsoonal wetland overgrown with *Paspalum distichum* in northern India. *Aquatic Botany* 40:239-259.

Middleton, B. A. 1994. Decomposition and litter production in a northern bald cypress swamp. *Journal of Vegetation Science* 5:271-274.

Middleton, B. A. Sampling devices for the measurement of seed rain and hydrochory in rivers. *Bulletin of the Torrey Botanical Club* 122:(in press).

Middleton, B. A. Characteristics of plants in forested wetlands. Management of Forested Wetlands in the Central Hardwoods Region. Symposium Proceedings, Purdue University, West Lafayette, IN. (in press).

5 ADDITIONAL PUBLICATIONS (of 23)

Middleton, B.A., A.G. van der Valk, C.B. Davis, D.H. Mason, and R. L. Williams. 1992. Litter decomposition in an Indian monsoonal wetland overgrown with *Paspalum distichum. Wetlands* 12:37-44.

Middleton, B.A. 1992. Habitat and food preferences of geese overwintering in the Keoladeo National Park, Bharatpur, India. *Journal of Tropical Ecology* 8:181-193.

A.G. van der Valk, B.A. Middleton,, D.H. Mason, R.L. Williams and C.B.Davis. 1993. The biomass of an Indian monsoonal wetland before and after being overgrown with *Paspalum distichum* L. *Vegetatio* 109:81-90.

Middleton, B.A. and D.H. Mason. 1992. Seed herbivory by herbivores in the Keoladeo National Park, Bharatpur, India. *Biotropica*: 24:538-543.

Middleton, B.A. Ecology of greenways. Book Review. *Restoration Ecology* (accepted).

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Journal of Vegetation Science 5: 271-274, 1994
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Decomposition and litter production in a northern bald cypress swamp

Middleton, Beth A.[1]

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Abstract. Primary production as measured by annual mean litter fall in the Lower Cache near Perks, Illinois, was the lowest recorded for cypress swamps (2345.5 kg/ha/yr). This swamp is continuously flooded with a low input of phosphorus (< 0.24 mg l). Rates of leaf litter decomposition were higher in the Lower Cache for *Taxodium distichum* than in swamps to the south of the region. The winter rates of leaf litter decomposition in the Lower Cache were slower than summer rates for *Cephalanthus occidentalis, Echinochloa muricata, Polygonum pensylvanicum, Jussisaea repens, Taxodium distichum*, and *Eleocharis obtusa*, but not for *Typha latifolia*. Because the 99 % turnover rates for these species (0.69-5.10 years) often exceeds one year, undecomposed litter can be expected to accumulate or be exported from the system. Most leaves are shed in the autumn (October through December; 83.6 %).

Keywords: Gulf Coastal Plain; Leaf litter fall; *Taxodium distichum*.

Nomenclature: Mohlenbrock (1986).

Introduction

Primary production controls the input of energy and detrital decomposition regulates energy flow in cypress swamps of the southeastern United States (Mitsch & Gosselink 1993). High rates of primary production coupled with high rates of decomposition can facilitate movement of energy into secondary levels of the food chain (Murkin 1989). In situations where high amounts of primary production are not linked to either detrivory or herbivory, organic matter may be available for either peat accumulation or export.

Primary production is fastest in cypress swamps with seasonal hydrological pulsing (Conner & Day 1982), flowing water (Brinson et al. 1981), and high nutrient inflow (Brown 1981). Decomposition rates increase in sites which have high average ground temperatures, and wet but not permanently flooded conditions, but this varies depending on the species and type (leaf litter or roots) of the material (Mitsch & Gosselink 1993). All other factors being equal, in the north rather than in the south of a vegetation zone in the northern hemisphere, primary production and decomposition should be lower due to the length of the growing season (Bray & Gorham 1964).

The objective of this study was to determine the rates of litter production and decomposition at the northern limit of distribution of cypress swamps. The complete range of bald cypress swamps in North America include the southeastern U.S. extending south from Illinois to Louisiana in the Mississippi embayment, west to central Texas, southeast to Florida and north to New Jersey along the Atlantic Coastal Plain (Mitsch & Gosselink 1993). Ecoclinal variation (*sensu* van der Maarel 1990) in primary production of bald cypress (*Taxodium distichum*) communities is examined at their northern terminus in southern Illinois. The hypotheses tested were that both the rates of production, as measured by leaf litter fall, and decomposition were lower in swamps in the north than that of those to the south in the bald cypress region in similar conditions of nutrient loading and hydrology.

Study area

Bald cypress swamps line the floodplain of the Cache River, an abandoned channel of the Ohio River (Horberg 1950), 177 km in length (Anon. 1990) with a watershed of 1912 km^2 (Mitsch & Gosselink 1993). After the Devonian and Mississippian seas receded, a large portion of present day southern Illinois became a wetland. Subsequently, none of the glaciers of the Pleistocene touched the region (Dorge et al. 1984).

The humid climate (Trewartha 1954) of southern Illinois is typical of the southeastern U.S. and is marked by intense rain from November to June (mean of more than 109 cm/yr) due to the mixing of cold northern and warm southern air masses. Mean January temperatures are 3 °C and July temperatures 27 °C (Voigt & Mohlenbrock 1964).

The Lower Cache near Perks, Illinois (37°17'50" N;

Table 2. Decomposition rates (k) and 99 % turnover for litter of plants during a winter and summer study along the Lower Cache, southern Illinois (October 1991-April 1992 and August 1992-February 1993, respectively). Patterns of winter versus summer decomposition were tested using contrasts based on differences in the intercepts, linear and quadratic components of the curves with $F_{3,13}$. * = $P < 0.05$.

	k			99 % turnover	
	Summer 1992-3	Winter 1991-2	F	Summer 1992-3	Winter 1991-2
Cephalanthus occidentalis	7.29	1.29	4.3 *	0.69	3.87
Echinochloa muricata	3.29	1.91	4.4 *	1.52	2.62
Polygonum pensylvanicum	3.09	1.48	11.8 *	1.62	3.38
Jussisaea repens	3.03	0.98	10.9 *	1.65	5.10
Taxodium distichum	2.97	1.04	3.3 *	1.68	4.81
Eleocharis obtusa	2.64	1.05	10.3 *	1.89	4.76
Typha latifolia	1.40	1.27	0.5	3.57	3.93

(385.9, 263.2, and 131.1 kg/ha/yr). Other alluvial cypress swamps to the south of Illinois all have higher rates of primary production (3580-6428 kg/ha/yr; Table 2). Heron Pond, in the Upper Cache of southern Illinois, had a higher rate of primary production (3480 kg/ha/yr; Dorge et al. 1984) than Owl Pond in the Lower Cache.

Temperature and growing season length may be important factors in the relative primary production of ecoclinal populations of species. Based on estimates from dendrometer studies in the Gulf Coastal Plain, cambial growth in trees commences earlier in the south than in the north (Eggler 1955; Robertson 1992). *Taxodium distichum* ceases to grow by June in unflooded swamps in Louisiana, due to lack of moisture and high temperatures. It is not known if summer growth cessation in *Taxodium distichum* is a photoperiodic response (Eggler 1955), or indeed, whether it occurs in the northernmost part of the Gulf Coastal Plain.

Primary production is also affected by nutrient levels. In pond cypress swamps, increases in phosphorus levels are related positively to total litter fall (0.05-5.86 mg/l and 4330-9410 kg/ha/yr, respectively) within a specific region (Brown 1981). However, if swamps along a latitudinal gradient with similar phosphorus loadings are compared, swamps in the north have lower levels of production than those in the south (Table 1).

Continuous high water also can contribute to low rates of annual primary production. Swamps that remain flooded throughout the summer have lower levels of production than those that dry out in the summer (Conner & Day 1992). Pond cypress grows slowly if flooded periods exceed nine months in duration (Ewel & Wickenheiser 1988). In this study, the swamp remained flooded for the entire summer with the lowest water depth recorded in June 1992 (30 cm) and the highest in January 1993 (205 cm). Similarly, beaver dams impound the water all year in Heron Pond (Dorge et al. 1984). In Louisiana, a seasonally flooded wetland had higher amounts of annual litter fall than an impounded one with lowest mean water depths of 10 cm during the summer (4740 kg/ha/yr and 3580 kg/ha/yr, respectively; Table 1; Conner & Day 1992).

Decomposition

In decomposition, macroclimate is more important than microclimate, and microclimate more important than resource quality (Anderson & Swift 1983). Decomposition rates were higher than expected at the northern terminus of the cypress swamp region in the Lower Cache, given the latitude. In the Great Dismal Swamp, *Taxodium distichum* decomposed much more slowly (k = 0.327; Day 1982) than in the Lower Cache either in the summer or winter (k = 2.97 and 1.04, respectively, Table 2).

Riverine swamps that are permanently flooded usually do not have low oxygen levels (mean annual dissolved oxygen in the Lower Cache = 6.5 mg/l), and thus can have fast rates of turnover (Day 1982). On the other hand, the dry microclimate of unimpounded swamps in the summer foster slow rates of decomposition. Pond cypress leaves decomposed more quickly when sites were permanently flooded rather than dry (k = 1.21-1.40 and 0.50-0.69, respectively; Deghi et al. 1980). In Big Cypress Swamp, Florida, *Taxodium distichum* leaves decomposed somewhat faster in dry sites than in sites flooded 61 % of the time (k = 0.47 and 0.30, respectively; Duever et al. 1984).

Most leaves fall in the autumn (October through December; 83.6 %; Fig. 1). Because the 99 % turnover rates in winter are slow relative to the summer rates

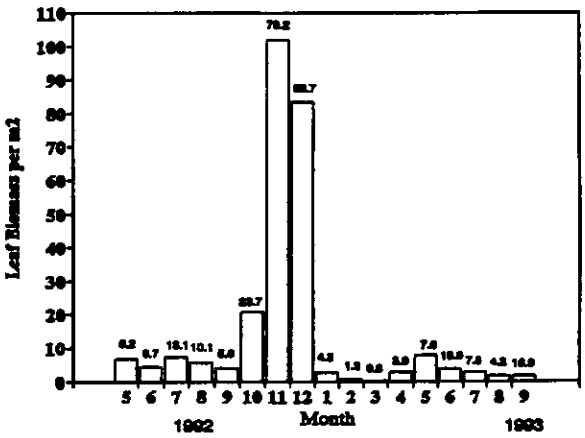

Fig. 1. Seasonal leaf litter fall (g/m^2) in the Lower Cache, southern Illinois. Litter was collected in aerial traps in Owl Pond from May 1992 to September 1993.

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corrections I wish to be made.
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Signed Beth Middleton
Telephone april 14, 1995

Bulletin of the Torrey Botanical Club 122(2), pp. 000-000

PLEASE FORWARD ILLUSTRATION PHOTOPRINTS TO THE EDITOR WITH YOUR PROOFS.

TORREYA

Sampling devices for the measurement of seed rain and hydrochory in rivers[1]

Beth A. Middleton[2]

Department of Plant Biology, Southern Illinois University, Carbondale, Illinois 62901

SEND PROOFS TO EDITOR. SEND REPRINT ORDER TO ALLEN PRESS.

MIDDLETON, B. A. (Department of Plant Biology, 411 Life Science II, Southern Illinois University, Carbondale, IL 62901). Inexpensive sampling devices for the measurement of seed rain and hydrochory in rivers and other aquatic systems are described. The seed rain trap for aerially dispersed seeds consisted of the bottom 20 cm of a bucket attached to a Styrofoam block for flotation. The hydrochore trap for aquatic dispersal of seeds consisted of the top portion of a bucket, a cloth liner secured to the bucket with bottom removed, and two 2-liter beverage bottles for flotation. The total cost of one pair of seed rain and hydrochore traps was less than $1.00. The seed dispersal estimates from the aquatic seed traps reflected the relative numbers of species and seeds dispersed in aquatic systems. A test of the efficiency of the aquatic seed traps demonstrated that traps placed in a swamp over a period of a month captured 1.8 times the biomass of debris and seeds than were present on the surface of the water at any given time.

Keywords: seed dispersal, river, swamp, seed trap.

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The study of the seed dispersal dynamics can contribute greatly to understanding the regeneration ecology of the species which comprise an ecosystem (Leck 1989). Sampling devices for the measurement of seed rain and hydrochory in riverine systems are difficult to devise because, in many cases they must be able to accommodate current changes and sudden or seasonal rises and falls in water level.

Few seed trap designs for aquatic situations have been described in the literature. The aquatic seed trap described by Schneider and Sharitz (1988) with a frame of PVC pipe cost approximately $27 per trap (1991 prices). A similar device has been suggested for sampling macroinvertebrates (DeLong et al. 1993). The high cost of such sampling devices reduces the number of replicate sets of traps a researcher can afford to place in the field and, thus, severely reduces the precision of the resultant data.

In this report I describe inexpensive traps to collect seeds dispersed either by gravity (aerial traps) or water (aquatic traps). These were used in the Lower Cache River in southern Illinois. The water can rise 1 m or more in a few hours, reverse its direction of slow flow, or freeze in the winter. With minimal repair, the original traps have been used continuously for over 3 years.

Materials and Methods. The study site, Owl Pond, was a bald cypress swamp in south-central Illinois on the Lower Cache near the town of Perks (37°17′50″N; 89°03′10″E). Bald cypress (*Taxodium distichum* (L.) Rich.) dominated the vegetation, with groups of water tupelo (*Nyssa aquatica* L.) and thick stands of buttonbush (*Cephalanthus occidentalis* L.: Ugent et al. 1981). In the study area, subsurface water flow was undetectable except during flooded periods (Marsh-McBirney Model 201 portable flow meter). The highest surface flow I recorded was 4 m per minute West (downstream) in February 1994 after the spring thaw. Most of the time, water current is negligible.

Aerial traps were constructed of a plastic bucket (27 cm diameter; 20 cm deep). The bottom of each was lined with heavy weight aluminum foil painted with tanglefoot and attached with strips of duct tape, floating on a Styrofoam block balanced with a weight and tied to a post with rope (Fig. 1A). Tanglefoot Pest Barrier (Tanglefoot Company, Grand Rapids, Michigan) is a sticky substance painted at the base of trees to protect them from climbing insects. The buckets were sawed to proper depth using a jigsaw. Safety goggles were necessary to avoid getting small pieces of plastic in one's eyes. The Styrofoam was obtained from chemical and equipment packaging.

[1] This work was funded by the Southern Illinois University Office of Research and Development and Administration (#2-11770), The Nature Conservancy (#6-21345), the Illinois Department of Conservation (#2-10308), and Gaylord and Dorothy Donnelley.

[2] Students in the laboratory contributing ideas to the design of these seed traps included Yuzo Toya, Eduardo Sanchez, Scott Kuykendall, Jonathon Taylor, John Wilker and Allison Strauss. David Gibson critically reviewed the maunscript.

Received for publication October 24, 1994, and in revised form January 6, 1995.

Table 1. Numbers ($\bar{x}$ ± SE) of water-dispersed seeds m^{-2} yr^{-1} collected in aquatic and aerial traps from May 1, 1992 through April 30, 1993 in Owl Pond, on the Lower Cache River near Perks, Illinois.

	Aquatic traps			Aerial traps		
	Seeds present Water-dispersed			Seeds present Gravity-dispersed		
Species	Number	±SE	% Alive	Number	±SE	% Alive
Cephalanthus occidentalis L.	4940	3747	44	492	1298	74
Bidens discoidea (T. & G.) Britton	640	622	58	11	33	66
Taxodium distichum (L.) Rich	178	257	3	1	4	0
Rosa palustris Marshall	69	197	85	1	4	0
Fraxinus pennsylvanica Marshall	61	108	50	92	149	61
Leersia oryzoides (L.) Swartz	36	71	35	0	0	0
Brunnichia cirrhosa Gaertner	20	38	24	10	12	50
Nyssa aquatica L.	12	32	72	0	0	0
Other	531	855		98	422	
Total seeds	6487	~~5931~~		705	1922	
Total species	40			12		

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Aquatic seed traps were constructed of a bucket top (opening with effective trapping surface of 27 cm^2; circumference of bucket = 27 cm^2), floats, and cloth liner (Fig. 1B) attached with a wire tie through a hole near the rear of the bucket. The cloth was attached to the rear of the bucket with a wire tie and to the front with the lid. The center of the lid was removed with a jigsaw to create a ring. The handle of the bucket was removed. The floats were 2 liter plastic beverage bottles. The liners (27 cm long, width sufficient to fit over bucket rim) were constructed of dyed muslin or mixed cotton/polyester cloth with a sewing machine. Liners lasted at least one month without developing holes during the summer months. During winter months, the cloth liners were cleaned in a washing machine and reused.

While the traps can be used separately, in this study one aerial and one aquatic trap were tied together as a unit with the aerial trap trailing the aquatic trap in the water. These can be tied to a wooden stake with a wood staple using a polypropylene rope (truck rope) of sufficient length to allow the traps to settle on the ground in a drought or rise to the surface in a flood. A metal post could be used in streams with a strong current. Alternatively, the traps can be anchored with a brick if the water flow is not too great.

Twenty sets of aquatic and aerial traps were placed in the swamp at 20 locations along 4 parallel transects (5 sets of traps per transect placed 50 m apart along 200 m transect) placed randomly within 50 m intervals in an east/west direction in Owl Pond. The traps were at the site continuously for 1 year from 1 May 1992 through 30 April 1993. The seeds in the aquatic traps were collected by removing the cloth liner each month for one year. The seeds were rinsed from the cloth in the laboratory through a 0.1 mm (200) wire mesh screen. The foil liner was removed from the aerial seed traps each month. All seeds were separated by hand and tested with tetrazolium for viability (Shuel 1948). The seed traps described in this paper were reset from a boat or on foot in the field.

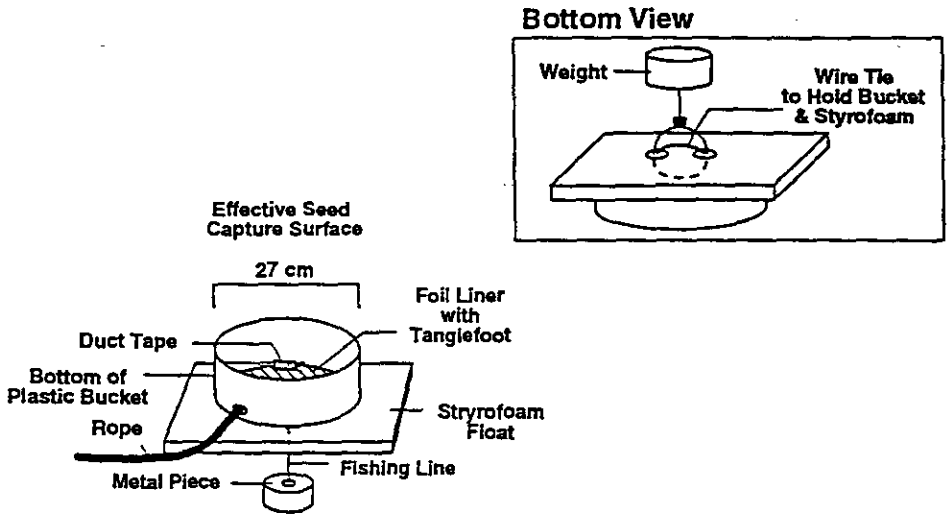
The efficiency of the aquatic traps was tested along a flooded transect (transect 3, traps 11–15) of the above study. The amount of debris and seeds captured in the cloth liners of the aquatic traps during one month (June 30 through July 31, 1994) was compared to that captured in cloth liners when the traps were dipped into the water for 5 seconds (July 31, 1994).

Calculations were done as follows. To convert the data to a m^2 basis (Schneider and Sharitz 1988), the total number of seeds captured in the aerial traps (27-cm diam) was multiplied by 17.5 and the aquatic traps (horizontal trapping surface of 27 cm^2) by 13.7. For the test of the efficiency of aquatic seed traps, the total weight of debris and seeds captured for one month versus dipped for 5 seconds were compared using ANOVA (Sokal and Rohlf 1981; Statistical Analysis System 1988).

Results and Discussion. The seed traps were inexpensive to the extent that free materials could be acquired. The buckets, beverage bottles, metal weights, Styrofoam, and wooden posts were all scraps obtained from college and private sources.

They would be useful to investigate seed rain and hydrochory in any aquatic system though these were designed for the variable water levels

(A) Aerial Traps - Gravity Dispersed Seeds



(B) Aquatic Traps - Water Dispersed Seeds

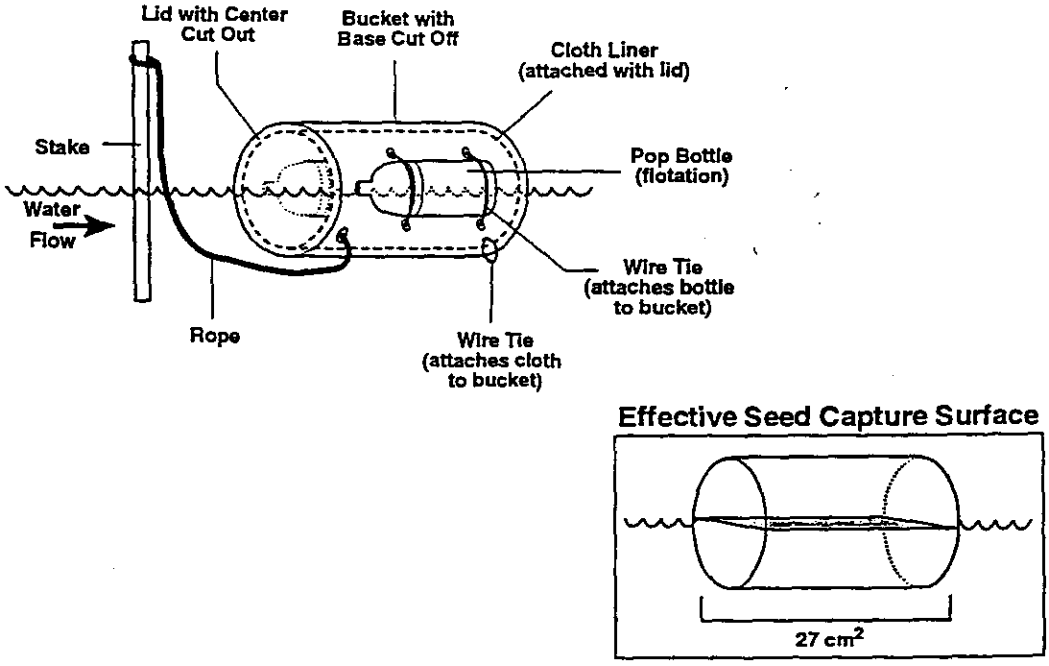


Fig. 1. A. Aerial seed traps designed to capture seed rain. B. Aquatic seed traps designed to capture seeds dispersing in the water.

fl. left

Table 2. Seed trap efficiency by comparison of the weight of debris and seeds captured during one month (g m^{-2} mo^{-1}) versus captured when the traps were dipped into the swamp (g m^{-2} 5 sec) in Owl Pond, on the Lower Cache River, Illinois, on July 31, 1994.

Debris/seed type	Total weight (g) m^{-2}	
	Month	Instantaneous
Leaves of Lemnaceae	124.5	70.3
Wood pieces	1.5	0.8
Buttonbush seed	1.4	0.2
Cypress seed	0.6	0.2
Buttonbush leaves	0.0	0.1
Total	128.0	71.6

Table 3. Sources of error in ANOVA for the test of the efficiency of aquatic seed traps by comparison of the weight of debris and seeds captured in one month (June 30, 1994 through July 31, 1994) versus that captured when the traps were dipped into the swamp for 5 seconds on July 31, 1994 in Owl Pond, Lower Cache River, Perks, Illinois. Trap type refers to traps placed for one month versus for 5 seconds; debris/seed type refers to the weight of seed, leaf or woody debris.

Sources of error	df	*F*	*P*
Trap type	1	4.7	0.03
Debris/seed type	5	56.2	0.01
Trap type × debris/seed type	5	4.3	0.01
Error	48		

(0–2.5 m) and low flow conditions of the Lower Cache River in Illinois.

These traps worked well. Approximately 1% of the aerial traps failed to capture seeds because they sometimes flipped over if they caught on branches during rise or fall of the water. Also, if the water rose higher than the length of rope, the trap became tethered under the water. The hydrochory traps failed less than 1% of the time to capture seeds and then because the cloth developed a hole.

The aerial seed traps in this study captured fewer cypress and tupelo seeds (1 ± 4 SD and 0 seeds m^{-2} yr^{-1}, respectively) than a study in South Carolina. In comparison, in two successive years, the aerial seed traps designed to capture seed rain by Schneider and Sharitz (1988) for a swamp in South Carolina captured a number of cypress (196 ± 149 SD and 23 ± 34 seeds m^{-2} yr^{-1}) and tupelo seeds (45 ± 48 and 29 ± 42 seeds m^{-2} yr^{-1}). Though dominants, both cypress and tupelo are sparse in the canopy in Owl Pond with a relative cover of less than 0.6% (Basinger 1994). The most common species in the area, *Cephalanthus occidentalis* (relative cover = 3.6%), also had the highest number of seeds in the seed rain (492 seeds m^{-2} yr^{-1}; Table 1).

In this study, 705 ± 1922 seeds m^{-2} yr^{-1} of 12 species were captured in the aerial traps including *Fraxinus pennsylvanica* Marshall, *Bidens discoidea* (T.&G.) Britton, *Brunnichia cirrhosa* Gaertner (92, 11, 10 m^{-2} yr^{-1}, respectively; Table 1). In addition to cypress and tupelo, over a period of two years, aerial seed traps in the South Carolina study captured a total of 548 seeds of 18 species.

In this study, the aquatic traps captured more species and 8 times more seeds than the aerial because of the ability of seeds to travel distances in the water. In addition, the seeds of 40 species were captured in the hydrochore traps, while only 17 vascular species with seeds grow in Owl Pond (Basinger 1994). As the remainder of the species have been found in other bottomland forests along the Cache River (Basinger 1994), this would suggest that seeds may move some distance in the water, and that the aquatic traps record the long distance dispersal of these species.

The seed traps accumulate 1.8 times the biomass of debris and seeds than is captured from the surface of the water at a given moment (Table 2). Because water movement typically is undetectable in this part of the Cache River except during floods (>0.01 m sec^{-1}, September 1993 through May 1994), higher values of debris/seeds captured in aquatic seed traps placed in the water continuously for a month would not be anticipated. The test of seed trap efficiency indicates that the aquatic seed traps do collect seeds dispersing in aquatic systems (Tables 2, 3).

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