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SYNOPSIS OF WETLAND FUNCTIONS AND VALUES: BOTTOMLAND HARDWOODS WITH SPECIAL EMPHASIS ON EASTERN TEXAS AND OKLAHOMA

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SYNOPSIS OF WETLAND FUNCTIONS AND VALUES: BOTTOMLAND HARDWOODS WITH SPECIAL EMPHASIS ON EASTERN TEXAS AND OKLAHOMA

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SUMMARY

Bottomland hardwood wetlands are the natural cover type of many floodplain ecosystems in the southeastern United States. They are dynamic, productive systems that depend on intermittent flooding and moving water for maintenance of structure and function. Many of the diverse functions performed by bottomland hardwoods (e.g., flood control, sediment trapping, fish and wildlife habitat) are directly or indirectly valued by humans. Balanced decisions regarding bottomland hardwoods are often hindered by a limited ability to accurately specify the functions being performed by these systems and, furthermore, by an inability to evaluate these functions in economic terms. This report addresses these informational needs. It focuses on the bottomland hardwoods of eastern Texas and Oklahoma, serving as an introduction and entry to the literature. It is not intended to serve as a substitute for reference to the original literature.

The first section of the report is a review of the major functions of bottomland hardwoods, grouped under the headings of hydrology, water quality, productivity, detritus, nutrients, and habitat. Although the hydrology of these areas is diverse and complex, especially with respect to groundwater, water storage at high flows can clearly function to attenuate peak flows, with possible reductions in downstream flooding damage. Water moving through a bottomland hardwood system carries with it various organic and inorganic constituents, including sediment, organic matter, nutrients, and pollutants. When waterborne materials are introduced to bottomland hardwoods (from river flooding or upland runoff), they may be retained, transformed, or transported. As a result, water quality may be significantly altered and improved. The fluctuating and flowing water regime of bottomland hardwoods is associated with generally high net primary productivity and rapid fluxes of organic matter and nutrients. These, in turn, support secondary productivity in the bottomland hardwoods and downstream through detrital export. A large number of studies detail the extensive utilization of bottomland hardwoods by animals. Several basic habitat components contribute to this support function, including (1) fluctuating water levels and permanent bodies of water, (2) hard mast (e.g., acorns), (3) dens and cavities, (4) high soil fertility, (5) diversity of food and cover, (6) predominance of woody plant communities, (7) close proximity of diverse structural features, and (8) linear features providing movement corridors.

The second section of the report focuses on the bottomlands of eastern Texas and Oklahoma, including topics such as climate, soils, water resources, historical perspective, vegetation, and fauna. Considerable attention is given to structural characteristics in this section, in order to provide contrasts with bottomland hardwood ecosystems in other areas. In general, the bottomland hardwoods of eastern Texas and Oklahoma are very similar to those

elsewhere in the southeastern United States. Differences include the occurrence and relative importance of some community types and plant species and the greater importance of reservoir construction as a source of bottomland hardwoods loss in eastern Texas and Oklahoma. Again, information on faunal utilization is extensive relative to the information available concerning other functions.

The final section, on economic valuation of the functions of bottomland hardwoods, is introduced by a discussion of general concepts of value. Some of the confusion regarding wetland valuation stems from interpreting work that has been based on different theories of value (e.g., energy theory of value). The general types of human values associated with various functions and attributes of bottomland hardwoods are summarized. Selected methods for quantifying these human values are then presented, followed by a discussion and several examples of specific valuations.

The text of the report is supplemented by a computerized bibliographic data base of relevant articles. Records in this data base include abstracts and can be retrieved using a broad range of keywords. Diskettes containing the data base files are available, on request, for use on selected microcomputer data base management systems.

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INTRODUCTION

Bottomland hardwoods, or floodplain forests, are diverse wetland ecosystems that perform a wide range of functions, many of which are valued, directly or indirectly, by man. Agricultural conversion and various hydrologic developments, including reservoir construction, have produced a substantial decline in bottomland hardwoods in recent years (MacDonald et al. 1979; Tiner 1984; Brabander et al. 1985; Frye 1987). Balanced decisions regarding the bottomland hardwood resource are often hindered by limited ability to accurately specify the functions being performed by these systems and, furthermore, by the inability to describe these functions in terms of dollar values that can be judged against more easily monetized alternatives, such as agricultural production.

A general review of functions and values of bottomland hardwoods is followed by a section focused on eastern Texas and Oklahoma that highlights unique aspects of this geographic area. Considerable attention is given to structural aspects of bottomland hardwoods in this section. This provides a basis for assessing information about functions of bottomland hardwoods in other States and applying it to bottomland hardwoods in eastern Texas and Oklahoma, where in many cases site-specific information is not available. Economic valuation of the functions of bottomland hardwoods is discussed by considering general theories of value, types of values associated with bottomland hardwoods, and appropriate methods. This is followed by several specific examples of valuation in terms of dollars. The report is supplemented by a bibliographic data base, with abstracts and several types of keywords, which is available for installation on microcomputers.

Common names for plant and animal species are used throughout the text. Associated scientific names are provided in Appendices C and G. In general, we have maintained the nomenclature of the original sources cited. Changes were made to correct obvious typographical errors, to achieve internal consistency in this report, and to update the nomenclature when it could be done unambiguously, based on the following references: American Ornithologists' Union (1983), Collins et al. (1978), Correll and Johnson (1979), Harrar and Harrar (1962), Lee et al. (1980), Neuner and Berger (1982), Reed (1986), and Robins et al. (1980). Several acronyms are used to simplify text citation to works attributed to agencies or organizations. These include USFWS (U.S. Fish and Wildlife Service), USACE (U.S. Army Corps of Engineers), OTA (Office of Technology Assessment), and CSA (Continental Shelf Associates). Original units of measurement have been converted to the metric system throughout. However, original units are also given in some cases where metric units are not as commonly used (e.g., dollars per acre).

FUNCTIONS OF BOTTOMLAND HARDWOODS

> The river . . ., ever restless, ate at its channeled banks and wandered back and forth across the floodplain . . . leaving terraces and trenches in the flatness of the bottomland. Through time, as the features of the land emerged, plants and animals adapted their life-styles to fit the kinds of environments that water carved from the land. Towering oaks and hickories stood rooted to the bottomlands . . . where water had stacked the fertile soils, layer by layer. Cypress and tupelo gum trees, crowned with nests of herons and egrets, bathed their feet in the wetness of abandoned river channels. Catfish lurked in the summer pools of the river, waiting for a freshet to send the river out of its banks and among the leaves, logs and debris of the bottomland, to expose the fat grubs and beetles to their foragings. The bottomland chestnut oaks drank their fill, and after the river subsided, dropped their acorns to feed the hungry turkeys and bears that came down from the hills in the fall. (Truett and Lay 1984, p. 143).

Bottomland hardwoods (BLH) are productive, wetland ecosystems that depend on water fluctuations (i.e., periodic flooding) for the maintenance of their structure and function. A bottomland hardwood wetland is defined by Huffman (in Larson et al. 1981) as "...a floodplain ecosystem dominated by woody vegetation that has demonstrated ability because of morphological adaptations, physiological adaptations and/or reproductive strategies to perform certain requisite life functions which enable the species to achieve maturity in an environment where the soils within the root zone may be inundated or saturated for various periods during the growing season." The components of these systems (land, water, plants, animals, atmosphere) are connected by a complex set of physical, chemical, and biological processes. The hydrologic regime strongly affects the structure and function of these systems, including the composition and productivity of vegetative communities, the transport and transformation of inorganic and organic materials, and the maintenance of fish and wildlife habitat.

Well-documented declines in the area of bottomland hardwoods (MacDonald et al. 1979; Tiner 1984) have prompted a number of synthesis volumes and workshops devoted to bottomland hardwoods (e.g., Clark and Benforado 1981; Wharton et al. 1982; Brabander et al. 1985; Roelle et al. 1987a, b, c; McMahan and Frye 1987). An increasing amount of attention is being devoted to bottomland hardwoods from the perspective of cumulative impacts (e.g., Gosselink et al. 1987; Lee et al. 1987). Some of the concerns focus on changes in landscape-level properties such as the extent of fragmentation, patch sizes, connectivity and corridors, and juxtaposition of cover types. Functions such as habitat for certain species may be related to these large-scale features and thus may be impacted in a greater than proportional fashion as individual bottomland sites are altered.

Some of the examples cited in this report refer to forested wetlands (e.g., Okefenokee Swamp and cypress domes) that are more aptly described as headwater swamps or isolated depressions rather than bottomland hardwood wetlands. These wetland systems are not characterized by the flowing water of a riverine floodplain, but they are included here because of similarity in vegetation, processes, and functions.

Bottomland hardwoods are an integral part of larger surrounding systems. They contribute to the physicochemical and biological characteristics of adjacent rivers through water and nutrient exchange and the export of organic matter, functioning in many places as buffer zones between terrestrial and aquatic systems (Langdon et al. 1981). The extent of buffering "ranges from protection of water quality in a single stream to life support values on a regional scale" (Cairns et al. 1981).

HYDROLOGY

Floodpeak Reduction and Water Storage

One of the most dramatic functions of riparian systems is flood peak attentuation. The frequency and duration of flooding depend on the elevation and topography of the floodplain, size of the watershed, and precipitation patterns. Floodplains absorb flood pulses by dispersing water over large areas. The hydrology of a floodplain is related to the river's alluvial deposits and topography, including natural levees (Figure 1). Annual flooding is generally confined to the river's first bottom area; higher flood levels (e.g., 5-year to 100-year floods) inundate the second bottom area. The river-floodplain as a functional system cannot be maintained without these water level fluctuations.

Where floodplain forests are left intact, flood peaks are not as high, nor do they rise and fall as rapidly (Belt 1975; Wharton 1980; Cairns et al. 1981). Under natural conditions, upland runoff moves through a swamp and is released gradually to downstream areas (Hopkinson and Day 1980a). In spring, when the soil is saturated and water loss through evapotranspiration is low, wetland areas release water to streams or rivers more quickly; when soils are drier and evapotranspiration is high, water is released more slowly (Mitsch 1979; Conner and Day 1982; Wharton et al. 1982). The rate of upland runoff is "dampened" by the storage capacity of swamp land adjacent to a stream or river (Kemp and Day 1984). Floodplains with backwater swamps provide greater surface water storage area. Highly organic soils in these areas act as sponges, increasing water storage capacity and minimizing potential for flood peak damage (Wharton et al. 1977a; Wharton 1980). Bedient (1975) found that a landscape that included 20% wetlands and ponds reduced flooding by 90% in a Florida river basin.

The real significance of water movement in unaltered bottomland hardwood systems can be clarified by studying altered systems. Hopkinson and Day (1980a,b) studied a Louisiana swamp forest and developed a model for stormwater

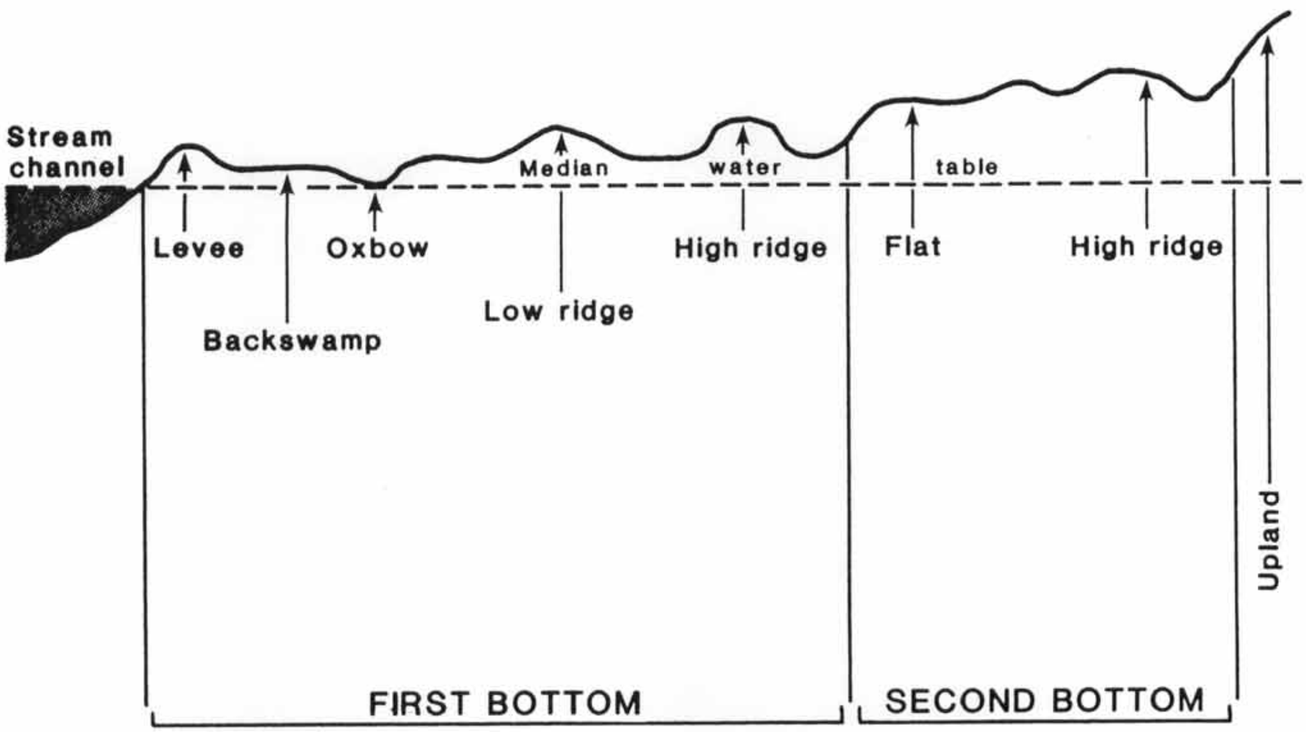

Figure 1. Floodplain topography (redrawn from Wharton 1980).

management. Simulation studies indicated that spoil banks located in the swamp significantly obstructed natural patterns of water flow. Their removal would allow runoff to pass freely through the backswamp and would probably (1) increase discharge rates to the downstream estuary by 22%, (2) increase the productivity of the swamp forest by 100%, and (3) decrease adjacent lake eutrophication by 43%.

Stream channelization disrupts the natural hydrologic regime of the floodplain system, resulting in impacts such as increased suspended sediment and reduction of suitable habitat for fish and wildlife. The conversion of floodplain forest to agriculture also produces negative impacts associated with the loss of bottomland hardwood functions (Kirby-Smith and Barber 1979). Stream responses to the loss of forested floodplains by conversion to cropland include (1) an increase in total discharge, (2) higher flood peaks, (3) greater sediment loading, and (4) increase in sediment particle size (Ritter 1978).

Groundwater recharge or discharge is site specific and is closely related to soil permeability (Taylor et al. 1984). The dynamic relationships between the alluvial aquifer and surface water in streams or oxbow lakes on the floodplain are described by Bedinger (1981). During periods of low or average river stages the direction of water flow is from the groundwater toward surface water features. Alluvial aquifers are part of the regional groundwater flow system beneath the bottomland hardwoods along the Mississippi river.

Groundwater discharge from these aquifers occurs through seepage to lakes and streams and through evapotranspiration. During periods of high river stages, groundwater recharge can occur as floodplains are inundated and water moves from the river (or floodplain surface) to the aquifer. In backwater areas, where the floodplain may be inundated 40% of the time, surface water may be the principal source of recharge to the aquifer. Drainage ditches cut into the floodplains to depths below the water table drain groundwater, and tend to lower the water table.

An example of a specific water budget is the description of swamp-river interactions for Heron Pond, Illinois (Mitsch et al. 1979). Major inputs of water were as follows: throughfall (74.3 cm), runoff (69.4 cm), and groundwater (21.6 cm). Outflows were: evapotranspiration (72.3 cm), surface outflow (56.5 cm), and groundwater (21.0 cm), with surface outflow and groundwater draining primarily into the river.

WATER QUALITY

Water moving through a bottomland hardwood system carries with it various organic and inorganic constituents in both dissolved and particulate forms, including sediment, nutrients, and pollutants. When these materials are introduced to the bottomland hardwood system (via flooding from an adjacent river system or runoff from an adjacent upland system), they may be retained, transformed, or transported, and as a result of these processes, water quality is often significantly improved (Kuenzler et al. 1977; Winger 1986).

Sediment Deposition and Erosion

The amount of sediment deposited in a floodplain is related to the sediment load (and composition) entering the floodplain, the volume and velocity of moving water, and the vegetation of the floodplain. Sediment yield of a stream or river is inversely related to the amount of vegetation present in the floodplain. The "frictional" effect of floodplain vegetation slows water flow, including runoff from upland areas. The volume of runoff often increases after areas are deforested, largely because of reductions in interception and evapotranspiration (Branson 1975). The high levels of biomass in forested areas provide a large degree of protection against erosion (Branson 1975; Gosselink et al. 1981). Along shorelines, roots and peat hold the soil in place, and plant growth stabilizes the soil and facilitates deposition of suspended sediments (OTA 1984). Through sediment trapping processes, movement of waterborne sediment into the river or stream is minimized. Thus, sediment trapping decreases turbidity and improves water quality downstream (Wharton 1980).

Filtration, Deposition, and Processing of Pollutants

The "pollutant sink" function of wetlands is described by Boto and Patrick (1979). Suspended sediments transport associated loads of nutrients, pesticides, heavy metals, and other toxins. Sediment deposition and burial result in removal of nutrients and toxins from the water to the bottomland area, where they may undergo decomposition and transformation.

Pollutants may be removed from water by extracellular enzymatic breakdown, ion-exchange on soil surfaces, biological uptake, or adsorption by clay particles. Pesticides can adsorb onto clay or organic particles at levels of 10,000-100,000 times their concentration in the water column (Keith 1966). Wharton (1980) noted that alluvial floodplains are sinks for radioactive cesium and plutonium, oil, nitrogen, phosphorous, sewage, and fly ash.

Filtration of river water occurs as flood waters pass over forest litter and soil. Bacteria and viruses from wastewater can be removed from water as it passes through peat, roots, and clay (H.T. Odum 1984). Inorganic nutrients are filtered or transformed from nutrient-rich discharges or runoff from agricultural land and are thus prevented from reaching the stream channel (Kitchens et al. 1975; Lowrance et al. 1983; Kemp and Day 1984).

Changes from aerobic (oxidizing) to anaerobic (reducing) conditions in the forest floor favor bacterial metabolic pathways such as methanogenesis, sulfate reduction, and denitrification (generating methane, hydrogen sulfide, and nitrogen gas, respectively). Because of a well-developed anaerobic sediment layer, swamp forests have high value as potential waste assimilators (H.T. Odum 1978).

When the bottomland hardwood ecosystem is altered by stream channelization, clearing, or reservoir construction that disrupts the normal flooding regimes, the opportunity for nutrient removal may be reduced. Under such altered conditions, downstream nutrient exports can increase, resulting in increased eutrophication rates in downstream water bodies. When hydrological patterns are greatly altered, it is likely that the disrupted riparian ecosystems become sources rather than sinks for nutrients and sediment (Brinson et al. 1981c).

Examples of water quality improvement by specific bottomland hardwood wetlands include the following:

- Distribution and dynamics of organic matter and phosphorus were studied in a sewage-enriched swamp in Florida (Nessel and Bayley 1984). This cypress strand had received wastewater for more than 45 years. Although the soil had a high concentration of phosphorus, there was a 75% reduction in phosphorus levels from surface water to groundwater, indicating that the soil profile acted as an effective filter in removing phosphorus from sewage inputs.

- A hardwood swamp in Florida removed 87% of the total nitrogen and 61.8% of the total phosphorus from wastewater discharges, primarily through infiltration (Winchester 1983).

- A mixed hardwood swamp in Florida was used for tertiary treatment of municipal water; filtration by the swamp trapped nutrients from water and stored them in plant biomass; bacteria were also removed (Boyt et al. 1977).

- Swamps of Georgia's coastal plain were used as tertiary treatment facilities to detoxify industrial effluents prior to their introduction into larger streams and estuaries (Hodson 1980).

- A tributary of the Alcovy River in Georgia was polluted with human wastes and chicken offal. After flowing 4.4 km through the nearby river-swamp, the water was designated "clean" by the Water Quality Control Board. After 11.3 km, the water quality was termed excellent by the board (Wharton 1970).

- A large number of studies have examined the wastewater treatment capabilities of cypress domes (e.g., Ewel and Odum 1978a,b; Fritz 1978; Dierberg 1980; Dierberg and Brezonik 1983). The general results of these studies showing retention of nutrients in biomass and transformations among chemical forms are applicable to some extent to the similarly vegetated forests of river floodplains.

PRODUCTIVITY, DETRITUS, AND NUTRIENTS

In forested floodplains, trees are the major source of primary production and detritus. Bottomland hardwoods are generally more productive than other wetlands, and most other ecosystems as well (Brinson et al. 1981c; H.T. Odum et al. 1981). Fluctuating water levels are essential for the maintenance of these high levels of productivity in floodplain systems. The frequency and duration of soil saturation (hyroperiod) have a profound influence on floodplain vegetation. This relationship forms the basis of zonal classifications of bottomland hardwood systems such as that described by Patrick et al. (1981).

A number of studies have detailed the relationships between variation in hydrologic regime and variation in the vegetation of specific forested floodplains (e.g., Boyce and Cost 1974; Brinson et al. 1981c; Klimas et al. 1981; Larson et al. 1981; Leitman et al. 1983). Sites with flowing water regimes and nutrient subsidies (e.g., sewage effluent) have the highest values for aboveground biomass production (Conner and Day 1976; Brown 1981; Klimas et al. 1981). Communities on sites with poor drainage, constantly saturated soils, and stagnant conditions have significantly lower productivity than areas subjected to moderate seasonal flooding. Net primary production has been measured on a number of specific forested wetland sites (e.g., Conner and Day 1976; Schlesinger 1978; Mitsch 1979; Mitsch and Ewel 1979; Brinson et al. 1981b; Brown 1981). Annual values for aboveground biomass production in bottomland hardwoods include 1,607 g dry wt/m^2 for a Florida floodplain cypress stand (Brown 1981) and 1,733 g dry wt/m^2 in Louisiana (Conner and Day 1976).

Annual litterfall provides an important energy source to extensive detrital-based food chains as well as a substantial release of nutrients from vegetation. Leaf litter is subject to fragmentation, leaching, and microbially mediated decomposition. The resulting altered or conditioned organic matter not only supports food chains of invertebrates, fish, birds, and mammals on site, but also is exported by flowing water to downstream systems. Beck (1977) suggested that such detritus might contribute to the stability of the floodplain system by serving to buffer large fluctuations in food or energy availability.

Nutrient availability and flux rates in bottomland hardwood systems are generally high. Processes of deposition, filtering, and transformation acting on waterborne inputs of sediments and pollutants (including excessive inorganic nutrients such as nitrogen and phosphorus) are discussed in the preceding section in the context of water quality. These same processes also result in large influxes of nutrients to the bottomland hardwood system. High rates of productivity, litterfall, and litter decomposition in bottomland hardwood systems are associated with correspondingly high rates of nutrient uptake, transfer, and release.

A number of specific aspects and examples of nutrient and organic matter processing in bottomland hardwoods are outlined below:

- Studies by Gomez and Day (1982) in the Great Dismal Swamp indicated that leaf litterfall (dry weight) was higher in more frequently flooded communities: maple-gum (536 $g/m^2/yr$), cypress (528 $g/m^2/yr$), Atlantic white cedar (506 $g/m^2/yr$), and mixed hardwoods (455 $g/m^2/yr$). Day (1984) found that frequently flooded communities in the Great Dismal Swamp did not accumulate substantial amounts of litter because of rapid decomposition.

- Water velocity and water depth affect the amount of carbon leached from the soil surface. At Creeping Swamp, North Carolina, 60 g carbon/m^2/yr were leached from the soil surface under the following conditions: mean water velocity of 0.10 m/sec, mean water depth of 0.30 m, and mean litter mass of 450 g carbon/m^2 (Mulholland and Kuenzler 1979). Also at Creeping Swamp, Mulholland (1981) found that the floodplain swamp was 64% efficient at retaining organic carbon because of debris dams and low water velocities.

- Qualls (1984) found that immobilization of inorganic substances by flooded litter over one linear kilometer at Creeping Swamp was 87 kg or about 25%. Other studies of nutrient and organic matter fluxes at Creeping Swamp include Kuenzler et al. (1980) and Yarbro (1979).

- Brinson et al. (1980) measured litterfall, streamflow, and throughfall in an alluvial swamp in North Carolina. These intrasystem fluxes of carbon and nutrients were relatively large (especially for nitrogen and phosphorus) compared to systems that did not receive comparable fluvial inputs (e.g., compared to upland forests and still-water swamps).

- At Horseshoe Island Lake, Illinois, Peterson et al. (1979) found that the accumulation of nitrogen in litter constituted a net gain of about 50% more nitrogen for the ecosystem. The litter layer is a sink for nitrogen and phosphorus; decomposer organisms retain these critical nutrients during periods of flooding.

- Studies at Tar River, North Carolina, of the nutrient assimilative capacity of baldcypress-tupelo floodplain swamp areas revealed a rapid loss of nitrate through denitrification. Nutrient removal capacities were highest for nitrate and lowest for phosphate. The swamp served as a nitrogen sink for the Tar River (Brinson et al. 1983, 1984).

- In the 454-km^2 Apalachicola River floodplain, where average litterfall was 800 g/m^2, leaching of nitrogen and phosphorus from litterfall was relatively rapid compared to loss rates of carbon and total biomass. Annual flooding was essential to the mobilization of litterfall products. Flooding also increased the rate of decomposition, which occurred at a slower rate in drier months (Elder and Cairns 1982).

- The Heron Pond-Cache River alluvial swamp in Illinois was found to be a sink for phosphorus, much of it originating from the deposition of high-phosphorus sediments during river flooding. High rates of deposition (3.6 g phosphorus/m^2/yr) and nutrient input (input of phosphorus was 10 times greater than outflow of phosphorus to the river) make this swamp a very productive system (Mitsch 1979; Mitsch et al. 1979).

- Comparisons between bottomland hardwoods and cropland in the Rhode River drainage basin, Maryland, indicated that cropland retained fewer nutrients. The following were removed from surface runoff water that transited approximately 80.5 km (50 miles) of riparian forest: 4.1 Mg of particulate matter, 11 kg particulate organic-N, 0.83 kg ammonium-N, 2.7 kg nitrate-N, and 3.0 kg total particulate-P per hectare of riparian forest. About 45 kg/ha/yr of nitrate-N was removed via subsurface flow through the riparian area (Peterjohn and Correll 1984).

Brinson (1977) found that there is little or no net release of nitrogen, phosphorus, calcium, or iron from autumn leaf litter until the following spring when the forest floor is again flooded. Timing of nutrient input to adjacent waters involves the retention of nutrients during the growing season and the export of nutrients after the growing season (OTA 1984).

Where bottomland hardwood areas are cleared, nutrients may be permanently lost from these areas and in some cases from coupled downstream systems due to: (1) timber removal (Francis 1984); (2) forage consumption by cattle that are then removed; (3) increased erosion into rivers and eventually into reservoirs, where waterborne sediment and nutrients settle to the bottom; and (4) harvest of agricultural crops (Truett and Lay 1984).

Waterborne Export

Waterborne organic matter is exported from bottomland hardwood systems to downstream systems, where it supports secondary production (Mulholland 1979; Day et al. 1980). Mulholland and Kuenzler (1979) found that the runoff from five small swamp watersheds in North Carolina contained greater amounts of organic carbon than did runoff from upland watersheds. High concentrations of dissolved organic carbon in swamp waters are probably due to high levels of production, increased contact time between water and organic debris, and concentration effects of high rates of evapotranspiration in swamps.

Freshwater delivery of upland sediments, organic matter, and nutrients is essential to the normal functioning of estuarine systems. Sand and silt are carried and deposited downstream, contributing to the formation of coastal features. "As a result of the nature of the integral coupling [of these ecosystems], any manipulation in the upstream reaches of a river can have pronounced effects at all levels on the system below" (Wharton et al. 1982: 104). Nutrients and organic matter from highly productive bottomland hardwood systems are supplied to estuarine nutrient cycles and detrital food chains (Conner 1975).

Detritus exported to downstream ecosystems is an important energy input to the food webs of lakes and estuaries (Livingston et al. 1974; Brinson 1977; Livingston and Loucks 1979). The importance of particulate organic detritus to filter-feeding crustaceans in lacustrine and marine ecosystems is well documented. In rivers, there is a constant downstream drift of organisms (Wharton 1980). Dissolved organic matter is transformed into particulate material by microorganisms, and thus is made available to other organisms, such as insect larvae, snails, and clams. Lignin and cellulose are converted by fungi and bacteria into protein sources, which are ingested by omnivorous crustaceans. These in turn are consumed by larger crustaceans, filter-feeders, and fish.

In the Apalachicola River floodplain (of which 15% of the 3,100-km^2 drainage area is bottomland hardwood forest), basic physical and chemical factors interact to support high biological productivity in the river, floodplain, and receiving estuary. Apalachicola Bay depends on the annual flux of organic matter and silt from these forests. Timing is important; larger fluxes occur during a major 5- to 7-year water cycle, which originates at the river's headwaters in the mountains of Georgia. This 5- to 7-year pulse involves large-scale imports of detritus from bottomland hardwood zones that are farther from the river channel; these zones are not flooded frequently and can accumulate more organic matter. The longer flooding cycles are linked with peaks in commercial fish harvest downstream via the detrital food chain; the detritus of river floodplain forests is consumed by invertebrates, which in turn are consumed by larger organisms (Livingston et al. 1974, 1976).

Similar studies in Barataria Bay, Louisiana, indicated that large amounts of nitrogen, phosphorus, and carbon were exported from upstream floodplain swamps at the same time that migrant fish species were entering the estuary to feed and spawn. Day et al. (1977) found that annual export of materials from the watershed (91% of the study area was forested) to Barataria Bay included 8,016 metric tons of organic carbon, 1,047 metric tons of nitrogen, and 154 metric tons of phosphorus. The bay provides 45% of the commercial fish catch of Louisiana (Day et al. 1977).

HABITAT

A number of studies reporting on animal use of bottomland hardwood areas are listed in Appendix D. Bottomland hardwoods provide some of the most productive wildlife habitat in North America (Forsythe and Gard 1980; Sanders and Soileau 1980; Shelton 1983). Several basic habitat components, combined with the fluctuating water levels characteristic of these areas, are essential for support of abundant fish and wildlife: (1) mast (e.g., acorns, sugarberry, maple), (2) dens and cavities (snags, trees, fallen logs), (3) permanent sources of water (Brabander et al. 1985), (4) high soil fertility, and

(5) diversity of food and cover (Klimas et al. 1981). Brinson et al. (1981c) attributed the importance of riparian ecosystems to (1) predominance of woody plant communities, (2) presence of surface water and abundant soil moisture, (3) close proximity of diverse structural features (live and dead vegetation, water bodies, unvegetated substrates) resulting in extensive edge and structural heterogeneity, and (4) distribution in long corridors that provide pathways for migration and movement between habitats.

A generally high diversity of species is due in part to the combination of terrestrial and aquatic systems and extensive linear ecotones (upland-floodplain-river) (Brinson et al. 1981c). For example, wildlife species diversity and abundance were higher in the Atchafalaya River Basin of Louisiana than in adjacent upland forests and meadows. This basin produces about 18 thousand metric tons (40 million pounds) of crayfish per year and supports 300 bird, 46 mammal, 53 reptile, 28 amphibian, and numerous invertebrate species. The area supports from 2 to 5 times more game animals and 10 times more wintering birds than adjacent pine-hardwood forests (Harris et al. 1984).

Organic matter export from the floodplain forest is extremely important to food webs in rivers or stream channels (Lambou 1983). Much of this downstream secondary production is located in habitats of submerged woody substrates or snags, which were found to be the most productive river habitat in the Satilla River, Georgia (Benke et al. 1979). Snag communities had the greatest species diversity and biomass; their major colonists were filter-feeders. Densities of 20,000 insect larvae/m^2 on underwater snags and 40,000 midge fly larvae/m^2 in sandy bottoms of the Satilla River, Georgia, have been recorded (Wharton 1980). Studies on the Savannah River in Georgia (Thorp et al. 1985) showed that submerged wood in cypress-tupelo sites on blackwater tributary streams held almost three times more invertebrate individuals and twice as many taxa than did logs in stagnant swamp and outflow streams.

Overflow Areas

Although the shallow edge of inundated habitat is a fairly small percentage of swamp area at any given time, this zone moves as flood waters rise and recede. Animals that follow this zone are always provided with rich food resources. "Any reduction in extent or duration of inundation of flooded woods habitat is likely to reduce the productive capacity of the swamp . . . Permanent water channels . . . will not support a fishery comparable to that produced from a wooded swamp habitat" (Pollard et al. 1983). A number of studies illustrate the importance of dynamic overflow areas as habitat; some of these are described in the following paragraphs.

Colonization of inundated areas by invertebrates is rapid. In a small stream swamp in eastern North Carolina, Sniffen (1981) noted that within 1 week of the start of flooding the composition of the invertebrate community had stabilized; biomass peaked in 6 weeks. For the 4-month period of floodplain inundation (December 15 through April 15), biomass varied from 2.3 to 3.2 g dry wt/m^2. Of the 92 taxa found during this seasonal inundation period, 34 were soil or semiterrestrial invertebrates and could thrive in moist to flooded litter and soil. The rest of the invertebrates were aquatic. Only about 20% of the total invertebrate production occurred in the main stream channel.

Large populations of red swamp crayfish are characteristic of southeastern bottomland hardwood forests that are intermittently inundated. They are not as plentiful in areas where water levels are more stable (Patrick et al. 1981). Crayfish play an important role in floodplain swamps. Besides being an important food source for a variety of fish, birds, mammals, snakes, and turtles, crayfish dig extensive networks of passages that lead down to the water table and are used by various animals (fish, salamanders, frogs, and snakes) during the dry season (Neill 1951). There is a close linkage between the crayfish life cycle and the hydrologic regime (Konikoff 1977).

The importance of overflow areas to the spawning and development of aquatic species was studied by Pollard et al. (1983) in the Atchafalaya Basin, Louisiana. Overflow areas were inundated only 2 to 4 months; data indicated that crayfish and adult fish use overflow edge habitat for spawning and nurseries. Fish production in the basin depends on availability of (1) food (primarily crayfish) for adult fish, (2) food (concentrated plankton) for young-of-the-year fishes, and (3) shallow spawning areas.

Catfish and centrarchids leave the river channel to feed among flooded oak and hickory roots. Largemouth bass, sunfish, and crappie spawn in temporarily flooded bottomland hardwood areas where there is an abundant supply of invertebrates (dense populations of zooplankton may be found in shaded areas under trees) for food (Wharton 1980; Patrick et al. 1981; Wharton et al. 1982). Alewife and blueback herring also spawn in flooded forests along the East Coast. Gallagher (1979) found that the young of over 50% of the fish species in the Mississippi River use the floodplains as a nursery. The fish species that most commonly use the floodplains during high waters are bowfin, American eel, redfin pickerel, chain pickerel, lake chubsucker, creek chubsucker, yellow bullhead, pirate perch, topminnows, mosquito fish, warmouth, flier, and swamp darter.

Fish populations in the flooded bottomland forests (baldcypress-tupelo gum) of two streams in North Carolina were measured by Tarplee (1979). Population estimates in Duke Swamp varied from 6,630 to 33,734 fish per hectare of water surface. In Hoggard Mill Creek, estimated numbers ranged from 17,656 to 103,891 fish per hectare of water surface. Biomass estimates for both stream areas ranged from 195 kg to 1,607 kg fish per hectare of water surface.

Resident and Migratory Birds

A number of studies have documented the importance of bottomland hardwoods to birds. Colonial wading birds, raptors, woodpeckers, shorebirds, and passerine birds all use bottomland hardwood habitat. Some species are relatively restricted to bottomland hardwood sites. These include barred owl; red-shouldered hawk; wood duck; yellow-crowned night heron; yellow-billed cuckoo; acadian flycatcher; prothonotary, Swainson's, and parula warblers; and redstart (Dickson 1978a). Others prefer bottomland hardwood sites because of food availability. For example, woodpeckers use areas of dead or dying timber in bottomland hardwood sites (such as those flooded by beaver ponds) because of the high concentrations of insects in the dying trees (Lochmiller 1979).

Bottomland hardwoods provide critical habitat for waterfowl in terms of winter food and cover or nesting habitat. One of the most valuable waterfowl habitats in the lower Mississippi flyway is the Cache River Basin in Arkansas; it harbors about 30,000 wood ducks and 250,000 overwintering mallards (Hancock and Barkley 1980).

Heitmeyer and Fredrickson (1981) found that bottomland hardwoods in the Mississippi Delta are critical winter habitat for mallards. Furthermore, winter foods and conditions play a role in reproduction; favorable mallard age ratios (for breeding) are dependent on abundance and quality of winter food and cover. Managed greentree reservoirs provide winter habitat that is attractive to waterfowl.

Lowland hardwood forests produce mast (e.g., acorns) that is an important food source for waterfowl. Wood ducks are particularly dependent on these areas for nesting, food, and cover (McGilvrey 1968; Landers et al. 1977; Fredrickson 1980; Heitmeyer and Vohs 1984b). Wood duck weight, percent dietary protein, and fat content are higher with good mast crops and lower when mast crops fail (Landers et al. 1977).

In addition, dabbling ducks depend heavily on the availability of invertebrates (such as midges, crustaceans, cladocerans) especially during the breeding season (Swanson 1984). For example, female wood ducks feed on macroinvertebrates extensively just before and during the breeding season for high protein intake (Wharton et al. 1981), successfully exploiting food resources in the temporarily flooded timber zone (Hall 1979a). Responses of dabbling ducks and macroinvertebrates to various manipulations of water level and cover-to-water ratios are discussed by Kaminski and Prince (1981).

Mammals

Temporarily flooded bottomland forests provide habitat that supports a variety of mammals. Food is abundant and diverse, and a variety of species are present. A number of the different species found in bottomland hardwood areas are discussed by Wharton et al. (1981). Sanders and Soileau (1980) list the following species for the Atchafalaya Basin, one of the most productive fish and wildlife areas in North America: black bear, squirrels (gray and fox), raccoon, river otter, cottontail rabbit, swamp rabbit, white-tailed deer, nutria, muskrat, mink, beaver, bobcat, gray fox, and Virginia opossum. Food sources for raccoon, opossum, and black bear include acorns, fruits, berries, and insects (raccoons also depend on crayfish in winter).

Bottomland hardwoods support among the highest populations of white-tailed deer in the United States. Estimates of carrying capacities (Hall 1979a) are as high as one deer per 2 to 6 ha (5 to 15 acres); in the best upland areas, carrying capacities are estimated at one deer per 8 to 14 ha (20 to 35 acres). The productivity of bottomland hardwoods for deer is dependent on the normal flooding cycle (Hall 1979a), which produces fertile, well-watered soil and subsequently leads to better food production in the form of browse, acorns, and a large variety of fruit-producing hardwoods (Stransky 1969).

BOTTOMLAND HARDWOODS IN EASTERN TEXAS AND OKLAHOMA

Bottomland hardwoods in Texas and Oklahoma are found mainly in 28 eastern Oklahoma and 48 eastern Texas counties (Figures 2 and 3). The western boundaries roughly approximate the zone where the forested region merges with the prairies, or where the major floodplains terminate. "Fingers" of bottomland hardwoods follow the floodplains of rivers far into the prairies and plains of Texas and Oklahoma. The eastern boundaries are drawn at State lines in Figures 2 and 3, but bottomland hardwood communities extend to the east and south, joining with other river systems or terminating at the Gulf of Mexico.

HISTORICAL PERSPECTIVE

Bottomland hardwoods and mixed riparian vegetation decreased by 63% in Texas from presettlement times (64,750 km^2) to 1980 (24,170 km^2) (Frye 1987). During this period over 2,695 km^2 of bottomland hardwoods were inundated by reservoirs (Parvin 1986). In Oklahoma, the original 8,900 km^2 of bottomland hardwoods have been reduced to 1,330 km^2, or less than 15% of the presettlement area (Brabander et al. 1985).

The following is a summary of Lay's (1987) historical overview for eastern Texas, but it is also generally applicable to eastern Oklahoma. Before settlement, bottomland hardwoods diversity was at its peak, and all stages of plant succession were present. The virgin (climax) forest was a mosaic of all ages due to the periodic death of old growth trees. Trees of all kinds, sizes, and ages were present, including dead and dying trees. Occasional floods brought nutrients from the uplands and flushed oxbow lakes, redistributing nutrients in the bottomlands. There was no commercial removal of trees or nutrients; most nutrients were recycled or exported downstream. The rich mosaic of wetland ecosystems was important to Indians and wildlife.

The archaeological resources of eastern Texas and Oklahoma can be divided into three cultural periods: Paleoindian (12,000 to 8,000 years B.P.), Archaic (8,000 B.P. to 500-900 A.D.), and Late Prehistoric (500-900 to 1528 A.D.) (USFWS 1984). In the Archaic period, people in northeastern Texas were probably mobile hunters and gatherers. USFWS (1984) described the transition from hunting and gathering to agriculture in the Late Prehistoric period as follows:

> The true Caddoan material culture of northeast Texas began about 700 A.D. and was marked by the construction of special sites for civic and ceremonial purposes. Spectacular ceremonial mounds were located in alluvial valleys of rivers and streams and served as central habitation areas surrounded by smaller

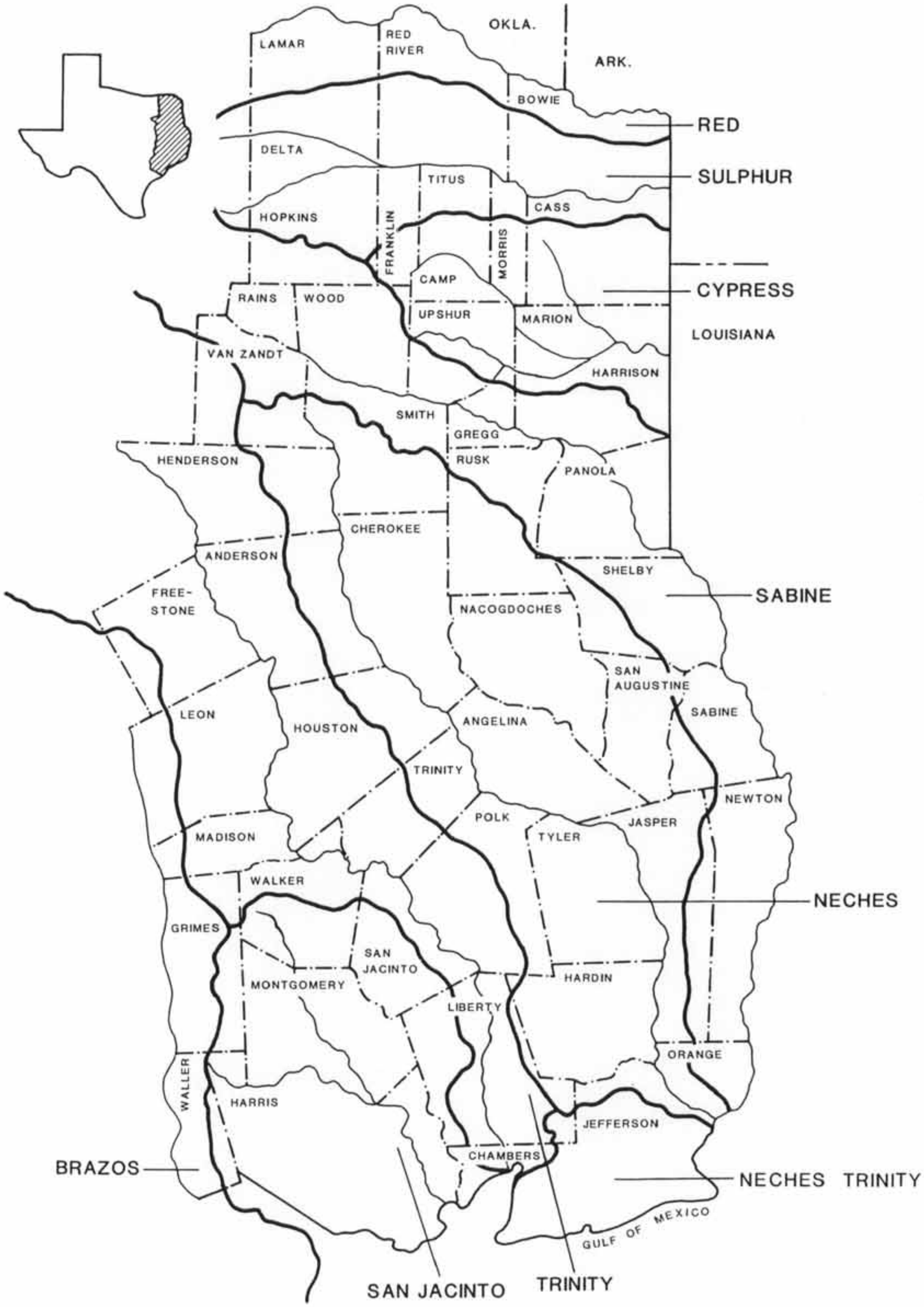

Figure 2. Counties and major river basins of eastern Texas (redrawn from USFWS 1984).

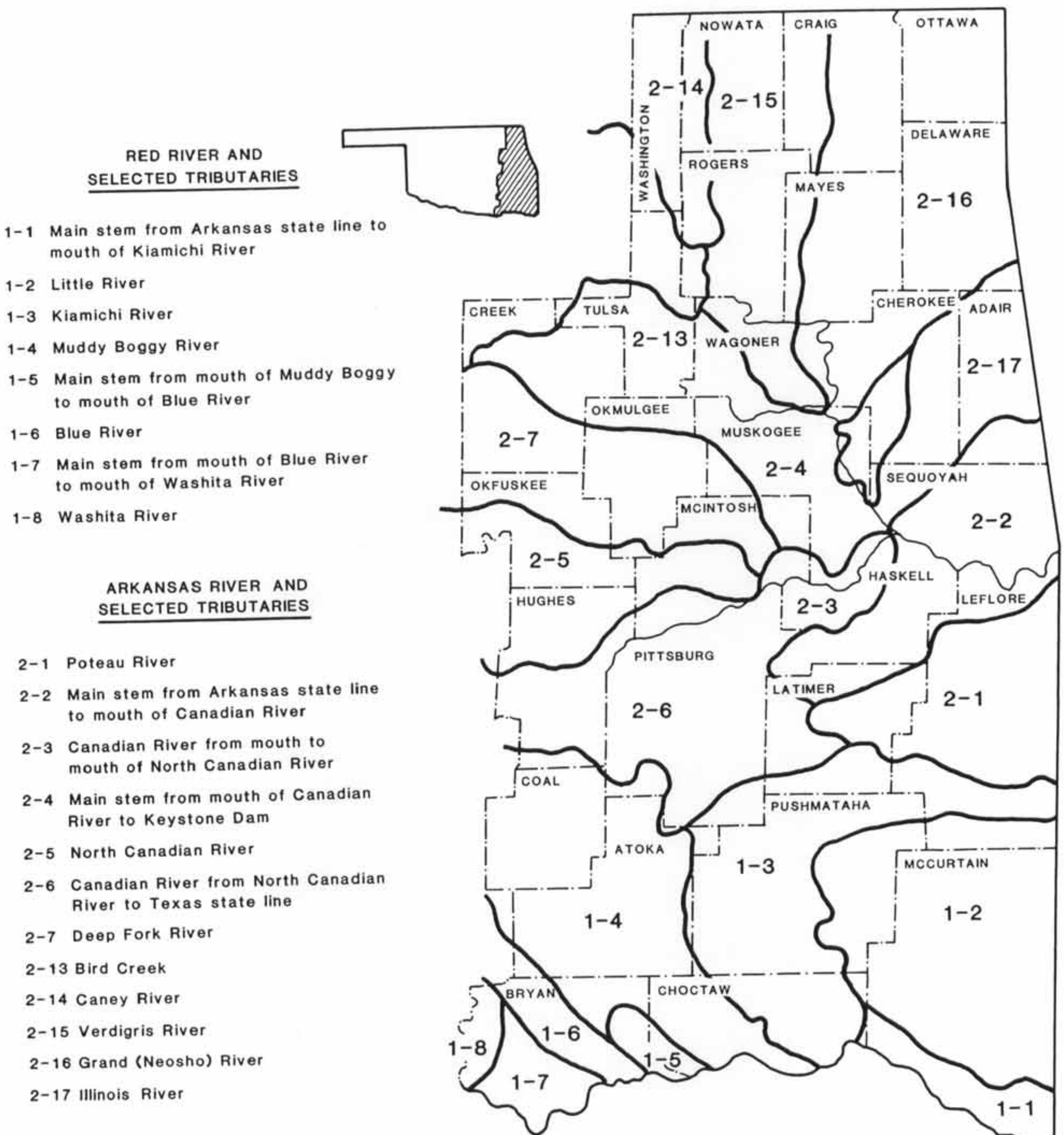

Figure 3. Counties and major river basins of eastern Oklahoma (redrawn from Oklahoma State University 1979).

villages on upland sites (Killen et al. 1982). Maize (eight-rowed corn) was introduced to the region about 780 A.D. (Story 1981). The southeast Texas people primarily utilized white-tailed deer, fish, turtles, bear, bison, squirrel, and rabbit for food (Patterson 1982).

The Indian tribes in the area at the time of contact with Europeans included the Caddoan Confederacies, Attacapan Culture, Wichita Culture, Tonkawa Tribe, Choctaw Tribe, Cherokee Tribe, Alabama Tribe, and Coushatta Tribe (Fox 1983). With the influx of Anglo-American settlers, all of these Indians were displaced except the Alabamas and Coushattas, who remain on a reservation in Polk County, Texas.

The next one hundred years (1820-1920) brought extensive settlement. River bottoms were the first sites to be exploited, because rivers were the arteries of transportation. Early logging of these areas produced wood for housing, boats, tools, and furniture. For most applications, bottomland hardwoods were more valuable than upland hardwoods or pines. The first commercial logging operations utilized cypress, then hardwood, and finally pine. Cypress swamps were the most severely modified bottomland hardwoods, because of the high value of cypress wood. Most of the bottomlands were altered by logging by the early 1900's (Bray 1906).

Bottomlands also provided virgin range for settlers' livestock, which were fattened on an abundance of acorns and other mast. Cattle and horses depended on bottomland switchcane for winter forage. Hunting and fishing were a source of meat; bottomlands were the most productive places in which to hunt. Small areas of bottomland forest were cleared for agriculture and later abandoned. "This first hundred years of 'pioneer' occupation was based on short-term expediency" (Lay 1987).

The next fifty years (1920-1970) were characterized by heavy use. Remaining virgin timber was cut and second-growth forests were highgraded (long-term selective harvest of the highest quality trees). After highgrading, no hardwood management techniques were employed, and many bottomland sites were converted totally to pine stands. During the depression (1930's), many people lived off the land, and wildlife populations were reduced as a result of heavy hunting. These populations began to recover during the 1950's as hunting pressure was reduced, but bottomland hardwoods began to decrease because of the clearing of large areas for farming and pasture and because of the construction of reservoirs.

Much of the prime farmland in eastern Texas and Oklahoma is located on floodplain area that was formerly bottomland hardwoods. Brabander et al. (1985) estimated that 6,688 km^2 of bottomland hardwoods in eastern Oklahoma have been converted to agriculture (largely cropland and improved pasture with introduced grasses). Livestock grazing has been a dominant factor in bottomlands. Before the introduction of cattle, the bottomlands abounded with canebrakes. Wild cattle, which were introduced as early as 1690, selectively removed the canebrakes (switchcane) and other species, no doubt changing the species composition of many of the bottomlands (Truett and Lay 1984). Long-term overgrazing causes the primary productivity and biomass accumulation of forests to decline (Brinson et al. 1981c). Secondary effects of overgrazing may include increased runoff, increased sedimentation, reduction in the stability of stream channels, and soil erosion (Heede 1980).

CLIMATE

Climate has significant influences on vegetative composition and on characteristics and distribution of soil resources. The climate of eastern Texas and Oklahoma is modified by the onshore flow of tropical air from the Gulf of Mexico. Eastern Texas has a subtropical maritime climate with hot summers, cool winters, and abundant rainfall. Eastern Oklahoma's climate is similar, but is influenced more by cold fronts.

Average annual high and low temperatures generally increase from north to south in the area, resulting in an increase in the length of the growing season from north to south. The growing season ranges from about 200 days in northeastern Oklahoma to over 280 days in southeastern Texas. Precipitation varies from 142.2 cm in the extreme southeastern corner of both States to 86.4 cm along the western side of the area. The monthly distribution of precipitation is somewhat erratic to the west but is more evenly distributed to the east. Differences in precipitation result in differences in vegetation over the region. Heavy precipitation causes floodplain overflow, which is critical for bottomland ecosystems.

SOILS

Exceptions can be found, but bottomland soils are usually more fertile than upland soils. Since the clay fraction is generally higher in bottomland soils, most plant nutrients, particularly bases and phosphorus, are higher in the clay fraction than in the coarser silt and sand fractions (Patrick et al. 1981). Soil nitrogen, which is highly correlated with soil organic matter, is also high in bottomland hardwood areas.

Most bottomlands in eastern Texas have a loamy, textured soil adjacent to the small streams and clayey, textured soils beside the large streams (Dolezel 1987). Sorting of sediments is directly related to stream velocity, with sand dropping first and clays settling when the water velocity slows further. In general, small, sandy stream bottomlands have high water velocities, whereas large bottomlands associated with more sluggish streams are characterized by more silt and clay.

WATER RESOURCES

Differences in the nature and location of water sources produce four types of waterways in the southeast: (1) alluvial rivers, (2) blackwater rivers, (3) spring-fed streams, and (4) bog and bog-fed streams (Wharton et al. 1982). The major rivers in eastern Texas and Oklahoma are alluvial, originating within the northern limits of the area of bottomland hardwoods distribution or north and west of the area (Trinity, Red, and Arkansas Rivers). These rivers historically derived most of their water from subsurface groundwater, but now surface runoff is the major source of water. Blackwater streams, such as Pine Island Bayou in southeastern Texas, originate in the Coastal Plain; most of their flow is from local precipitation. The water in these streams is high in humic substances. Spring-fed streams are characterized by flow originating from underground aquifers and are rare in eastern Texas but common in Oklahoma. Bogs and bog-fed streams are the result of continuous seepage from sand aquifers. These streams have limited distribution but are locally common in eastern Texas, especially in the region known as the Big Thicket.

Nine major river basins are located in eastern Texas (Figure 3). The Sabine and Red Rivers have the greatest discharges, followed by the Trinity, Neches, and Brazos Rivers. Other basins are the Angelina, Cypress, San Jacinto, and Sulphur. The Red River basin is shared by Texas and Oklahoma. In Oklahoma, the Arkansas and Red River basins are the two major basins in the area of important occurrence of bottomland hardwoods. Main tributaries of the Arkansas River are the Cimarron, Canadian, Verdigris, Grand (Neosho), Illinois, and Poteau Rivers. Principal eastern Oklahoma tributaries of the Red River are the Blue, Muddy Boggy, Kiamichi, and Little Rivers.

Rivers "charge" their floodplains at flood stages, leaving residual water perched in backswamps, pools, sloughs, oxbows, and depressions. These sites may be several feet higher than the adjacent river level during average conditions. Water levels in these sites are augmented by overbank flooding as well as local rainfall (Leitman 1978). Local precipitation is the primary source of recharge for areas that flood infrequently.

Many of the floodplains of the Arkansas and Red Rivers are now protected from flooding by levees (Bedinger 1981). In natural riparian systems, flood flows are accommodated by the first and second bottoms, but levee construction and some land-use alterations are usually incompatible with this normal function of the floodplain. Few basins still have unaltered hydrological patterns because the frequency and duration of flooding has been directly modified by the construction of reservoirs, channelization of streams, and construction of flood levees. Land-use practices, such as agriculture, forestry, mining, petroleum extraction, urban development, roads, and rights-of-way, have also modified the bottomland hardwood ecosystem.

Beneath the bottomlands of the Coastal Plain are the near-surface, alluvial aquifers. Surrounding uplands are underlain by artesian aquifers that lie below the alluvial aquifers. The exchange of water between the alluvium and underlying aquifers is relatively small, probably several-fold less than the flow through the alluvium aquifers (Bedinger 1981).

Reservoirs

Reservoir construction has been a major cause of bottomland hardwood loss (Parvin 1986). As of 1981, the State of Texas had 5,600 reservoirs with surface area greater than 4 ha (Frye 1987). Principal lakes in eastern Texas are listed in Table 1 (USFWS 1984). Existing major reservoirs in eastern Oklahoma are listed in Table 2 (Brabander et al. 1985). Additional reservoirs are planned for eastern Texas and Oklahoma. In Texas, 44 more reservoirs are anticipated by the year 2030; these would inundate an additional 1,024 km^2 of

Table 1. Principal lakes in eastern Texas (from USFWS 1984).

Name	County	Conservation pool surface area (hectares)
Athens	Henderson	615
Bonham	Fannin	413
Caddo	Harrison, Marion	10,279
Cedar Creek	Kaufman, Henderson	13,658
Cherokee	Gregg, Rusk	1,613
Coffee Mill	Fannin	263
Conroe	Montgomery, Walker	8,492
Crook	Lamar	496
Cypress Springs	Franklin	1,376
Davy Crockett	Fannin	152
Ellison Creek	Morris	614
Fairfield	Freestone	951
Forest Grove	Henderson	608
Gladewater	Upshur	324
Hawkins	Wood	314
Houston County	Houston	519
Jacksonville	Cherokee	534
Johnson Creek	Marion	263
Kurth	Angelina	312
Lake Fork	Woods, Rains	11,206
Lake O'The Pines	Marion, Upshur, Morris, Harrison	7,568
Lewis Creek	Montgomery	409
Livingston	Polk, San Jacinto, Walker	33,427
Martin	Rusk, Panola	2,032
Monticello	Titus	809
Murval	Panola	1,546
Nacogdoches	Nacogdoches	894
Palestine	Smith, Anderson, Cherokee	10,344
Pat Mayes	Lamar	2,425
Pinkston	Shelby	212
Quitman	Wood	329
Sam Rayburn	Jasper, Angelina, Sabine, San Augustine, Nacogdoches	46,337
Sandlin	Titus, Wood, Camp, Franklin	3,828
Striker Creek	Rusk, Cherokee	971
Sulphur Springs	Hopkins	542
Tawakoni	Rains, Van Zandt, Hunt,	14,852
Toledo Bend	Newton, Panola, Shelby, Sabine	73,491
Steinhagen	Jasper, Tyler	5,544
Trinidad	Henderson	299
Tyler	Smith	1,942
Welsh	Titus	552
Wright Patman	Bowie, Cass, Morris	8,215
TOTAL		269,570

Table 2. Major reservoirs in eastern Oklahoma (from Brabander et al. 1985).

Reservoir[a]	Surface area in hectares[b]	Estimated area of bottomland hardwood soils inundated in hectares
Atoke	2,246	1,603
Broken Bow	5,747	1,839
Copan	1,963	1,413
Eucha	1,165	839
Eufaula	41,359	27,159
Fort Gibson	8,053	6,022
Grand	18,818	11,036
Greenleaf	372	185
Henryetta	249	123
Heyburn	397	197
Holdenville	223	110
Hudson	4,411	2,382
Hugo	5,362	3,861
Keystone	2,591	1,166
McAlester	643	405
McGee Creek	1,356	414
Okemah	291	144
Okmulgee	260	129
Dripping Springs	560	278
Oologah	11,938	8,596
Pine Creek	1,538	892
Robert S. Kerr	16,997	13,546
Sardis	5,811	2,880
Spavinaw	662	501
Tenkiller	5,059	2,509
Texoma	6,404	4,034
Webbers Falls	4,411	3,573
Wister	1,619	1,376
TOTAL	150,485	97,212

[a]Includes those under construction.

[b]Includes only the portion of the reservoir occurring in the eastern Oklahoma study area.

bottomland hardwoods (Frye 1987). Total losses to bottomland hardwoods from reservoirs would then exceed 3,440 km². Currently, there are 28 reservoirs of 2 km² or more in eastern Oklahoma, inundating approximately 971 km² of potential bottomland hardwoods. Nine additional major reservoirs have been proposed; these would inundate an additional 324 km² of bottomlands.

VEGETATION

Regional Description

Eastern Texas and Oklahoma are part of the Eastern Deciduous Forest Formation of North America (Braun 1950). Braun included southeast Texas in the Southeastern Evergreen Forest Region. Bordering this is the Oak-Pine Forest Region to the north and the western part of the Oak-Hickory Forest Region to the west.

Gould (1969, 1975) divided eastern Texas into the Pineywoods and Post Oak Savannah Vegetational Areas, which closely approximates Braun's divisions. McMahan et al. (1984) mapped most of this region as Pine-Hardwood Forest or Post Oak Parks/Woods and Grasslands, recognizing three major bottomland associations (Willow Oak-Water Oak-Blackgum, Water Oak-Elm-Hackberry Forest, and Bald Cypress-Water Tupelo Swamp). Areal estimates of eastern Texas bottomland hardwoods and other riparian vegetation determined from satellite imagery (Frye 1987) are presented in Table 3.

Eastern Oklahoma vegetation can be roughly grouped into the Central and Southern Forest Regions as defined by Brinson et al. (1981c) and Bailey (1980). Bottomland hardwood forests near the western edge of eastern Oklahoma are included in the Plains-Grasslands Regions. Current, as well as projected, areas of bottomlands hardwoods in 28 eastern Oklahoma counties were estimated by Brabander et al. (1985) and are presented in Table 4.

Community and Species Composition

General. Southern hardwood bottomlands occur primarily in alluvial river valleys and to a lesser extent on streamsides. An active alluvial river channel is constantly changing the landscape as it meanders, deposits, and erodes sediment. Subsequent flooding resuspends sediments and reworks the topography to form new ridges, levees, and swales. Differences in topography, hydroperiod, and soils are reflected in a complex continuum of vegetation.

The National Wetlands Technical Council (NWTC) has developed a system of six zones to portray the relationship between plant communities and environmental factors in bottomland hardwoods (Larson et al. 1981). This classification only generally corresponds to the following floodplain features: Zone I--river channels, oxbow lakes, and permanently inundated backsloughs; Zones II-V--active floodplains including swales (Zones II and III), flats and backswamps (Zone IV), levees, relict levees, and terraces (Zone V); and Zone VI--transition to terrestrial or upland habitats (Wharton et al. 1982). Complex vegetational associations (which are not documented) characterize these zones and floodplain features.

Descriptions of plant associations by Earles (1976a,b) also attempt to relate plant communities to environmental factors in bottomland hardwood areas. The Elm-Ash-Cottonwood association is typical of floodplains with shorter hydroperiods and better-drained soils. The cottonwood type usually pioneers along major streams, but is not common in eastern Texas and Oklahoma. The Oak-Gum-Cypress association is generally found on wetter sites with finer-textured soils and more stable moisture conditions.

Table 3. Geographical distribution of bottomland hardwoods and other mixed riparian vegetation in Texas, 1980 (from Frye 1987).

Location	Area[a] (km^2)
Trinity River	1,234
Neches River	1,040
Sabine River	1,032
Sulphur River	708
Cypress Bayou	360
Angelina River	356
Major rivers (subtotal)	4,730
River tributaries, riparian drainages east of the Navosota River	12,391
Remaining river, creeks, riparian drainages	7,050
TOTAL	24,171

[a]Excludes swamps, a total area of approximately 384 km^2.

Community types. A list of communities known to occur in Texas and Oklahoma bottomlands is presented in Table 5, with a generalized assignment to the zones discussed in the preceding section. This list is drawn largely from the 24 types identified by Neal and Haskins (1986) and USFWS (1984). Comparison of this list of community types with dominance types discussed by Wharton et al. (1982) shows great similarity between bottomland community types in eastern Texas and Oklahoma to those throughout the southeastern coastal plain. Several exceptions noted by Neal (1986) are (1) a flatland hardwood community (swamp chestnut oak, willow oak, laurel oak) is apparently unique to Texas; (2) a western bottomland community dominated by cedar elm, common hackberry, and willow oak is not found in other areas of the Southeast; (3) communities dominated by slash pine, pond pine, yellow poplar, Atlantic white cedar, and pond cypress are rare or absent in eastern Texas and Oklahoma, and (4) two oak species, Nuttal and pin, are important bottomland species elsewhere, but are rare in Texas, although they are somewhat more abundant in Oklahoma.

A number of floristic studies have been conducted in eastern Texas and Oklahoma. Nixon (1987) compiled data on 91 bottomland communities in eastern Texas, based on a review of studies by Burandt (1974), Burandt et al. (1977), Chambless (1971), Chambless and Nixon (1975), Littlejohn (1979), Marks and Harcombe (1975), Matos and Rudolph (1985), Nixon and Willett (1974), Nixon and Raines (1976), Nixon et al. (1973), Nixon et al. (1977), and Raines (1971). He placed the communities into swamp (25 of the 91) or bottomland (66 of the 91) categories based on the moisture conditions at the site. Characteristic

Table 4. Present and projected areas of bottomland hardwoods in eastern Oklahoma (selected years from Brabander et al. 1985).

County	Areas in hectares		
	Present (1980-82)	Projected 2015	Projected 2040
Adair	1,386	654	474
Atoka	8,101	5,689	4,370
Bryan	3,813	2,248	1,515
Cherokee	1,980	1,326	983
Chocktaw	10,633	7,420	5,951
Coal	1,061	528	322
Craig	2,284	1,595	1,221
Creek	6,350	4,278	3,184
Delaware	1,456	552	336
Haskell	2,261	1,384	959
Hughes	1,346	465	277
Latimer	3,603	2,509	1,915
LeFlore	11,373	6,254	4,511
McCurtain	16,977	11,236	7,711
McIntosh	4,777	3,219	2,222
Mayes	1,652	1,126	751
Muskogee	5,123	3,650	2,793
Nowata	2,120	1,388	903
Okfuskee	6,132	4,450	3,503
Okmulgee	7,679	5,964	4,938
Ottawa	3,002	2,113	1,626
Pittsburg	2,757	1,501	985
Pushmataha	7,933	5,711	4,469
Rogers	4,372	3,374	2,476
Sequoyah	2,718	1,762	1,122
Tulsa	3,202	1,943	1,214
Wagoner	4,449	2,274	1,376
Washington	4,481	3,586	2,758
TOTALS	133,021	88,199	64,865

overstory species of eastern Texas swamp communities were water tupelo, baldcypress, green ash, water locust, water hickory, sweetgum, red maple, laurel oak, and blackgum. Common understory tree and shrub species in the swamp communities were water elm, swamp privet, Carolina ash, and buttonbush.

Bottomland communities occupied sites with better drainage. Green ash, cedar elm, sugarberry, water oak, willow oak, overcup oak, American elm, sweetgum, and water hickory were characteristic of the overstory (Nixon 1987). Midstory species were red mulberry, American hornbeam, hawthorn, common persimmon, American holly, pasture haw, and parsley hawthorn. The understory tree and shrub species layer was generally sparse but contained such species

Table 5. Natural community types of bottomland hardwoods in eastern Texas and Oklahoma.

Community/forest type [a]	SAF type [b]	NWTC zone [c]	Common landscape position	Characteristic species
Forested Wetland (Palustrine)				
Black Willow	95	III	wet flats, point bars, levees	black willow, cottonwood
Cottonwood	63	III, IV	wet flats, point bars, levees	cottonwood, black willow, sandbar willow
Silver Maple-American Elm	62	III, IV	wet flats, point bars, levees	silver maple, American elm, sweetgum, green ash, pin oak
Loblolly Pine-Hardwood, Floodplain Hardwood-Pine	82	V	alluvial & backwater floodplains, lower slopes	loblolly pine, beech, sweetgum, blackgum, southern magnolia, water oak, white oak, red maple American holly
Slope Hardwood Forest		V, VI	toe slopes, bottomland ridges	black walnut, sweetgum, southern red oak, winged elm, redbud
Floodplain Hardwoods		II-V	alluvial & backwater floodplains	water oak, sweetgum, American hornbeam, blackgum, hophornbeam
Flatland Hardwoods (Swamp Chestnut Oak-Willow Oak-Laurel Oak)		IV	poorly drained clay floodplains	swamp chestnut oak, willow oak, laurel oak, overcup oak, dwarf palmetto, southern arrow-wood
Willow-Oak-Water Oak-Laurel Oak	88	IV, V	alluvial & backwater floodplains, second terraces	willow oak, water oak, laurel oak, blackgum
Live Oak (Coastal Floodplain Forest)	89	IV	alluvial & backwater floodplains	live oak, water oak, southern magnolia
Swamp Chestnut Oak-Cherrybark Oak	91	IV, V	alluvial & backwater floodplains, second terraces	swamp chestnut oak, cherrybark oak, green ash, white ash, shagbark hickory, mockernut hickory, bitternut hickory, white oak, bottomland post oak, shellbark hickory, Shumard oak, blackgum
Sweetgum-Willow Oak	92	IV, V	alluvial & backwater floodplain	sweetgum, willow oak, water oak, sugarberry, green ash, American elm
Sugarberry-American Elm-Green Ash	93	III, IV	drier alluvial floodplain soils	sugarberry, American elm, green ash, water hickory, willow oak, water oak, overcup oak, sweetgum, boxelder, baldcypress

Table 5. (Continued)

Community/forest type [a]	SAF [b] type	NWTC [c] zone	Common landscape position	Characteristic species
Sycamore-Sweetgum-American Elm	94	III	point bars, wetter floodplains	sycamore, sweetgum, American elm, green ash, sugarberry, water hickory
Cedar Elm-Water Oak-Willow Oak	92v	IV	alluvial & backwater floodplain	cedar elm, water oak, willow oak, sugarberry
Cedar Elm-Sugarberry-Willow Oak		IV	bottomflats	cedar elm, sugarberry, willow oak, water oak
Sugarberry-Hawthorn		V,VI	narrow alluvial stream margins	sugarberry, hawthorn, water oak, willow oak
Overcup Oak-Water Hickory	96	III,IV	wet flats, depressions	overcup oak, water oak, water hickory, green ash, sugarberry, American elm, water locust, red maple, cedar elm
River Birch-Sycamore	61	IV	successional, floodplains	river birch, sycamore, black willow
Red Maple	108	IV	wet flats, higher floodplains, stream margins	red maple, water oak, sweetgum
Beech-Magnolia	90	V,VI	old terraces, well-drained bottoms	beech, southern magnolia, loblolly pine, American holly, hophornbeam, sweet bay, sweetgum, blackgum
White Oak-Laurel Oak	97	V,VI	lower slopes, old terraces	white oak, laurel oak, beech, black hickory, cherrybark oak, loblolly pine
Sweetbay-Red Bay	104	IV,V	alluvial upland stream bottoms	sweet bay, red bay, blackgum red maple, American holly, sweetgum, baygall holly
<u>Forested Wetland-Swamp (Palustrine & Estuarine)</u>				
Baldcypress	101	II	sloughs, channels	baldcypress
Baldcypress-Tupelo	102	II	sloughs, channels, oxbows	baldcypress, swamp tupelo, blackgum
Water Tupelo-Swamp Tupelo	103	II	sloughs, channels, oxbows	water tupelo, swamp tupelo

Table 5. (Concluded)

Community/forest type [a]	SAF [b] type	NWTC [c] zone	Common landscape position	Characteristic species
Sweet Bay-Swamp Tupelo	104	II	branch heads, pocosins	sweet bay, red bay, blackgum baygall holly, red maple, American holly, sweetgum, swamp tupelo
Green Ash		II	sloughs, channels, oxbows	green ash, water locust, water hickory, sweetgum, red maple, blackgum, baldcypress, swamp tupelo
Scrub/Shrub Wetland (Palustrine)				
Water Elm/Swamp Privet Flat		II,III	ponds, depression pools, channels, sloughs	water elm, swamp privet, green ash
Baygall Shrub Thicket	104	II,IV,V	abandoned beds, channels in upper terraces with water seepage	sweet bay, swamp tupelo, red bay, black titi, gallberry holly
Shrub Swamp and Beaver Marsh Ponds		II,III	ponds, depressions, and pools	buttonbush, smooth alder, water elm, western mayhaw, silver bells
Emergent Wetland (Palustrine)				
Fresh Marsh (Various Species and Combinations)		I,II	forest glades, pools, ponds	rush, smartweed, sedge, arrowhead, cattail, southern wildrice
Lacustrine, Palustrine, and Riverine Beds				
Aquatic Beds		I	water margins	water fern, duckweed, water lily, lotus, hornwort, water-milfoil, alligator-weed, mermaid-weed, spatterdock

[a] Sources: Neal 1986; Neal and Haskins 1986; CSA 1985a,b; USFWS 1984; Wilkinson 1982; and Nixon, in press.

[b] SAF refers to Society of American Foresters forest type.

[c] NWTC refers to National Wetland Technical Council system of bottomland zonation.

as deciduous holly, roughleaf dogwood, English dogwood, sebastian-bush, snowdrop-tree, yaupon, and American beautyberry. Vines were common on all sites, with poison ivy, common greenbrier, supplejack, and muscadine being the predominant species. Dwarf palmetto was found in some drainages in the lower coastal plain, usually occurring as a dense shrub layer.

Many of the studies reviewed by Nixon (1987) were conducted in the southern and western half of eastern Texas, with the majority taking place along the Trinity River floodplain. The dominant species along the Trinity River are cedar elm, sugarberry, and green ash (Nixon and Willett 1974). Allen's (1974) data for the Navasota River supports the observation of increasing importance of cedar elm and sugarberry in bottomlands along the western edge of eastern Texas.

Along the Angelina River, important bottomland species are overcup oak, willow oak, American hornbeam, and sweetgum; but green ash is also a dominant. Willow oak, cedar elm, water oak, blackgum, American hornbeam, and hawthorns are important near the confluence of the Angelina and Neches Rivers. Floodplains of the lower Neches drainage are dominated by sweetgum, water oak, lobolly pine, baldcypress, blackgum, water tupelo, overcup oak, water hickory, and swamp chestnut oak (Mohler 1979). Additional studies not reviewed by Nixon (1987) dealing with bottomland communities in southeastern Texas include CSA (1985b), Harcombe and Neaville (1977), Marks and Harcombe (1981), McLeod (1971), Morrill (1976), and Wilkinson (1982).

The studies cited above were all performed in the southern part of eastern Texas; however, quantitative data are lacking on plant community composition in northeastern Texas. Nonetheless, two studies conducted in northeastern Texas indicate species composition similar to that of bottomland communities in southeastern Texas. Wilkinson (CSA 1985a) found that along Big Sandy Creek (Sabine watershed) sweetgum, water oak, and overcup oak were the predominant species, with red maple, river birch, sugarberry, and green ash important in localized sites. Mahler (1973) reported that the common trees in creek bottoms along Blundell Creek (Cypress watershed) were water oak, Shumard oak, willow oak, sweetgum, blackgum, black willow, river birch, American basswood, winged elm, slippery elm, red mulberry, osage orange, sugarberry, and white ash.

In eastern Oklahoma, bottomland communities can be segregated by latitude into northern and southern divisions that equate roughly with the Central and Southern Forest Regions. Brabander et al. (1985) summarized unpublished data of F.L. Johnson (Oklahoma Biological Survey) for 17 floodplain forest sites in the northern and southern part of eastern Oklahoma. The ten most important overstory species in the northern area were American elm, sugarberry, green ash, common pecan, pin oak, Shumard oak, boxelder, pignut hickory, red mulberry, and silver maple. In the southern area the most important species were overcup oak, green ash, American elm, willow oak, sugarberry, winged elm, water oak, osage orange, pignut hickory, and blue beech.

Based on topographic position and thus hydroperiod, seven major community types, typical of the Southern Forest Region, are found in the southern part of Oklahoma (Brabander et al. 1985). The tupelo-cypress association occurs on sites with extremely long hydroperiods. This association is very limited in distribution since it is restricted to the wettest and most deeply flooded sites, although it was formerly more widespread in the southeastern part of Oklahoma (Heitmeyer 1980). Baldcypress is native only along Little River and its tributaries (Little 1980). Sites with a shorter hydroperiod typically support mature dominants of overcup oak and water hickory. Still drier sites have sugarberry, American elm, and green ash. The importance of overcup oak in the southern area indicates generally longer hydroperiods. Old meandering scar ridges may be dominated by sweetgum, blackgum, hickories, and white oak. Newly formed point bars, levees, and scoured or disturbed sites are invaded by pioneer species such as black willow, eastern cottonwood, river birch, and silver maple. These species may be replaced by green ash, American elm, and boxelder. However, on more poorly drained sites, succession could be dominated by buttonbush, cottonwood, swamp privet, black willow, and green ash.

Several general patterns can be identified in the flora of eastern Texas and Oklahoma bottomlands. There is an east-west moisture gradient; the eastern edge of the region is wetter. Western communities have decreased abundance of oak species (Brinson et al. 1981c) and overall lower species richness (Rice 1965). Comparison of Texas and Oklahoma bottomland forests shows that the same species are present over much of the area, but that the dominants change from north to south. Northeastern Oklahoma bottomland forests are characterized by American elm, common hackberry, green ash, and common pecan. In southern Oklahoma, important species are overcup oak, green ash, American elm, willow oak, and sugarberry. In southeastern Texas, green ash, overcup oak, American elm, Shumard oak, water oak, cedar elm, and sugarberry are dominants.

Southeastern Texas is within Braun's (1950) Southern Evergreen Forest Region, where most of the floodplain communities have a substantial evergreen component. None of the species listed by Brabander et al. (1985) for northeastern Oklahoma are evergreen; however, one species (water oak) in southern Oklahoma is semievergreen. Further south in Texas, evergreens (and semievergreens), such as loblolly pine, southern magnolia, laurel oak, water oak, and sweet bay, become increasingly important components of the overstory of bottomland hardwoods (Mohler 1979).

Of 73 plant species considered to be of special concern in eastern Texas, 48 are found in bottomland hardwoods or associated wetlands. The complete list is in Appendix F. Rare woody and herbaceous plants of Oklahoma's bottomland hardwoods are listed in Appendix E.

Timber production. Bottomland hardwood systems support much of the major hardwood timber resource of the southern United States. Silvicultural management on bottomland sites ranges from selective removal of mature trees to clearcutting and to the replacement of natural forest stands with pine monocultures. Conversion to agriculture may also follow timber harvest. Light, selective cutting has negligible, short-term effects on ecosystem processes, but clearcutting causes temporary decreases in evapotranspiration, primary production, and nutrient cycling. Highgrading can reduce the quality of wood products. Regeneration may be through stump sprouting or by seeding. Sprouting results in rapid growth and recovery of much of the plant biomass, but often results in poorly stocked stands. In mixed hardwood floodplain forests where regeneration occurs by seeding, species composition of the forest is determined by available seed sources, germination conditions, competition, and light availability.

Bottomland forests normally have less than 45.9 m^2/ha (200 ft^2/acre) of basal area, and most have less than 34.4 m^2/ha (150 ft^2/acre); however, dense stands of baldcypress and water tupelo commonly support basal areas of 57.4 m^2/ha (250 ft^2/acre) (Johnson 1979). In bottomlands and streamside forests of eastern Texas, basal areas range from 16.8 to 67.3 m^2/ha (73.2 to 293.1 ft^2/acre) (Allen 1974; Marks and Harcombe 1981; Wilkinson 1982; CSA 1985a,b). Brabander et al. (1985) reported that a representative basal area for comparatively mature, good to excellent stands in northeastern Oklahoma was 19.0 m^2/ha (82.6 ft^2/acre), whereas a mean value for southern Oklahoma stands was 22.1 m^2/ha (96.1 ft^2/acre). While the growth of individual trees may be small, stand production can be over 7.0 m^3/ha/yr (100 ft^3/acre/yr). Volumes of 420 m^3/ha (6,000 ft^3/acre) have been reported for second-growth baldcypress and water tupelo (McGarity 1977).

Bottomland hardwood communities account for 21% of the forest land in eastern Texas (Barron 1987). The leading hardwood producing counties in eastern Texas in 1984, according to harvest trends, were Cass, Newton, Cherokee, San Augustine, Hardin, Shelby, Tyler, Jasper, and Bowie (Barron 1987).

FAUNA

There are few differences in fauna between the bottomland hardwoods of Texas and Oklahoma and other southeastern bottomland hardwoods (Neal 1986). An abundance of both game and nongame species use these areas. Those species known or believed to use bottomland hardwoods and closely related habitats in eastern Texas and Oklahoma are listed in Appendix G (from USFWS 1984 and Brabander et al. 1985). Total numbers are as follows:

- 187 species of fish (119 TX, 153 OK),
- 49 species of amphibians (36 TX, 37 OK),
- 76 species of reptiles (59 TX, 55 OK),
- 282 species of birds (279 TX, 155 OK), and
- 61 species of mammals (48 TX, 49 OK).

Faunal species of special concern because of rare, threatened, or endangered status in eastern Oklahoma and Texas are listed in Appendices H and I.

Small mammals characteristic of bottomlands include the marsh rice rat, short-tailed shrew, eastern woodrat, least shrew, and eastern mole. Abundance of these species is dependent on the frequency and duration of flooding. In Texas, feral hogs are commonly found in bottomlands. They influence the habitat of other species and are frequently in competition with species dependent on bottomlands.

Numerous invertebrate and vertebrate (fish, reptiles, amphibians) species inhabit rivers, creeks, and floodplains throughout the region and serve as food for other species of wildlife. Invertebrates form the basis of most vertebrate food chains of the floodplain and are a direct food source for a number of vertebrates. Forage fish, diving ducks, dabbling ducks, and ducklings all use aquatic invertebrates as an important food source (Collias and Collias 1963; Tilton and Schwegler 1979). A few invertebrate species that are dependent on floodplain habitats are of economic importance to man, most notably crayfish and freshwater mussel. Near the coast, blue crab use the floodplain as nursery grounds.

Fishery Resources

Commercial and sport fishery resources are important in eastern Texas and Oklahoma; 34 species of gamefish are known to occur in this region. The quality of the fishery resource is directly linked to the bottomland hardwood ecosystem; many of the fish utilize bottomland hardwood floodplains during seasonal inundation. Various studies conducted in the southeastern United States have found that over 50 fish species, primarily catfish, white bass, sunfish, gar, perch, and species in the sucker family, feed or spawn in the floodplains (Wharton et al. 1982).

Waterfowl and Game Birds

The bottomland hardwoods of eastern Texas and Oklahoma provide important habitat for waterfowl. The primary emphasis of the U.S. Fish and Wildlife Service's Bottomland Hardwood Preservation Program is on perpetuating waterfowl resources dependent on bottomlands. The Service "has acknowledged the importance of this area (East Texas) along with adjacent Oklahoma bottomlands and the lower Mississippi River Delta of Arkansas and Louisiana. . . . The region is of primary importance to two species: the mallard and wood duck" (USFWS 1984).

Eastern Texas and Oklahoma are part of a major migration corridor for dabbling ducks (Bellrose 1968). The principal species migrating or wintering in the area are mallard, wood duck, green-winged teal, blue-winged teal, northern pintail, hooded merganser, northern shoveler, gadwall, and American wigeon. The black duck is a rare migrant in the area (USFWS 1984).

Diving ducks and geese also use bottomlands during migration and as a wintering area. Principal diving ducks that use the area are lesser scaup, canvasback, redhead, ring-necked duck, and hooded merganser. The snow goose, white-fronted goose, and Canada goose are also present, but the snow goose is the only common winter resident. The fulvous whistling duck, loons, grebes, coots, and gallinules also use bottomland hardwoods (USFWS 1984). Blue-winged teal, pied-billed grebe, purple gallinule, common gallinule, and American coot nest in the area.

In eastern Texas, waterfowl are hunted extensively in bottomlands. Over 20,000 Texas (1981) and 29,000 Federal (1980) duck stamps were purchased in 38 eastern Texas counties. Most were purchased by waterfowl hunters (USFWS 1984).

The American woodcock is sometimes locally abundant in bottomland hardwoods. The eastern wild turkey is heavily dependent on bottomland hardwood sites. Once near extinction in eastern Texas, the turkey has made a significant comeback. In eastern Texas, recently restocked eastern wild turkeys prefer pine-hardwood forests and bottomland hardwoods (where they feed on acorns) during fall and winter, and they use bottomland hardwoods for brood habitat in the spring (Campo 1983).

Nongame Birds

Bottomland hardwoods in eastern Texas and Oklahoma provide important habitat for colonial wading birds, raptors, woodpeckers, and passerine species. Breeding densities in an Oklahoma floodplain forest were 1,637 birds/km^2 (Winton 1980). Comparative studies during the breeding season by Anderson (1975) showed that bottomland hardwood stands in eastern Texas had a higher bird density (1,050 individuals/km^2) than did pine stands (835/km^2) or pine-hardwood stands (422/km^2). Similar results were obtained from other studies in Louisiana and eastern Texas, where summer bird densities ranged from 752 to 1,480 territorial male birds/km^2, two to four times the density found in the best upland stands (Dickson 1978a,b).

Mature bottomland hardwood sites harbor dense populations of birds during the winter. In eastern Texas, the estimated winter bird population was 1,168/km^2 in bottomland hardwoods compared to 845/km^2 for a pine stand and 672/km^2 for a pine-hardwood stand (Anderson 1975). In south-central Louisiana, winter bird populations in bottomland hardwoods ranged from 1,235 to 2,035/km^2. Large migratory flocks of robins, waxwings, and blackbirds rest in bottomland hardwoods, feeding on tupelo, sugarberry, possumhaw, grapes, and other fruits.

Other Wildlife

Squirrels (gray and fox) are the most important game animals in eastern Texas, where over 2.5 million hunter-days annually are devoted to squirrel hunting. The importance of this sport has not been carefully evaluated in economic terms (USFWS 1984). Gray squirrels prefer hardwoods along floodplains, whereas fox squirrels are better adapted to upland sites.

The white-tailed deer is the next most important game animal. Over 101,000 hunters spent 739,802 hunter-days in eastern Texas during 1979-1980 and killed 29,536 deer (Boydston and Harwell 1980). The number of deer killed in bottomlands is not known. Bottomland habitats are preferred by white-tailed deer in the South (Stransky 1969), primarily due to the presence of mast-bearing trees and fruiting shrubs (Lay 1965).

Other important game species in eastern Texas bottomland hardwoods are the eastern cottontail and swamp rabbit. Eastern cottontails are not dependent on bottomland hardwoods, but occur in open or cutover bottomland forest. Swamp rabbits are dependent on bottomland hardwoods, preferring dense thickets in the floodplains (Schmidly 1983).

Principal furbearers are raccoon, opossum, gray fox, bobcat, coyote, striped skunk, nutria, muskrat, mink, and beaver (Schmidley 1984). Of these species, the coyote and striped skunk use a variety of habitats and are not particularly dependent on bottomlands. The gray fox, bobcat, and opossum are also generalists, but prefer or at least heavily use bottomlands and wet habitats. The raccoon, nutria, muskrat, mink, beaver, and river otter all prefer wetland and aquatic habitats and are heavily dependent on bottomland, riverine, marsh, and other floodplain habitats; these species are seldom found far from water. Beaver are important to the bottomland ecosystem because of their dam-building activities. Beaver activity increases habitat diversity and produces areas that are useful to waterfowl in the Southeast (Arner 1964; USFWS 1984).

SOCIOECONOMIC VALUATION

Many of the functions and attributes of wetlands, and bottomland hardwood systems in particular, are valued by humans. These values must be identified and quantified if they are to be considered in decisions that would alter the functions and attributes of bottomland hardwoods. Monetary quantification (i.e., dollar value) is especially desirable because it is readily interpreted in a relative sense and can logically be used to identify preferred alternatives. There are valid theoretical questions about whether all human values associated with wetlands can be appropriately expressed in economic terms (e.g., interspecific ethical issues such as those raised by the animal rights movement). Even leaving such questions aside, there are tremendous differences among various wetland values in terms of the ease with which valid monetary quantification can be established. This section introduces some economic value concepts and methods relevant to establishing the monetary value of wetland functions and attributes, and closes with some examples and discussion of economic evaluation of bottomland hardwoods.

GENERAL CONCEPTS

General literature concerning the economic valuation of wetlands is extensive (e.g., Clawson and Knetsch 1966; Herfindahl and Kneese 1974; Batie et al. 1980; Desvousges et al. 1980; Shabman and Batie 1980, 1981; Leitch 1981; Randall 1981). However, a clear consensus among economists, ecologists, and natural resource managers concerning appropriate approaches and methods is lacking. There is thus a continuing need for clarification and emphasis on essential concepts. There are several theories of value that might be applied to the various functions and attributes of bottomland hardwoods.

First, there is the well known "labor theory of value" described by early writers such as Adam Smith and David Ricardo. This is a "single factor" theory that relates to the amount of labor required. Smith, for example, described this theory as follows (Samuelson 1967):

> . . . the proportion between the quantities of labour necessary for acquiring different objects seems to be the only circumstance which can afford any rule for exchanging them for one another. If among a nation of hunters, for example, it usually costs twice the labour to kill a beaver which it does to kill a deer, one beaver should naturally exchange for or be worth two deer. It is natural that what is usually the produce of two days' or two hours' labour, should be worth double of what is usually the produce of one day's or one hour's labour.

More recently, Gosselink et al. (1973) described a theory of value based on energy:

> H.T. Odum (1971) has suggested an ecosystem approach for translating the total work into monetary terms, so that the overall value of a delimited natural area can be determined without having to specify how the work flow might be divided into different uses and functions. Odum and Odum (1972) have extended this approach in terms of land-use planning in which natural areas are considered as a necessary part of man's total environment. Since the exchange of energy and money is the basis of economic transactions it is suggested that the ratio of Gross National Product to National Energy Consumption can be used to equate energy with money. In round figures for the United States, 10^{16} kilocalories are consumed yearly to produce a Gross National Product of 10^{12} dollars, so that approximately 10^{4} kilocalories is equal to one dollar. Since the rate of primary production is a measure of energy flow of a natural community, and an index of the useful work that might be accomplished, the ratio can be used to place a dollar value on any part of the natural environment where primary production can be measured or estimated.

Recent work by Mitsch and Gosselink (1986) further describes extensions of an energy theory of value to encompass embodied energy:

> A completely different approach that shows much promise uses the idea of energy flow through an ecosystem or the similar concept of embodied energy. The concept of embodied energy, the total energy required to produce a commodity (Costanza 1980), is assumed to be a valid index of the totality of ecosystem functions and is applicable to human systems as well. Thus, natural and human systems can be evaluated on the basis of one common currency, "embodied energy."

Both the energy and labor theories of value involve estimating or converting all of the features of a good or service, or all the inputs required to produce a good or service, into a single unit or factor (labor or energy). Dollar values are then obtained based on a direct relationship between that factor and dollars. Such theories are perhaps best considered as hypotheses about the basis on which individuals and societies assign, or should assign, value. As such, they can provide interesting insights into how values assigned by society reflect, or fail to reflect, the relative quantities of these single factors embodied in various goods and services. They should not be viewed, however, as a substitute for attempts to measure values actually assigned by individuals or societies. In particular, considerations of supply and demand must be incorporated into a valid concept of economic value.

The reference point for an economic theory of value is the well-being of humans, appropriately integrated over individuals. When making decisions, the individual considers what must be given up in order to attain a goal or some other improvement in well-being. The well-being of the individual is measured by the satisfaction or utility that the products, services, or amenities provide (Samuelson 1967; Randall 1981). The value, in dollars, of these goods, services, or amenities is shown by the willingness to pay to obtain, use, or maintain them. The dollars paid are costs to the individual, who foregoes other items that could have been purchased instead.

Individual decisions on purchases are based on the amount of satisfaction that is anticipated from the purchased item. As additional units of the same item are purchased the satisfaction obtained from each unit will decrease (diminishing marginal utility). Total purchases are constrained by available income. Thus, individuals generally seek to purchase goods so as to obtain the most satisfaction or utility from each dollar spent (Randall 1981).

Collectively, society uses market purchase concepts to determine how the available resources are allocated. Overall, society obtains the optimum level of satisfaction when no further market exchanges can be made without resulting in a net loss in satisfaction, given that gainers in a transaction compensate the losers (Samuelson 1967; Sinden and Worrell 1979; Shabman 1986). In a perfect market, the marginal value of a good or service is the price at which the last unit of that good or service is exchanged.

Unfortunately, a number of considerations complicate economic valuation of wetland functions and attributes. The first is that many of the functions and attributes are not exchanged in a perfect market. Functions such as water quality improvement, flood peak reduction, and migratory bird habitat, or the attribute of mere existence, often do not result in significant income to the owner of a wetland. In such cases, the total value to the public may exceed the income obtained by the private owner of the wetland. Methods are thus required to estimate dollar values in the absence of market prices.

A second consideration involves the purpose or objective of the analysis. Economic values may be estimated at a number of different scales or from a number of "accounting stances." Two extreme levels are the stance of an individual wetland owner faced with a decision to modify or preserve a wetland based on the economic returns received from each alternative, as opposed to a National, societal stance considering public values that cannot be captured by individual owners. There is no single "correct" accounting stance. Rather, the analysis, and its scale, must be tailored to the specific questions being addressed.

Another important distinction related to the objectives of the analysis is whether the analysis is restricted to a "small" increment or unit of the good or service (i.e., marginal) or whether a "total" value of all units is desired. If a total value for all units, or a total value for an increment of units that is "large" relative to the shapes of the demand or supply curves, is desired then the analysis must consider more than just current marginal prices.

The general objective in many economic analyses is to make a choice or to discriminate among alternatives. Careful distinctions thus need to be maintained between net and gross values and costs. In general, assessment of net economic values involves the estimation of economic surplus, or values in excess of actual expenditures. Economic surplus may involve both consumer surplus (the willingness to pay more than the current price) and producers surplus or economic rent (price less costs or the willingness of producers to accept less than the current price).

Alternatives must be clearly defined and treated consistently. This is especially important when wetland functions and attributes contribute only a fraction of the factors required to produce a good or service. An example is commercial fish harvest where the market may provide direct information on the price of fish caught. Wetland functions (e.g., habitat and detrital export) are only some of the factors necessary to produce the catch (e.g., labor in catching the fish also is required), and thus it is not appropriate to equate the full gross value of the commercial harvest with the net value of the wetland contribution.

TYPES OF VALUES

In the context of an economic analysis, a wetland value refers to an interaction between the functions and attributes of a wetland (or wetlands) and humans that provides utility to humans (i.e., people do, or would be willing to, pay for it). Several different types of values can be identified.

User Values

User values can be further subdivided into consumptive and nonconsumptive. Consumptive values are associated with activities such as hunting, fishing, and forestry, which involve consumption of the resource. Nonconsumptive use values are associated with activities such as photography, bird watching, and education, which do not involve consumption of the resource. In fact, this distinction is somewhat arbitrary as noted by Weeden (1976) and Wilkes (1977). Some activities regarded as nonconsumptive may, in fact, significantly influence the functions or attributes being valued (e.g., a large number of bird watchers constituting a disturbance to birds).

Odum et al. (1981) identified nine major use categories for Southeastern bottomland hardwoods, each of which might have multiple, specific user values:

(1) urban and industrial development,
(2) agricultural crop production,
(3) forest products production,
(4) aquacultural production,
(5) flood control,
(6) wildlife propagation and harvest,
(7) fish propagation and harvest,
(8) recreation and aesthetics, and
(9) general life support (including water purification, groundwater recharge and discharge, etc.).

Although other classifications of functions and values are certainly possible (e.g., Adamus and Stockwell 1983), the above list indicates the diversity of both natural and developmental values associated with wetland sites. Some specific use values of bottomland hardwoods in their natural or seminatural state include the following:

- Harvest of hardwood timber for wood products, construction, firewood, and pulp (Boyce and Cost 1974; Irland 1976).

- Harvest of wildlife for hunting and furs. Game species include swamp rabbit, squirrels, woodcock, turkey, white-tailed deer, and waterfowl (Haygood 1970; Irland 1976). Furbearers include beaver, fox, bobcat, Virginia opossum, nutria, river otter, and raccoon.

- Harvest of fish and shellfish. This includes both recreational fishing (e.g., largemouth bass, catfish, crappie, sunfish) and commercial harvest (e.g., crayfish).

- Education. Because of the diversity of life found in bottomland hardwood systems, such areas often harbor unique, outstanding, or rare natural phenomena (Smardon 1979). The study of these systems can demonstrate a variety of basic ecological principles and concepts applicable to the structure and function of natural ecosystems (Wharton 1970). Outdoor exhibits, interpretive centers, and scientific laboratories are available for people who otherwise would have little opportunity to learn about wetlands.

- Water quality. Bottomland hardwoods remove, transform, and export waterborne materials (Winger 1986). These processes may result in changes in water quality that are valued either directly (e.g., as an alternative to treatment facilities) or indirectly in terms of effects on downstream aquatic systems.

- Flood control. In a natural hydrologic configuration, forested bottomlands are flooded and store water at high river stages. This moderates flood peaks and can result in benefits of reduced downstream flood damages (Wharton 1980).

- Recreation. Recreational activities afforded by bottomland hardwoods include hiking, photography, boating, birdwatching, and other wildlife observation (Haygood 1970). "Millions of Americans spend millions of hours annually mucking . . . paddling, fishing, driving and hunting in swamps and marshes, as American custom and culture have led them to do for almost 4 centuries . . ." (Fritzell 1979). Bottomland hardwood areas also are valuable for providing wilderness experience oportunities:

  > The river swamps are . . . the last wilderness. True, they are narrow, even the mighty Altamaha swamp scarcely exceeds 5 miles in width; yet in length they are large indeed, often stretching more than half the length of the state. Narrow as they are, many provide a true wilderness experience. (Wharton 1970).

- Research. Bottomland hardwoods may contain organisms or compounds that have potential value for food, chemicals, and medicinal products. Natural bottomland hardwood systems provide baseline data that can be used to determine effects of human activities and pollution. Although information regarding the contribution of wetland areas to the maintenance of global atmospheric stability (including carbon, nitrogen, and sulfur cycling) is incomplete, preservation of intact natural areas is essential for continued research (Hirsch and Segelquist 1979; OTA 1984; Niering 1986). Strong funding of research by private, State, and Federal agencies is one indication of the importance or value of wetlands (Reimold and Hardisky 1979).

Other Values

Option and bequest values are somewhat intermediate between user and nonuser values. An option value involves the utility derived from ensuring that the option to use a wetland will exist in the future, even if that option is not certain to be used. A bequest value involves the utility derived from ensuring that a wetland will be available for others in the future. The assurance that such areas exist for present and future generations can be a strong motivating force (OTA 1984). This consideration is eloquently expressed by Truett and Lay (1984, p. 148):

> The change from legions of passenger pigeons to none was disquieting because it was final . . . Minerals in the land, and the wealth of life they supported-once gone, they cannot be rebuilt in time measured by human generations. It would be easier if things gone could be blotted from memory . . . But we are set up to preserve pictures of the past, to remind ourselves how it was. So we are stuck with the knowledge that our fore-bearers let some things go. Likewise, those who come after us will know what we lose. Some of them, like some of us, will think, half seriously, "Yes, I would like to have seen one." Some might even say, more seriously, "We could have used some."

Existence value involves the utility derived merely from the knowledge that a wetland exists. Many people believe that unaltered natural areas are worth preserving for their intrinsic value regardless of any tangible benefits they may provide. Existence value of wetlands is also related to "quality of life" issues, which involve highly personal value judgments and philosophical issues. These can fall outside the realm of traditional scientific approaches and market analyses (Reimold and Hardisky 1979; Niering 1986).

In practice, some of these various types of values may be difficult to distinguish. One individual may simultaneously derive utility from option, bequest, and existence values (as well as from various use values), and furthermore, may not be able to partition the total utility accurately.

Additional Determinants of Value

In addition to the functions and attributes of bottomland hardwoods discussed in preceding sections, several other factors can contribute to their economic value. These include the following:

- Location and accessibility. Bottomland hardwoods that are located near urban areas have increased value to local populations for some functions. Also, natural areas that are connected by greenbelts, parks, or other corridors have additional value as part of a larger system, such as a river corridor (Clark 1980; Grubb and Magee 1980; Niering 1986). Smardon's (1979) concept of "cultural enhancement" values of wetlands includes: (1) proximity of the wetland area to educational institutions and (2) accessibility to and within a wetland area (roads, trails, connected waterways).

- Aesthetic attributes. Aesthetic attributes of bottomland hardwood wetlands are important to the sensory experiences of viewing, smelling, hearing, tasting, and feeling. According to Reimold and Hardisky (1979, p. 561) " . . . all aesthetic components serve as witness to the utility of having wetlands without doing anything to them . . . aesthetic experiences have value, yet none of the values can be priced by the present market system." The attraction of the land-water interface seems to have particular aesthetic appeal (OTA 1984). Aesthetic quality is also related to what Smardon (1979) describes as the "ambient quality" of the wetland--the degree of pollution, noise, or incompatible land use.

- Historic attributes. Bottomland hardwoods played an important role in the lives of early settlers. They provided plants and animals for food; fur and skins for clothing; and wood for homes, implements, furniture, and fuel. These areas also frequently include significant archaeological sites (Fritzell 1979; Niering 1979; Truett and Lay 1984).

- Scarcity. Scarcity and uniqueness may be important aspects of the existence value of bottomland hardwoods. Quantitative evaluations of remaining bottomland forests include:

  (1) 150 years ago there were 202,340 km^2 (50 million acres) of floodplain forests in the United States; 93% are now gone. Remaining forests are disappearing at the rate of 1,214 km^2 (300,000 acres) per year (Sklar 1985).

  (2) An estimated 47,750 km^2 (11.8 million acres) of bottomland hardwoods in the Mississippi alluvial plain in 1937 had been reduced to 21,040 km^2 (5.2 million acres) by 1978; 60% were seasonally flooded basins and the remainder were wooded and shrub swamps (MacDonald et al. 1979).

  (3) Turner et al. (1981) found that an average of 1,740 km^2 (431,000 acres) of bottomland hardwoods were lost each year from 12 southeastern States between 1960 and 1975. Much of this loss of bottomland hardwoods in the southeastern United States is through clearing and drainage for agriculture (Taylor et al. 1984). From 1937-1978, bottomland hardwood area decreased by about 26,710 km^2, while agricultural cropland increased by about 20,230 km^2 (MacDonald et al. 1979).

VALUATION METHODS

Several of the more common and well-accepted methods for estimating economic values in dollars are briefly described below. Additional, detailed information may be obtained from a number of sources including U.S. Water Resources Council (1983) and USFWS (1985).

Market Prices

Some functions and attributes of wetlands result in goods or services that are exchanged in a market (e.g., timber and commercial fish harvest). Total expenditures (price times quantity) provides some useful information about these goods and services. For example, the National Survey of Fishing, Hunting, and Wildlife-associated Recreation clearly identifies the economic importance of these activities by estimating levels of participation and expenditures (U.S. Department of the Interior, Fish and Wildlife Service, and U.S. Department of Commerce, Bureau of the Census 1982). Calculation of the economic value of wetlands, however, involves several additional considerations. The first is a consideration of net value (less costs). Market imperfections (e.g., government subsidies or lack of a competitive market) must be corrected for. Total market value for the good or service must often be partitioned among multiple contributing factors (e.g., commercial fish harvest requires more than just certain wetland functions). Finally, estimation of economic values (rather than just market values) may require knowledge of the underlying supply and demand curves in order to calculate economic (consumer and producer) surplus.

Replacement Costs

One approach for estimating the value of wetlands in producing goods and services for which direct market prices are not available is to calculate the cost of replacing those goods and services by the least costly alternative means. This approach yields a maximum estimate of value. The wetlands can be worth no more than their least costly alternative means of production (or else that means of production would be used). In some cases, their value might be less because people might not be willing to pay for the same quantity at a higher price. For example, a maximum dollar value for the water quality improvement function of a bottomland hardwood site might be estimated by calculating the cost of a treatment facility designed to achieve the same level of improvement as that provided by the natural system. The value of the natural system (for this service) cannot exceed the value of the alternative and may, in fact, be less if the level of treatment provided naturally is greater than people desire or are willing to purchase.

Unit Day Value Method

A straightforward approach often used for nonmarket goods and services is to assign a standard value for each unit of the good or service. Thus, a recreational experience (e.g., hunting or fishing) would be assigned a fixed value per individual per day. Subsequent analysis estimates dollar values of alternatives by multiplying the dollar value per unit (e.g., dollars/fishing day) by an estimated number of units (e.g., total fishing days expected under an alternative). This method is accepted by the U.S. Water Resources Council

(1983) for valuing recreational activities, as are the more sophisticated travel cost and contingent valuation methods discussed below. Although acceptable in some circumstances, the accuracy of this method rests on the site-specific accuracy of the value per unit day. U.S. Water Resources Council (1983) and USFWS (1985) provide detailed procedures, as well as adjustment factors to modify standard unit day values for conditions of a specific site.

Travel Cost Method

The travel cost method has become an accepted tool for valuing outdoor activities such as duck hunting or fishing (Randall 1981). The travel cost method is based on an assumption that all individuals participating in an activity at a site obtain the same total value from the activity. Thus, a person traveling 200 km to hunt ducks in a bottomland hardwood wetland would obtain the same value from a day of hunting as a person who travels only 20 km to the site. Both obtain the "same" day of duck hunting. The total value of a day of duck hunting is assumed to be equal to the average costs of travel, including the value of time, of those traveling the farthest distance to the site. For example, if individuals traveling about 200 km to the site have an average, actual cost of $70 then this is assumed to be the gross value per day for each duck hunter at the site.

The actual costs (taking into account the value of time) that are paid by individuals who live closer to the site are substracted from this gross value (e.g., $70). Thus, a person traveling 20 km may spend $15 per day and have a net (surplus) value, above cost, of $55 per day. The $55 is the difference between the $70 maximum value that people actually paid when traveling the maximum distance, and the actual costs of $15 per day paid by those living closer to the site. The $55 per day represents net benefit to the public, above cost, that is provided by the site. Aggregating over individuals produces an estimate of total net benefits or consumer surplus for the specific site.

Contingent Valuation Method

The contingent valuation method is also an accepted approach for estimating nonmarket values. It involves a survey using telephone, mail, or personal interviews. Various question formats are used to determine expenditures that were made to participate in an activity and the willingness to pay additional dollars for continued participation in the activity. The willingness to pay dollars, above those actually spent, compares conceptually with the estimated dollar values, above actual expenditures, obtained from the travel cost method.

Contingent valuation can be applied to determine the willingness to pay for functions other than recreational activities. For example, there may be a willingness to pay just to know that the wetland is preserved (existence value) and to know that it will continue to exist for future generations (bequest value). The travel cost method, on the other hand, cannot be used to determine such values, since it is based on actual travel behavior. The hypothetical nature of the contingent valuation method is also a major drawback, however, because there may be differences between the way people would actually behave and the way they respond to hypothetical questions.

EXAMPLES OF SPECIFIC VALUATIONS

Only a limited number of studies have estimated the economic value of bottomland hardwoods. None of these studies provides complete estimates of total, net economic value (above the cost of production), but they do represent attempts to quantify and measure wetland values in economic terms.

- In assessments of the market value of timber, Langdon et al. (1981) and Johnson (1979) estimated inventory (stumpage) values of approximately $250/acre ($617/ha) for bottomland hardwood forests of the southeastern United States. Stumpage prices are the most appropriate market price because they are closest to a net value. Retail prices for finished lumber would include a number of costs (e.g., transportation and processing) not properly attributable to the bottomland hardwoods sites.

- Brabander et al. (1985) estimated values for selected goods and services provided annually by a hypothetical 1,000-acre (405-ha) bottomland hardwood site in eastern Oklahoma. The meat value, based on equivalent retail prices, of annual estimated harvest of eight game species (swamp rabbit, white-tailed deer, turkey, mallard, wood duck, fox squirrel, gray squirrel, and woodcock) was $1.40/acre ($3.45/ha). Recreational value of hunting was estimated using a unit day approach (i.e., dollars per hunting day) resulting in an annual value of $10.26/acre ($25.34/ha). Annual furbearer harvest (beaver, bobcat, coyote, gray fox, mink, muskrat, opossum, raccoon and striped skunk) was estimated as $0.30/acre ($0.74/ha) based on average prices for raw pelts from 1978 to 1983. Annual timber harvest was estimated as $30 to $40/acre ($74 to $99/ha). Other recreational activities (e.g., hiking, nature study, fishing), were assessed using a unit value (use day) approach resulting in an annual estimate of $12.76/acre ($31.51/ha). Finally, a potential pecan harvest on the hypothetical stand was estimated at $47.14/acre ($116.43/ha).

- Wetlands in the floodplain can reduce peak flows and hence flood damages by storing floodwaters. A classic estimation of this value was performed on riverine wetlands of the Charles River Basin in Massachusetts (USACE 1972). Drainage of 3,400 ha was estimated to increase flood damages by $17 million per year. Although this type of analysis is highly site-specific because of both the specific hydrologic characteristics and the values of downstream resources it does illustrate how an individual site can be valued by placing it in an appropriate larger (watershed) context.

- Data from Schmidly (1983) on harvest and estimated value of furbearers in eastern Texas, including but not limited to bottomland hardwoods, are presented in Table 6. This type of information establishes the general importance of particular habitat functions of bottomland hardwoods.

- Davis and Lim (1987) conducted an economic analysis of agricultural conversion of a 1,010 acre (409 ha) tract of bottomland hardwoods in

Table 6. Estimated harvest of furbearers in eastern Texas[a] (from Schmidly 1983).

Species	Harvest (#)	Value ($)	Rank ($)
Raccoon	1,212,750	20,991,680	1
Ringtail	46,951	296,604	8
Opossum	835,202	1,711,605	4
Red fox	8,443	319,939	7
Gray fox	46,488	1,390,258	5
Bobcat	26,970	1,804,332	3
Coyote	102,921	1,936,697	2
Badger	628	3,684	15
Spotted skunk	8,145	32,261	14
Striped skunk	99,514	209,310	9
Nutria	128,811	1,029,561	6
Muskrat	15,961	104,667	12
Mink	16,695	161,651	10
Otter	1,556	55,202	13
Beaver	14,079	107,393	11

[a]Area includes pineywoods, coastal prairie and marshes, post oak woodlands, and blackland prairies in Texas east of the Balcones Fault Zone.

Louisiana that illustrated some of the insights that can be obtained from careful economic analysis, as well as some of the complexities of nonmarket values and accounting stances. Values of hunting (net of the value of hunting on the converted land) were estimated using information on willingness to pay for hunting in Louisiana bottomland hardwoods from Miller (1984), based on application of a regional travel cost method and estimates of hunter-days. Annual costs and returns for the agricultural conversion and the opportunity cost of timber production were obtained from Herrington and Shulstad (1982). Determination of the net benefits of conversion was highly dependent on the accounting stance. A societal accounting stance corrected for effects of Federal crop subsidies and considered the full value of hunting lost as a result of conversion. This produced a net present loss (20-year time stream of net benefits discounted at 10% per year) to society of $279/acre ($689/ha) from conversion. Thus a society accounting stance produced a conclusion that the land should remain as bottomland hardwoods. On the other hand, a private accounting stance considered the perspective of the landowner. This approach used market prices and considered only the capturable benefits lost by conversion (e.g., from hunting leases) as opportunity costs of the conversion. A private accounting stance produced a net present gain from conversion of $42/acre ($104/ha), indicating that the landowner would benefit from conversion.

DISCUSSION

Although the preceding material illustrates that economic analysis of bottomland hardwoods is feasible, it fails to provide the basis for a single dollar value per unit area for the natural functions and attributes of bottomland hardwoods throughout eastern Texas and Oklahoma. Such a number would be extremely useful to government agencies, landowners, and private interest groups in comparing the benefits of alternative uses. Some discussion is thus appropriate concerning the prospects for developing such an estimate and alternative approaches. This discussion must be qualified, however, by strongly acknowledging that natural resource economics, and wetland valuation in particular, is an active area of research and methods development. Informed disagreement is possible with almost any general statement in this area, including those made here.

Energy Values

Ecological energetics has been a powerful paradigm for understanding the structure and function of ecosystems, providing many meaningful comparisons of disparate sites and ecosystems. Thus, assigning monetary values based on caloric contents or on the energy required to generate a natural function or attribute can be a very appealing approach to ecologists. However, this type of assignment amounts to adopting a distinct energy theory of value. As discussed in the earlier section on theories of value, an energy theory of value is fundamentally different from the accepted economic theory of value that bases value on human choices that reveal relative preferences. Comparison of energy-based valuations with those based on accepted economic value theories can be a meaningful research activity. However, energy-based valuations are conceptually distinct and should not be used interchangably with economic valuations even though both yield results expressed in dollars. Furthermore, energy-based valuation is not consistent with generally accepted concepts and practice in natural resource economics and is subject to severe criticism from this perspective (e.g., Shabman and Batie 1978) when used as a practical wetlands valuation procedure.

Site-Specific Factors

Currently, many wetland decisions are made on a site-by-site basis, attempting to weigh the costs and benefits of alternative uses. These assessments are often made with limited resources and would be considerably more efficient if generalized monetary values were available for natural bottomland hardwood functions. Unfortunately, the extent to which such economic valuations of specific sites can be generalized or applied to other sites without doing an actual economic assessment of each site is severely limited by site-specific factors. These factors can be roughly considered as internal (i.e., characteristics of the site itself) and contextual (i.e., having to do with the site's position in a larger system or landscape). These factors influence both ecological functions and attributes as well as the economic value of the related goods and services. To the extent that they differ from site to site, economic values will differ from site to site.

Examples of important internal characteristics that vary across sites include plant and animal species composition and productivity, visual attributes, habitat quality for species of interest, and hydrology (e.g., whether the site is a groundwater recharge or discharge area). Contextual characteristics include the economic value of downstream resources that might benefit from a flood reduction function, the location of the site with respect to centers of demand for recreational opportunities, opportunities to perform certain water quality improvement functions (e.g., inputs or loadings of pollutants to be processed), and how the site functions as a part of a larger system that provides economically valuable outputs. These larger systems include complex moving populations such as those of migratory birds and fish; landscape features such as corridors and large, contiguous tracts; and other ecosystems connected to the bottomland hardwood site by complex transport mechanisms (e.g., detrital processing and export influencing downstream commercial fisheries).

Batie and Shabman (1982, pp. 271-272) well summarized these limitations on the application of economic valuation methods to natural wetland services as follows:

> Such valuation requires detailed biological assessment studies for specific wetlands areas in order to establish whether such areas are capable of producing a particular wetlands service. Since all wetlands are not of equal productivity, the detailed biological assessment analysis needed will be both time-consuming and costly (Shabman and Batie 1980). In addition to this problem, application of economic valuation techniques in individual cases will further increase analytical cost and time requirements. These cost and time requirements mean that for numerous small wetlands areas, careful economic valuation of services will be infeasible. Unfortunately, general value estimates are not applicable to individual areas because of the differing productivity of wetlands areas and the site-specific nature of the demand for wetlands services.

Analysis Objectives

As with almost any quantitative analysis, a clear problem statement is essential to economic valuation of natural functions and attributes of bottomland hardwoods. Several conceptual and methodological distinctions are especially important to make because of the confusion generated by a failure to do so.

Economic activity or economic value. Generally, expenditures measure economic activity but not net economic value. Expenditures can provide some information regarding the existence of an economically important good or service and are essential to assessing certain kinds of the economic impacts (e.g., how will a particular action influence various other economic sectors or employment at a local level). However, the appropriate measure for use in a cost-benefit comparison of alternatives is net economic benefit, not expenditures. Net economic benefit involves economic surplus or value in excess of expenditures: either expenditures less costs in the case of producers surplus, or willingness to pay in excess of expenditures in the case of consumer surplus.

and attributes of bottomland hardwoods on a site-by-site basis. This sugges
the need for additional research. Several such research needs are highlight
here, without any attempt to provide an exhaustive list.

- Continued research on the ecological functions of bottomland har woods is needed. Many functions (e.g., groundwater relations) a still poorly understood and much additional work is needed accurately quantify levels of performance of various functio across different sites and management alternatives.

- Detailed case studies providing economic values for a complete se of natural functions on several specific bottomland sites might used to compare economic methods and to judge the relative importanc of various natural functions. However, such studies are likely t be expensive, both in terms of the economic analyses and in th acquisition of necessary ecological data on the functions. Further more, they are unlikely to lead to reliable "rapid assessment methods for other sites, although they might contribute to modelin activities designed to generalize results.

- Batie and Shabman (1982) suggested an economic research focus on th economics of conversion decisions and factors or policies influencin those decisions. They emphasize that research in this area [e.g. Shabman (1980), Davis and Lim (1987)] may be more productive tha continued site-by-site assessments.

- Finally, more attention needs to be directed at the cumulativ impacts of incremental changes in bottomland hardwoods on large-scal functions and values such as support of wide-ranging and migrator species, detrital export, and interactions within large hydrologi systems. In many cases, the relationship of a valued good or servic to a particular site may be very complex and diffuse. Furthermore landscape properties such as patch sizes, linear connectivity, an fragmentation may be extremely important (Gosselink et al. 1987; Le et al. 1987). It is difficult to incorporate these consideration in site-by-site assessments based on current understanding; however increased understanding of structure and function at the landscap level may allow the application of economic analyses at a higher an more productive scale than that of individual site assessments.

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BROOD HABITAT USE, REPRODUCTION AND MOVEMENT OF RECENTLY RESTOCKED EASTERN WILD TURKEYS IN EAST TEXAS
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PH.D. DISS., TEXAS A&M UNIV., COLLEGE STATION, 144PP.
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WILD TURKEYS WERE STUDIED ON TWO UNITS IN EAST TEXAS:(1) BEEF CREEK IN JASPER COUNTY, AND (2) BRUSHY CREEK WILDLIFE MANAGEMENT AND RESEARCH AREA IN POLK AND TRINITY COUNTIES. BEEF CREEK IS CHARACTERIZED BY PINE PLANTATIONS, PINE TIMBER AREAS, AND BOTTOMLAND HARDWOOD/PINE-HARDWOOD. DOMINANT TREES INCLUDED LOBLOLLY PINE, LONGLEAF PINE, SHORTLEAF PINE, SLASH PINE, RED OAK, POST OAK, WATER OAK, WILLOW OAK, CHERRYBARK OAK, BLACKGUM TUPELO, AND BALDCYPRESS. BRUSHY CREEK CONTAINS PINE PLANTATIONS AND STANDS, PINE-HARDWOOD, SOME OPEN AREAS, AND A SMALL AREA OF BOTTOMLAND HARDWOODS. TURKEYS PREFERRED PINE-HARDWOOD AND BOTTOMLAND HARDWOOD FOREST TYPES DURING FALL AND WINTER. ENHANCEMENT OF THESE AREAS IS RECOMMENDED AS PART OF FOREST MANAGEMENT THAT ACCOMPANIES TURKEY RESTOCKING OR OTHER MANAGEMENT. ALTHOUGH TURKEYS HAVE BEEN ESTABLISHED IN BOTH STUDY AREAS, MANAGEMENT PRACTICES DIFFER. AT BEEF CREEK, MAINTENANCE OF EXISTING PREFERRED HABITAT IS RECOMMENDED. AT BRUSHY CREEK, PINE MONOCULTURES SHOULD BE PERIODICALLY BURNED, SELECTIVELY THINNED, AND SUPPLEMENTED ANNUALLY WITH FOOD PLANTING TO MAINTAIN THE TURKEY POPULATIONS. THE IMPORTANCE OF MAINTAINING A DIVERSITY OF HABITAT TYPES WAS EMPHASIZED, TURKEYS PREFER A VARIETY OF HABITATS FOR NESTING, BROODING, AND FEEDING. OF THE HENS THAT WERE RESTOCKED IN 1978-80, 64% AND 42% SURVIVED AT BEEF CREEK AND BRUSHY CREEK, RESPECTIVELY. AVERAGE CLUTCH SIZE AT BOTH SITES WAS 8 EGGS. A HIGH REPRODUCTIVE POTENTIAL WAS INDICATED FOR POPULATIONS OF BIRDS AT BOTH SITES, DUE TO HIGH INITIAL NESTING AND RENESTING RATES. (KSM)

Figure A-1. Sample record from Wetlands Values Data Base.

APPENDIX B. REQUEST FOR DATA BASE FILES

The bibliographic data base is available through September 1988, in following standard distributional package:

1. Two 5¼", 360K, DS-DD, IBM PC/XT/AT formatted diskettes each cont ing one ASCII data file with the structure outlined in Append (two blank diskettes provided by requestor).

2. A users manual for the complete Wetlands Values Data Base contai detailed field descriptions.

3. Detailed format descriptions of the data files.

4. Instructions for creating a single QUICKTEXT data base from diskette files on an IBM PC/XT/AT compatible microcomputer that QUICKTEXT installed and that is equipped with a hard disk.

Note that a hard disk is required to use the information effectively single data base.

Please copy or detach the request form below and mail to:

Inland Freshwater Ecology Section
National Ecology Center
U.S. Fish and Wildlife Service
2627 Redwing Road
Fort Collins, CO 80526-2899

NAME AND ADDRESS

______________________________ __ Please send information regardi QUICKTEXT

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______________________________ __ Please send standard distributional package for bottomlanc hardwoods subset of Wetland Wetland Values bibliographic data base. Two blank diskettes are enclosed.

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APPENDIX C. SCIENTIFIC NAMES OF PLANTS CITED IN TEXT

Common name	Scientific name
Alligator-weed	*Alternanthera philoxeroides*
American basswood	*Tilia americana*
American beautyberry	*Callicarpa americana*
American elm	*Ulmus americana*
American holly	*Ilex opaca*
American hornbeam, blue beech	*Carpinus caroliniana*
Arrowhead	*Saggitaria* spp.
Baldcypress	*Taxodium distichum*
Baygall holly	*Ilex coriacea*
Beech, American beech	*Fagus grandifolia*
Bitternut hickory	*Carya cordiformis*
Black hickory	*Carya texana*
Black locust	*Robina psuedoacacia*
Black titi	*Cyrilla racemiflora*
Black walnut	*Juglans nigra*
Black willow	*Salix nigra*
Blackgum	*Nyssa sylvatica*
Boxelder	*Acer negundo*
Buttonbush	*Cephalanthus occidentalis*
Cattail	*Typha* spp.
Cedar elm	*Ulmus crassifolia*
Cherrybark oak, swamp red oak	*Quercus falcata* var. *pagodaefolia*
Chestnut oak	*Quercus prinus*
Common greenbrier	*Smilax rotundifolia*
Common hackberry	*Celtis occidentalis*
Common pecan	*Carya illinoenisis*
Common persimmon	*Diospyros virginiana*
Cottonwood	*Populus* spp.
Deciduous holly	*Ilex decidua*
Duckweed	*Lemna* spp.
Dwarf palmetto	*Sabal minor*
Eastern cottonwood	*Populus deltoides*
English dogwood, stiff cornel dogwood	*Cornus foemina*
Gallberry holly	*Ilex glabra*
Grape	*Vitis* spp.
Green ash	*Fraxinus pennsylvanica*
Hawthorn	*Crataegus* spp.
Honey locust	*Gleditsia triacanthos*
Hophornbeam	*Ostrya virginiana*

Common name	Scientific name
Hornwort	*Ceratophyllum* spp.
Laurel oak	*Quercus laurifolia*
Live oak	*Quercus virginiana*
Loblolly pine	*Pinus taeda*
Lotus	*Nelumbo lutea*
Maidencane	*Panicum hemitomon*
Mermaid-weed	*Prosperpinaca* spp.
Mockernut hickory	*Carya tomentosa*
Muscadine	*Vitis rotundifolia*
Osage orange	*Maclura pomifera*
Overcup oak	*Quercus lyrata*
Parsley hawthorn	*Crataegus marshallii*
Pignut hickory	*Carya glabra*
Pin oak	*Quercus palustris*
Poison ivy	*Toxicodendron radicans*
Post oak	*Quercus stellata*
Red bay	*Persea borbonia*
Red maple	*Acer rubrum*
Red mulberry	*Morus rubra*
Redbud	*Cercis canadensis*
River birch	*Betula nigra*
Roughleaf dogwood	*Cornus drummondii*
Rush	*Juncus* spp.
Sebastian-bush	*Sebastiania fruticosa*
Sedge	*Carex* spp.
Shagbark hickory	*Carya ovata*
Shellbark hickory	*Carya laciniosa*
Shortleaf pine	*Pinus echinata*
Shumard oak	*Quercus shumardii*
Silver maple	*Acer saccharinum*
Slippery elm	*Ulmus rubra*
Smartweed	*Polygonum* spp.
Smooth alder, hazel alder	*Alnus serrulata*
Snowdrop-tree	*Halesia diptera*
Southern arrow-wood	*Viburnum dentatum*
Southern magnolia	*Magnolia grandiflora*
Southern red oak	*Quercus falcata*
Southern wildrice	*Zizaniopsis miliacea*
Spatterduck	*Nuphar luteum*
Sugarberry	*Celtis laevigata*
Supplejack	*Berchemia scandens*
Swamp chestnut oak	*Quercus michauxii*
Swamp privet	*Forestiera acuminata*
Swamp tupelo	*Nyssa sylvatica* var. *biflora*
Sweet bay	*Magnolia virginiana*

Appendix C. (Concluded)

Common name	Scientific name
Sweetgum	*Liquidambar styraciflua*
Switchcane	*Arundinaria gigantea*
Sycamore	*Platanus occidentalis*
Water elm	*Planera aquatica*
Water fern	*Azolla caroliniana*
Water hickory	*Carya aquatica*
Water lily	*Nymphaea* spp.
Water locust	*Gleditsia aquatica*
Water oak	*Quercus nigra*
Water tupelo	*Nyssa aquatica*
Water-milfoil	*Myriophyllum* spp.
Western mayhaw	*Crataegus opaca*
White ash	*Fraxinus americana*
White oak	*Quercus alba*
Willow	*Salix* spp.
Willow oak	*Quercus phellos*
Winged elm	*Ulmus alata*
Yaupon	*Ilex vomitoria*

APPENDIX D. FAUNAL SPECIES SUPPORTED BY BOTTOMLAND HARDWOODS

Appendix D. Faunal species supported by bottomland hardwoods.

Sources	Birds	Mammals	Reptiles and amphibians	Fish	Invertebrates
Allen (1961)	Anhinga				
Anderson (1975)	General				
Arner (1964)		Beaver			
Arner et al. (1976)		Furbearers		General	Aquatic invertebrates
Baker et al. (1945)	Waterfowl	Raccoon	Water snakes		Crayfish, insects
Barclay (1979)	General	General	General		
Bass (1974)	Cattle egret, little blue heron				
Beck (1977)					Macroinver-tebrates
Benke et al. (1979)				General	Invertebrates
Boyd (1976)		Cotton mouse			
Brabander et al. (1985)	General	General	General	General	General
Brinson et al. (1981c)	General	General	General	General	
Cache River Basin Task Force (1978)	Waterfowl				
Caldwell (1963)		Raccoon			
Campo (1983)	Wild turkey				
Chabreck (1979)	Waterfowl	Beaver, muskrat, nutria, river otter, mink, raccoon	Alligator		
Curtis (1983)	Green heron, barred owl, wood duck, turkey, quail, kingfisher	Game species, deer, squirrel, mink, raccoon, rabbit	Alligator	General	

Appendix D. (Continued)

Sources	Birds	Mammals	Reptiles and amphibians	Fish	Invertebrates
Dennis (1975)	General				
Dickson (1978a)	Non-game species				
Dickson (1978b)	General				
Drobney and Fredrickson (1979)	Wood duck				
Echternach (1982)		Beaver			
Evans (1976)	Woodcock	White-tailed deer			
Frederickson (1979b)	General	General	General		
Frederickson (1980)	Ivory-billed woodpecker, Bachman's warbler, wood duck	Swamp rabbit, black bear, river otter, mountain lion			
Glasgow and Noble (1971)	Wild turkey, waterfowl	White-tailed deer, squirrels, rabbits			
Haines and Montague (1979)					General
Hall (1962)	Waterfowl				
Hall (1979a)	Wild turkey, wood duck, waterfowl (migratory)	White-tailed deer, raccoons		General	
Hall (1979b)				General	
Hamilton and Marchinton (1977)		Black bear			
Hancock and Barkley (1980)	Waterfowl, wild turkey, osprey, bald eagle	Deer, squirrels, furbearers			
Harlow (1959)		White-tailed deer			

Appendix D. (Continued)

Sources	Birds	Mammals	Reptiles and amphibians	Fish	Invertebrates
Harris et al. (1984)	General	General	General		Crayfish, invertebrates (general)
Hebert (1977)		Small mammals			
Heitmeyer and Frederickson (1981)	Waterfowl, mallard				
Heitmeyer and Vohs (1984a,b)	Waterfowl, wood duck				
Heller (1978)	Non-game species				
Herbrard and Mushinsky (1978)			Snakes		
Heuer (1976)		Squirrels, rabbits			
Holder (1970)				General	
Hooper and Hamel (1977)	Bachman's warbler				
Humphrey and Zinn (1982)		River otters, Everglades mink			
Johnson (1970)		Raccoon			Crayfish, insects
Kennedy (1977)	General				
Klimas et al. (1981)	Wood duck, mallard, turkey, merganser, woodcock, non-game species	Swamp rabbit, cottontail, raccoon, squirrels, mink, otter, deer, bobcat	General		
Kroodsma (1979)	Non-game species				
Konikoff (1977)					Red swamp crayfish

Appendix D. (Continued)

Sources	Birds	Mammals	Reptiles and amphibians	Fish	Invertebrates
Kushlan (1974)			alligator		
Kushlan (1979)	White ibis			General	Crayfish
Lambou (1963)				General	
Landers et al. (1977)	Wood duck				
Landers et al. (1979)		Black bear			
Lantz (1970)				General	General
Lay (1942)		Opossum			
Lochmiller (1979)	Woodpeckers				
Lowe (1958)		Swamp rabbit			
McCombe and Noble (1981)			Snakes, lizards, tree frogs		
McGilvrey (1968)	Wood duck				
Meyers (1982)	Breeding birds				
Miller et al. (1977)	General	General	General	General	General
Moore (1967)		Deer			
Murphy and Noble (1973)		Deer			
Neck (1984)					Molluscs (freshwater)
Neill (1951)			Salamanders, frogs	General	Crayfish
Newling (1981)	Waterfowl, non-game birds				
Nichols (1973)		Furbearers-mink, raccoon, nutria	Alligator		

O'Brien (1977) Crayfish

Appendix D. (Continued)

Sources	Birds	Mammals	Reptiles and amphibians	Fish	Invertebrates
Office of Technology Assessment (1984)	Waterfowl, Shorebirds Non-game birds	General, muskrat nutria, mink	General, alligator	Largemouth bass, alewife, blueback herring, perch, pike, sunfish	Crayfish, shellfish
Pardue et al. (1975)	General	General		General	
Patrick et al. (1981)	Wood duck, mallard, ivory-billed woodpecker	Furbearers	Marbled salamander, tree frog	Bass, crappie	Zooplankton; red swamp crayfish
Penn (1950)			General	General	Crayfish
Perry (1974)		Opossum, raccoon, gray squirrel			
Pollard et al. (1983)				Bowfin, gar, large-mouth bass	Crayfish
Potter (1981)			Alligator		
Raun (1965)			General		
Raun and Gehlbach (1972)			General		
Roberts and Arner (1984)		Beaver			
Samson (1979)	Nongame, general				
Sanders and Soileau (1980)	Migratory birds, woodcock, turkey, endangered species	Black bear, furbearers, rabbits and squirrels, Florida panther	Alligator	General	Crustaceans
Schmidley (1983)		General			
Schmidley (1984)		Furbearers			

Appendix D. (Continued)

Sources	Birds	Mammals	Reptiles and amphibians	Fish	Invertebrates
Shelton (1983)	Wild turkey, waterfowl, wood duck	Deer, squirrels, furbearers			
Sheppard (1974)					Crayfish
Singleton (1974)	Waterfowl				
Smith (1973)	Waterfowl				
Smith et al. (1980)		Small mammals			
Sniffen (1981)					Benthic invertebrates
Spiller (1977)			Alligator		
Stieglitz and Thompson (1967)	Everglade kite				Snails
Stransky (1969)		Deer			
Tanner (1942)	Ivory-billed woodpecker				
Tarplee (1979)				General population	
Texas Colonial Waterbird Society (1982)	Water birds				
Texas Organization for Endangered Species (1984)	Endangered species	Endangered species	Endangered species	Endangered species	
Texas Parks and Wildlife Department (1982)	Waterfowl				
Thorp et al. (1985)					Macro-invertebrates
Tinkle (1959)			General		
Truett and Lay (1984)	General, turkey, ivory-billed woodpecker, waterfowl	General, black bear, squirrels, panther, coyote, red wolf	General	General	

Appendix D. (Concluded)

Sources	Birds	Mammals	Reptiles and amphibians	Fish	Invertebrates
U.S. Fish and Wildlife Service (1985)	General, waterfowl	General	General	General	
U.S. Fish and Wildlife Service (1984)	General, waterfowl, mallard, wood duck	General, game, furbearers	General	General	General
U.S. Fish and Wildlife Service (1983)	Waterfowl				
U.S. Fish and Wildlife Service (1978a)	General, endangered species, waterfowl	Furbearers, general		General	Crawfish, crabs, shrimp
U.S. Fish and Wildlife Service (1979a,c)	General	General	General	General	General
Valentine and Noble (1970)	Sandhill crane				-
Wharton (1980)	General, endangered species, waterfowl	Deer, black bear, rodents, furbearers	Salamanders, frogs	Catfish centarchids, blue-back herring	Insects
Warton et al. (1981)	General, waterfowl, endangered species	Deer, black bear, rodents, furbearers	Salamanders, frogs	Catfish, centarchids, blue-back herring	Insects
Wharton et al. (1982)	Waterfowl	Deer, squirrels, furbearers	General	General	General
Winton (1980)	General				
Wright (1959)	Mallard				
Ziser (1978)					Macro-invertebrates
Zwank et al. (1979)		White-tailed deer			

APPENDIX E. FLORA OF SPECIAL CONCERN IN EASTERN OKLAHOMA (from Brabander et al. 1985)

Appendix E. Flora of special concern in eastern Oklahoma (from Brabander et al. 1985).

Species	Scientific name	Remarks/characteristics
Plants (rare, woody)		
Yellow wood	*Cladastris lutea*	Typically overhangs mountain streams
Umbrella tree	*Magnolia tripetala*	Occurs on alluvial soils in floodplains
Blue ash	*Fraxinus quadrangulata*	Occasional on fertile floodplain soils
Ozark chinquapin	*Castanea ozarkensis*	Found bordering floodplain wetlands
Hercules club	*Aralia spinosa*	Occurs on moist bottomland soils
Water hickory	*Carya aquatica*	Water-loving tree of bottomlands
Nutmeg hickory	*C. myristicaeformis*	Floodplain species found along the Red River
Fringe tree	*Chionanthus virginica*	Occurs on rich moist soil on stream banks
Witch hazel	*Hamamelis macrophylla*	Found on rich bottomland soils
American beech	*Fagus grandifolia*	Margins of floodplain wetlands, along streams
American holly	*Ilex opaca*	Found in moist rich soils of bottomlands
Cucumber tree	*Magnolia acuminata*	Occurs along rocky streams
Water elm	*Planera aquatica*	Floodplain wetland species found on wetter sites
Baldcypress	*Taxodium distichum*	Mainly in southeastern Oklahoma
Red elm	*Ulmus serotina*	Found along streambanks
Red buckeye	*Aesculus pavia*	Shrub found along streams
Seaside alder	*Alnus maritima*	Occurs on streambanks in southern Oklahoma
Hazel alder	*A. rugosa*	Southeastern Oklahoma shrub of streambanks
Mountain indigo	*Amorpha glabra*	Found along moist streambanks
Stiff cornel dogwood	*Cornus foemina*	Occurs in wet bottomlands
Atlantic leatherwood	*Dirca palustris*	Shrub of wet, rich bottomlands
Carolina silverbell	*Halesia carolina*	Found on rich, well drained streambank soils
Yaupon	*Ilex vomitoria*	Broad-leaved evergreen shrub of streambanks
Waxmyrtle	*Myrica cerifera*	Evergreen shrub of sandy floodplain wetlands
American snowbell	*Styrax americanum*	Occurs in rich, moist soil near floodplains wetlands
Common sweatleaf	*Symplocus tinctoria*	Shrub of rich bottomland soils in southeastern Oklahoma
Blue jasmine	*Clematis crispa*	A vine of bottomlands in McCurtain County
Glaucous leatherflower	*C. glaucophylla*	Found in moist bottomlands
Virginsbower	*C. virginiana*	Occurs along streams in BLH habitat
Small's greenbrier	*Smilax smallii*	Found in BLH habitat in McCurtain County
Kentucky wisteria	*Wisteria macrostachya*	Usually found in wet BLH habitat, known from McCurtain County
Dwarf palmetto	*Sabal minor*	Found on wet alluvial soils in southeastern Oklahoma
Plants (rare, herbaceous)		
American beakgrain	*Diarrhena americana*	Clonal herb of dense BLH habitat
Nodding muhly	*Muhlenbergia brachyphylla*	Known from Dripping Springs, Delaware County
Bustle basketgrass	*Oplismenus setarius*	Occurs in rich alluvial soils of Little River floodplain
Sugarcane plumegrass	*Erianthus giganteus*	Low wet areas of southeast corner of Oklahoma
Thicketbean	*Phascolus polystachios*	Found in BLH habitat in Adair County

APPENDIX F. FLORA OF SPECIAL CONCERN IN EASTERN TEXAS
(from USFWS 1984)

Appendix F. Flora of special concern in eastern Texas (from USFWS 1984).

Scientific and common name[a]	Texas County location	Habitat	Listing agency or organization[b]	Comments
Abronia macrocarpa Sand verbena	Leon	Sandy soils	Texas Natural Heritage Program (TNHP)	Endemic. Known only from one location.
Amorpha laevigata Smooth amorpha	Cass and Van Zandt	Moist rich soil along stream	TNHP	Peripheral.
Amsonia glaberrima Blue-star	Extreme southeast Texas	Dense woods and low pinelands	TNHP	Very limited distribution. Also occurs in adjacent areas of Louisiana.
Armoracia aquatica Lake cress	Tyler	Quiet waters of lakes streams, and on muddy shores	TNHP	Peripheral.
Aster azureus Azure aster	Grayson	Along borders of woods, fields, and prairies	TNHP	Peripheral.
A. scabricaulis Aster	Anderson, Smith, Van Zandt, Wood	Boggy ground	TNHP	Endemic. Limited number of locations.
A. subulatus var. euroaster Hierba del marrano	Orange	In and near ponds	TNHP	Peripheral.
Bartonia texana Texas bartonia	Hardin, Nacogdoches, Newton, San Jacinto, and Tyler	Elevated clumps of Sphagnum Moss, organic matter, etc. in seepages and wet creek bottoms	TNHP and Texas Organization for Endangered Species (TOES)	Endemic. Low populations.
B. verna Spring bartonia	Tyler	In pitcher plant bogs and low savannas.	TNHP	Peripheral.
Brachyeletrum erectum Bearded shorthusk	Nacogdoches	Moist woodlands	TNHP and TOES	One known location in Texas and small population size threatened by clear-cutting and grazing. Peripheral.
Brazoria pulcherrima Centerville brazosmint	Anderson, Freestone, Houston, and Leon	Sandy soils along roadsides and open fields	TNHP and TOES	Endemic.

Appendix F. (Continued)

Scientific and common name[a]	Texas County location	Habitat	Listing agency or organization[b]	Comments
Calopogon barbatus Bearded grass-pink	Henderson	Moist acid sandy soils on edge of bogs, swamps, and marshes, and in open woodlands	TNHP	Peripheral.
Carex alata Wingseed sedge	Anderson	Mud and wet, sandy loam soil	TNHP	Peripheral.
C. comosa Sedge	Wood	Lakes, marshes, and ponds	TNHP	Peripheral.
Carex granularis Sedge	Bowie	Ditches, water of flowing streams, wooded swamps, and prairie swales	TNHP	Peripheral.
C. tenax Sedge	Hardin	Pine-oak forests	TNHP	Peripheral.
Chloris texensis Fingergrass	Brazos, Brazoria, and Harris	Silty, loam soils and in coastal prairies	TNHP	Endemic. Very limited range.
Conyza bonariensis Conyza	Brazos and Orange		TNHP	Peripheral.
Coreopsis tripteris Tall coreopsis	Bowie	Thickets and wood edges	TNHP	Peripheral.
Crataegus warneri Hawthorn	Anderson, Cherokee, Morris, and Walker	Sandy woods and dry banks	TNHP	Endemic. Range limited to East Texas.
Cuphea carthagensis Waxweed	Hardin, Newton	Edge of low wet woods	TNHP	Peripheral.
Cypripedium calceolus var. pubescens Yellow ladyslipper	Cass, Harrison, Nacogdoches, Newton, and San Augustine	Hardwood slopes	TOES	Small populations occur in old growth communities. Peripheral.
Danthonia sericea Downy danthonia	Bowie	Pine and pine-hardwood forests	TNHP	Peripheral.
Dichanthelium clandestinum Dicanthelium	Bowie	Sandy woodlands	TNHP	Peripheral.

Appendix F. (Continued)

Scientific and common name[a]	Texas County location	Habitat	Listing agency or organization[b]	Comments
Dioclea multiflora Dioclea	Jasper and Tyler	Woods along creeks and rivers	TNHP	Peripheral.
Dryopteris cristata Crested shield fern	Bowie	Marshes, bogs, swamps, thickets, meadows, and springy wooded slopes	TNHP	Peripheral.
D. ludoviciana Shield fern	Hardin	Swamps, seepages at bases of bluffs, low wet woods, and stream banks	TNHP	Peripheral.
Eleocharis elongata Spikesedge	Hardin	Quiet waters of lakes and ponds	TNHP	Peripheral.
E. melanocarpa Spikesedge	Leon and Upshur	Moist, sandy soil, often in boggy loams	TNHP	Peripheral.
Eriocaulon kornickianum Smallhead pipewort	Brazos, Hardin, and Tyler	"Springy" places on prairies and wet sandy soil	TNHP	Three locations in Texas; also Southeast U.S.
Caura demareei Guara	Nacogdoches		TNHP	One known population in Texas, also in Arkansas.
Hedyotis purpurea Bluet	Newton	Open woods	TNHP	Peripheral.
Hibiscus dasycalyx Rose - mallow	Trinity	Marshes and along canals	TNHP	Endemic. Very restricted.
Ilex galbra Gallberry holly	Harrison	Low, sandy soil, usually in pine lands, pine barrens, and swamps	TNHP	Peripheral.
I. verticillata Black alder	Orange	Swamps, pond margins, river banks, and damp thickets	TNHP	Peripheral.
Leavenworth aurea Golden yelloweye	San Augustine	Limestone cedar glades and fossil outcrops	TNHP and TOES	One location in Texas and in southeast Oklahoma.

Appendix F. (Continued)

Scientific and common name[a]	Texas County location	Habitat	Listing agency or organization[b]	Comments
Lesquerella pallida White bladderpod	San Augustine	Moist, exposed Weches outcrops in small prairies	TOES	Only one known population, habitat limited. Endemic.
Liatris cymosa Gayfeather	Brazos, Burleson, Walker, and Washington	Tight, clayloam soil	TNHP	Endemic. Restricted to to limited area.
Liatris tenuis Gayfeather	Angelina, Jasper, Newton, Sabine, San Augustine, and Tyler	Open, pinewoods on sandy soil	THNP	Endemic. Limited range and very restricted habitat preference.
Magnolia fraseri Mountain magnolia	Jasper	Rich, wooded slopes	TNHP	Peripheral.
Ophioglossum nudicaule var. tenerum Adder's-tongue	Hardin	Grassy slopes, wet meadows, damp depressions in pinelands, moist open woods, and on the edge of bogs	TNHP	Peripheral.
Panicum flexile Wiry witchgrass	Red River	Moist soil of pastures and open woods	TNHP	Peripheral.
Parnassia asarifolia Grass-of-parnassus	Nacogdoches	Bogs, dam wooded slopes and wet creek bottoms	TNHP and TOES	Three known populations in Texas, one threatened by reservoir. Peripheral.
Parthenium hispidum Feverfew	Bowie	Dry woods and prairies	TNHP	Peripheral.
Phaseolus polystachios Wild bean	Harrison, Newton	Dry woods and sandy soil	TNHP	Peripheral.
Philadelphus pubescens Mock-orange	Red River	Wooded bluffs.	TNHP	Peripheral.
Phlox carolina ssp. angusta Phlox	Smith	Meadows	TNHP	Peripheral.

Appendix F. (Continued)

Scientific and common name[a]	Texas County location	Habitat	Listing agency or organization[b]	Comments
P. nivalis ssp. texensis Texas trailing phlox	Hardin and Tyler	Open grassy pinelands	TNHP and TOES	Low populations, restricted habitat. Endemic.
Polygonatum biflorum Great solomonseal	Angelina, Cass, Grayson, Hardin, Lamar, Sabine, San Augustine	Rich, moist, wooded slopes	TOES	Low populations. Peripheral.
Polygonatum parksii Jointweed	Atascosa, Bexar, Guadalupe, Leon, and Wilson	Deep, sandy soils	TNHP	Endemic. Limited populations.
Prenanthes altissima Rattlesnake root	Newton	Moist, rich beech woodlands	TNHP	Peripheral.
Psilotum nudum Whiskfern	Hardin	Swamps, and low, wet woods near bases of trees	TNHP	Peripheral.
Quercus boyntoni Oak	Angelina	Deep sands in loblolly pine forests	TNHP	Very limited distribution in Texas. Found in Alabama also.
Rhexia alifanus Meadow beauty	Hardin	Savannas, bogs, and peaty pinelands	TNHP	Peripheral.
Rhynchospora miliacea Milet breakrush	Tyler	Wooded slopes with springs and seepages	TNHP and TOES	One known population of a few individuals in Texas. Peripheral.
R. mixta Beak-rush	Nacogdoches	Sandy forested areas near streams	TNHP	Peripheral.
Sabatia brachiata Rose gentian	Hardin		TNHP	Peripheral.
S. campanulata Slender marsh-pink	Hardin	Sandy or peaty soil	TNHP	Peripheral.
Scirpus atrovirens Bulrush	Angelina	Moist loam	THNP	Peripheral.

Appendix F. (Continued)

Scientific and common name[a]	Texas County location	Habitat	Listing agency or organization[b]	Comments
S. divaricatus Elliott's bulrush	Hardin	Low wet woods and swamps	TNHP and TOES	One known population of a few individuals in Texas. Peripherial.
S. etuberculatus Bulrush	Hardin	Ponds, and fresh and brackish marshes	TNHP	Peripheral.
Scleria baldwinii Stone-rush	Harris	Moist soil	TNHP	Peripheral.
Scrophularia marilandica Carpenter's square	Red River	River terraces in rich woods and thickets	TNHP	Peripheral.
Setaria corrugata Bristlegrass	Jasper, Walker, and Harris	Along streams	THNP	Peripheral.
Smilax herbacea Carrion-flower	San Augustine	Moist soil in thickets along roadsides, and woodlands	TNHP	Peripheral.
Spiranthes parksii Navasota ladies tresses	Brazos, Burleson, Grimes, and Robertson	Open areas of oak woodlands	TNHP and TOES, Texas Parks and Wildlife (TPWD), U.S. Fish and Wildlife Service (USFWS)	Federal and State Endangered Species. Small populations and restricted habitat. Threatened by lignite mining and development. Endemic.
Stewartia malacodendron Silky camellia	Newton	Wooded banks, hillsides, and along streams	TNHP	Peripheral.
Talinum rogospermum Flameflower	Nacogdoches	Open disturbed areas on deep sandy soil	TNHP and TOES	Small populations in Texas. Peripheral.
Thalictrum texanum Houston meadow-rue	Gonzales and Hardin	Moist woodlands	TNHP	Endemic.
Trillium recurvatum Prairie trillium	Rusk and Nacogdoches	Alluvial banks in rich woodlands	TNHP and TOES	Very limited in Texas. Peripheral.

Appendix F. (Concluded)

Scientific and common name[a]	Texas County location	Habitat	Listing agency or organization[b]	Comments
T. texanum Texas trillium	Cass, Hardin, Houston, Nacogdoches, Panola, Smith, Tyler, and Wood	Carrizo Sand locals, low moist woods, bogs, and stream banks	TOES	Low populations and restricted habitat. Endemic.
Utricularia purpurea Purple bladderwort	Hardin	Pools of quiet water	TNHP	Peripheral.
Wahlenbergia marginata Wahlenbergia	Hardin	Savannas and beech forests.	TNHP	Peripheral.

[a] Sources:

Ajilvsgi 1979; Continental Shelf Associates 1985a; Correll and Correll 1972; Correll et al. 1970; Gould 1975; Moehring et al. 1978; Peterson and McKenny 1968; Poole 1975; Texas Organization for Endangered Species 1983; Texas Parks and Wildlife Department 1983a; Vines 1960.

[b] Listing agency or organization codes:

TNHP = Texas Natural Heritage Program
TOES = Texas Organization for Endangered Species
TPWD = Texas Parks and Wildlife Department
USFWS = U.S. Fish and Wildlife Service

APPENDIX G. FAUNA OF BOTTOMLAND HARDWOODS AND RELATED HABITATS OF EASTERN TEXAS AND OKLAHOMA (from Lee et al. 1980, Schmidly 1983, USFWS 1984, Brabander et al. 1985, and Dixon 1987)

Appendix G. Fauna of bottomland hardwoods and related habitats of eastern Texas and Oklahoma (from Lee et al. 1980, Schmidly 1983, USFWS 1984, Brabander et al. 1985, and Dixon 1987).

Common name	Scientific name	Distribution TX	Distribution OK
FISH:			
Chestnut lamprey	*Ichthyomyzon castaneus*	x	x
Southern brook lamprey	*I. gagei*	x	x
Paddlefish	*Polyodon spathula*	x	x
Shovelnose sturgeon	*Scaphirhynchus platorynchus*	x	x
Spotted gar	*Lepisosteus oculatus*	x	x
Longnose gar	*L. osseus*	x	x
Shortnose gar	*L. platostomus*	x	x
Alligator gar	*L. spatula*	x	x
Bowfin	*Amia calva*	x	x
American eel	*Anguilla rostrata*	x	x
Alabama shad	*Alosa alabamae*		x
Skipjack herring	*A. chrysochloris*	x	x
Gizzard shad	*Dorosoma cepedianum*	x	x
Threadfin shad	*D. petenense*	x	x
Goldeye	*Hiodon alosoides*	x	x
Mooneye	*H. tergisus*	x	x
Rainbow trout	*Salmo gairdneri*		x
Grass pickerel	*Esox americanus vermiculatus*	x	x
Chain pickerel	*E. niger*	x	x
Mexican tetra	*Astyanax mexicanus*	x	x
Stoneroller	*Campostoma anomalum*		x
Goldfish	*Carassius auratus*		x
Common carp	*Cyprinus carpio*	x	x
Grass carp	*Ctenopharyngodon idella*	x	x
Central silvery minnow	*Hybognathus nuchalis*	x	x
Cypress minnow	*H. hayi*	x	x
Plains minnow	*H. placitus*		x
Silver chub	*Hybopsis storeriana*	x	
Speckled chub	*H. aestivalis*	x	
Bigeye chub	*H. amblops*		x
Gravel chub	*H. x-punctata*		x
Redspot chub	*Nocomis asper*		x
Golden shiner	*Notemigonus crysoleucas*	x	
Emerald shiner	*Notropis atherinoides*	x	
Sharpnose shiner	*N. oxyrhynchus*	x	
Texas shiner	*N. amabilis*	x	
Ribbon shiner	*N. fumeus*	x	
Common shiner	*N. cornutus*	x	
Ironcolor shiner	*N. chalybaeus*	x	x
Striped shiner	*N. chrysocephalus*	x	x

Appendix G. (Continued)

Common name	Scientific name	Distribution TX	Distribution OK
Weed shiner	_N. texanus_	x	x
Red River shiner	_N. bairdi_	x	x
River shiner	_N. blennius_	x	x
Bigeye shiner	_N. boops_	x	x
Smalleye shiner	_N. buccula_	x	x
Bluntface shiner	_N. camurus_		x
Pugnose minnow	_N. emiliae_	x	x
Arkansas River shiner	_N. girardi_		x
Wedgespot shiner	_N. greenei_		x
Sabine shiner	_N. sabinae_	x	
Bluehead shiner	_N. hubbsi_	x	
Pallid shiner	_N. amnis_	x	x
Red shiner	_N. lutrensis_	x	x
Blackspot shiner	_N. atrocaudalis_	x	x
Ghost shiner	_N. buchanani_	x	
Taillight shiner	_N. maculatus_	x	x
Ozark minnow	_N. nubilus_		x
Kiamichi shiner	_N. ortenburgeri_		x
Peppered shiner	_N. perpallidus_		x
Duskystripe shiner	_N. pilsbryi_		x
Chub shiner	_N. potteri_	x	x
Rosyface shiner	_N. rubellus_		x
Silverband shiner	_N. shumardi_	x	x
Spotfin shiner	_N. spilopterus_		x
Sand shiner	_N. stramineus_	x	x
Redfin shiner	_N. umbratilis_	x	x
Blacktail shiner	_N. venustus_	x	x
Mimic shiner	_N. volucellus_	x	x
Steelcolor shiner	_N. whipplei_		x
Suckermouth minnow	_Phenacobius mirabilis_	x	x
Southern redbelly dace	_Phoxinus erythrogaster_		x
Mountain redbelly dace	_P. oreas_		x
Bluntnose minnow	_Pimephales notatus_	x	x
Fathead minnow	_P. promelas_	x	x
Slim minnow	_P. tenellus_		x
Bullhead minnow	_P. vigilax_	x	x
Creek chub	_Semotilus atromaculatus_	x	x
River carpsucker	_Carpiodes carpio_	x	x
Highfin carpsucker	_C. velifer_	x	x
White sucker	_Catostomus commersoni_		x
Blue sucker	_Cycleptus elongatus_	x	x
Creek chubsucker	_Erimyzon oblongus_	x	x
Lake chubsucker	_E. sucetta_	x	
Northern hog sucker	_Hypentelium nigricans_		x
Smallmouth buffalo	_Ictiobus bubalus_	x	x

Appendix G. (Continued)

Common name	Scientific name	Distribution TX	OK
Bigmouth buffalo	I. cyprinellus	x	x
Black buffalo	I. niger	x	x
Spotted sucker	Minytrema melanops	x	x
River redhorse	Moxostoma carinatum		x
Gray redhorse	M. congestum	x	
Black redhorse	M. duquesnei		x
Golden redhorse	M. erythrurum	x	x
Shorthead redhorse	M. macrolepidotum	x	x
Blacktail redhorse	M. poecilurum	x	
Blue catfish	Ictalurus furcatus	x	x
Black bullhead	I. melas	x	x
Yellow bullhead	I. natalis	x	x
Brown bullhead	I. nebulosus		x
Channel catfish	I. punctatus	x	x
Mountain madtom	Noturus eleutherus		x
Slender madtom	N. exilis		x
Stonecat	N. falvus		x
Tadpole madtom	N. gyrinus	x	x
Brindled madtom	N. miurus		x
Freckled madtom	N. nocturnus	x	x
Neosho madtom	N. placidus		x
Flathead catfish	Pylodictis olivaris	x	x
Ozark cavefish	Amblyopsis roase		x
Pirate perch	Aphredoderus sayanus	x	x
Atlantic needlefish	Strongylura marina	x	
Red River pupfish	Cyprinodon rubrofluviatilis	x	
Blair's starhead topminnow	Fundulus blairae	x	
Northern studfish	F. catenatus		x
Golden topminnow	F. chrysotus	x	
Starhead topminnow	F. notti	x	x
Blackstripe topminnow	F. notatus	x	x
Blackspotted topminnow	F. olivaceus	x	x
Plains topminnow	F. sciadicus		x
Plains killifish	F. zebrinus	x	x
Mosquitofish	Gambusia affinis	x	x
Sailfin molly	Poecilia latipinna	x	
Brook silverside	Labidesthes sicculus	x	x
Inland silverside	Menidia beryllina	x	x
Rough silverside	Membras martinica	x	
White bass	Morone chrysops	x	x
Yellow bass	M. mississippiensis	x	x
Striped bass	M. saxatilis	x	x
Rock bass	Ambloplites rupestris		x
Flier	Centrarchus macropterus	x	x
Banded pygmy sunfish	Elassoma zonatum	x	x

Appendix G. (Continued)

Common name	Scientific name	Distribution TX	Distribution OK
Warmouth	*Chaenobryttus gulosus*	x	x
Redbreast sunfish	*Lepomis auritus*	x	x
Green sunfish	*L. cyanellus*	x	x
Orangespotted sunfish	*L. humilis*	x	x
Bluegill	*L. macrochirus*	x	x
Dollar sunfish	*L. marginatus*	x	x
Longear sunfish	*L. megalotis*	x	x
Redear sunfish	*L. microlophus*	x	x
Spotted sunfish	*L. punctatus*	x	x
Bantam sunfish	*L. symmetricus*	x	x
Smallmouth bass	*Micropterus dolomieui*		x
Spotted bass	*M. punctulatus*	x	x
Largemouth bass	*M. salmoides*	x	x
Guadalupe bass	*M. treculi*	x	
White crappie	*Pomoxis annularis*	x	x
Black crappie	*P. nigromaculatus*	x	x
Western sand darter	*Ammocrypta clara*	x	x
Scaly sand darter	*A. vivax*	x	x
Crystal darter	*A. asprella*		x
Mud darter	*Etheostoma asprigene*	x	x
Greenside darter	*E. blennoides*		x
Swamp darter	*E. fusiforme*	x	x
Scaleyhead darter	*E. f. barrattii*		x
Bluntnose darter	*E. chlorosomum*	x	x
Creole darter	*E. collettei*	x	x
Arkansas darter	*E. cragini*		x
Fantail darter	*E. flabellare*		x
Slough darter	*E. gracile*	x	x
Harlequin darter	*E. histrio*	x	x
Least darter	*E. microperca*		x
Johnny darter	*E. nigrum*		x
Goldstripe darter	*E. parvipinne*	x	x
Cypress darter	*E. proeliare*	x	x
Stippled darter	*E. punctulatum*		x
Orangebelly darter	*E. radiosum*	x	x
Orangethroat darter	*E. spectabile*	x	x
Speckled darter	*E. stigmaeum*		x
Redfin darter	*E. whipplei*	x	x
Banded darter	*E. zonale*		x
Yellow perch	*Perca flavescens*		x
Logperch	*Percina caprodes*	x	x
Channel darter	*P. copelandi*	x	x
Blackside darter	*P. maculata*	x	x
Bigscale logperch	*P. macrolepida*	x	x
Longnose darter	*P. nasuta*		x

Appendix G. (Continued)

Common name	Scientific name	Distribution TX	OK
Leopard darter	*P. pantherina*		x
Slenderhead darter	*P. phoxocephala*	x	x
Dusky darter	*P. sciera*	x	x
River darter	*P. shumardi*	x	x
Sauger	*Stizostedion canadense*	x	x
Walleye	*S. vitreum vitreum*	x	x
Freshwater drum	*Aploidinotus grunniens*	x	x
Blue tilapia	*Tilapia aurea*	x	x
Mountain mullet	*Agonostomus monticola*	x	x
Striped mullet	*Mugil cephalus*	x	x
White mullet	*M. curema*	x	
Banded sculpin	*Cottus carolinae*		x
Hogchoker	*Trinectes maculatus*		x
AMPHIBIA:			
Two-toed amphiuma	*Amphiuma means*		x
Three-toed amphiuma	*A. tridactylum*	x	
Gulf Coast waterdog	*Necturus beyeri*	x	
Red River waterdog	*N. maculosis louisianensis*		x
Western lesser siren	*Siren intermedia nettingi*	x	x
Central newt	*Notophthalmus viridescens louisianensis*	x	x
Ringed salamander	*Ambystoma annalatum*		x
Spotted salamander	*A. maculatum*	x	x
Marbled salamander	*A. opacum*	x	x
Mole salamander	*A. talpoideum*	x	x
Smallmouth salamander	*A. texanum*	x	x
Eastern tiger salamander	*A. tigrinum tigrinum*	x	x
Barred tiger salamander	*A. t. mavortium*		x
Southern dusky salamander	*Desmognathus auriculatus*	x	
Central dusky salamander	*D. fuscus brumleyosum*		x
Four-toed salamander	*Hemidactylium scutatum*		x
Grotto salamander	*Typhlotriton spelaeus*		x
Slimy salamander	*Plethodon glutinosus glutinosus*	x	
Cave salamander	*Eurycea lucifuga*		x
Greybelly salamander	*E. multiplicata griseogaster*		x
Many-ribbed salamander	*E. m. multiplicata*		x
Oklahoma salamander	*E. tynerensis*		x
Dwarf salamander	*E. quadridigitata*	x	x
Hurter's spadefoot	*Scaphiopus holbrooki hurteri*	x	x
Dwarf American toad	*Bufo americanus charlesmithi*	x	x
Houston toad	*B. houstonensis*	x	

Common name	Scientific name	Distribution TX	Distribution OK
Gulf Coast toad	B. valliceps valliceps	x	
Woodhouse's toad	B. woodhousei woodhousei	x	x
Fowler's toad	B. w. fowleri		x
East Texas toad	B. w. velatus	x	x
Northern spring peeper	Hyla crucifer crucifer	x	x
Gray treefrog	H. versicolor	x	x
Cope's gray treefrog	H. chrysoscelis	x	x
Green treefrog	H. cinerea	x	x
Squirrel treefrog	H. squirella	x	
Eastern narrowmouth toad	Gastrophryne carolinensis	x	x
Great Plains narrowmouth toad	G. olivacea	x	
Blanchard's cricket frog	Acris crepitans blanchardi	x	x
Northern cricket frog	A. c. crepitans	x	
Spotted chorus frog	Pseudocris clarki	x	
Strecker's chorus frog	P. streckeri	x	x
Upland chorus frog	P. triseriate feriarum	x	x
Western chorus frog	P. t. triseriata		x
Northern crawfish frog	Rana aerolata circulosa		x
Southern crawfish frog	R. a. areolata	x	x
Green frog	R. clamitans melanota		x
Bronze frog	R. c. clamitans	x	x
Bullfrog	R. catesbeiana	x	x
Pig frog	R. grylio	x	
Pickerel frog	R. palustris	x	x
Southern leopard frog	R. sphenocephala	x	
REPTILLA			
American alligator	Alligator mississippiensis	x	x
Alligator snapping turtle	Macroclemys temmincki	x	x
Common snapping turtle	Chelydra serpentina serpentina	x	x
Razorback musk turtle	Sternotherus carinatus	x	x
Stinkpot	S. odoratus	x	x
Yellow mud turtle	Kinosternon flavescens flavescens	x	
Mississippi mud turtle	K. subrubrun hippocrepis	x	x
Map turtle	Graptemys geographica		x
Mississippi map turtle	G. kohni	x	x
Ouachita map turtle	G. pseudogeographica ouachitensis	x	x
Sabine map turple	G. p. sabinensis	x	
Slider	Pseudeyms concinna hieroglyphica		x
Texas River cooter	P. c. texana	x	

Appendix G. (Continued)

Common name	Scientific name	Distribution TX	Distribution OK
Metter's river cooter	P. metteri	x	
Missouri slider	Trachemys floridana hoyi		x
Southern painted turtle	T. picta dorsalis	x	x
Red-eared slider	T. scripta elegans	x	x
Three-toed box turtle	Terrapene carolina triunguis	x	x
Ornate box turtle	T. ornata ornata	x	x
Western chicken turtle	Deirochelys reticularia miaria	x	x
Midland smooth softshell	Trionyx muticus muticus	x	x
Western spiny softshell	T. spiniferus hartwegi		x
Pallid spiny softshell	T. s. pallidus	x	
Green anole	Anolis carolinensis	x	x
Brown anole	A. sagrei	x	
Ground skink	Scincella lateralis	x	x
Five-lined skink	Eumeces fasciatus	x	x
Broadhead skink	E. laticeps	x	x
Southern coal skink	E. anthracinus pluvialis	x	x
Southern prairie skink	E. septentrionalis obtusirostris	x	
Texas spotted whiptail	Cnemidophorus gularis	x	x
Six-lined racerunner	C. sexlineatus sexlineatus	x	x
Western slender glass lizard	Ophisaurus attenuatus attenuatus	x	
Northern fence lizard	Sceloporus undulatus hyacinthinus	x	
Texas glossy snake	Ariyona elegans arenicola	x	
Buttermilk racer	Coluber constrictor anthicus	x	
Tan racer	C. c. etheridgei	x	
Eastern yellowbelly racer	C. c. flaviventris	x	
Southern black racer	C. c. priapus	x	
Green water snake	Nerodia cyclopion	x	
Yellow-bellied water snake	N. erythrogaster flavigaster	x	x
Blotched water snake	N. e. transversa	x	x
Broad-banded water snake	N. fasciata confluens	x	x
Diamondback water snake	N. rhombifera rhombifera	x	x
Northern water snake	N. sipedon sipedon		x
Midland water snake	N. s. pleuralis	x	x
Graham's crayfish snake	Regina grahami	x	x
Gulf crayfish snake	R. rigida sinicola	x	x
Texas brown snake	Storeria dekayi texana	x	x
Florida redbelly snake	S. occipitomaculata obscura	x	
Checkered garter snake	Thamnophis marcianus marcianus	x	
Gulf Coast ribbon snake	T. proximus orarius	x	
Western ribbon snake	T. p. proximus	x	x
Red-sided garter snake	T. sirtalis parietalis	x	
Eastern garter snake	T. s. sirtalis	x	x

Appendix G. (Continued)

Common name	Scientific name	Distribution TX	Distribution OK
Central lined snake	*Tropidoclonion lineatum annectans*	x	
Western mud snake	*Farancia abacura reinwardti*	x	x
Dusty hognose snake	*Heterodon nasicus gloydi*	x	
Eastern hognose snake	*H. platyrhinos*	x	x
Texas night snake	*Hypsiglena torquata jani*	x	
Western worm snake	*Carphophis amoenus vermis*	x	x
Prairie ringneck snake	*Diadophis punctatus arnyi*	x	x
Mississippi ringneck snake	*D. p. stictogenys*	x	
Rough earth snake	*Virginia striatula*	x	
Western earth snake	*V. valeriae elegans*	x	
Texas coral snake	*Micrurus fulvius tenere*	x	
Eastern coachwhip	*Masticophis flagellum flagellum*	x	x
Western rough green snake	*Opheodrys aestivus majalis*	x	x
Eastern rough green snake	*O. a. aestivus*	x	
Western smooth green snake	*O. vernalis blanchardi*	x	
Texas rat snake	*Elaphe obsoleta lindheimeri*	x	
Corn snake	*E. guttata guttata*	x	
Great Plains rat snake	*E. g. emoryi*	x	
Black rat snake	*E. o. obsoleta*		x
Northern scarlet snake	*Cemophora coccinea lineri*	x	x
Louisiana pine snake	*Pituophis melanoleucus ruthveni*	x	
Bullsnake	*P. m. sayi*	x	x
Prairie kingsnake	*Lampropeltis calligaster calligaster*	x	
Central Plains milk snake	*L. triangulum gentilis*		x
Red milk snake	*L. t. syspila*		x
Louisiana milk snake	*L. t. amaura*	x	x
Speckled kingsnake	*L. getulus holbrooki*	x	x
Flathead snake	*Tantilla gracilis*	x	x
Northern flathead snake	*T. g. hallowelli*		x
Northern copperhead	*Agkistrodon contortrix mokeson*		x
Southern copperhead	*A. c. contortrix*	x	x
Western cottonmouth	*A. piscivorous leucostoma*	x	x
Western pigmy rattlesnake	*Sistrurus miliarius streckeri*	x	x
Canebrake rattlesnake	*Crotalus horridus atricaudatus*	x	
Timber rattlesnake	*Crotalus h. horridus*		x
BIRDS			
Common loon	*Gavia immer*	x	
Red-throated loon	*G. stellata*	x	

Appendix G. (Continued)

Common name	Scientific name	Distribution TX	OK
Pied-billed grebe	*Podilymbus podiceps*	x	
Horned grebe	*Podiceps auritus*	x	
Eared grebe	*P. nigricollis*	x	
Western grebe	*Aechmophorus occidentalis*	x	
White pelican	*Pelecanus erythrorhynchos*	x	
Double-crested cormorant	*Phalacrocorax auritus*	x	
Olivaceous cormorant	*P. olivaceus*	x	
Anhinga	*Anhinga anhinga*	x	x
Great blue heron	*Ardea herodias*	x	x
Green-backed heron	*Butorides striatus*	x	x
Cattle egret	*Bubulcus ibis*	x	
Great egret	*Casmerodius albus*	x	x
Little blue heron	*Egretta caerulea*	x	x
Snowy egret	*E. thula*	x	x
Tricolored heron	*E. tricolor*	x	x
Black-crowned night-heron	*Nycticorax nycticorax*	x	x
Yellow-crowned night-heron	*N. violaceus*	x	x
Least bittern	*Ixobrychus exilis*	x	x
American bittern	*Botaurus lentiginosus*	x	x
Roseate spoonbill	*Ajaia ajaja*	x	
Wood stork	*Mycteria americana*	x	x
White ibis	*Eudocimus albus*	x	
White-faced ibis	*Plegadis chihi*	x	x
Fulvous whistling duck	*Dendrocygna bicolor*	x	
Greater white-fronted goose	*Anser albifrons*	x	
Snow goose	*Chen caerulescens*	x	
Canada goose	*Branta canadensis*	x	
Northern pintail	*Anas acuta*	x	x
American wigeon	*A. americana*	x	
Green-winged teal	*A. crecca*	x	x
Northern shoveler	*A. clypeata*	x	
Cinnamon teal	*A. cyanoptera*	x	
Blue-winged teal	*A. discors*	x	x
Mottled duck	*A. fulvigula*	x	
Mallard	*A. platyrhynocs*	x	x
Black duck	*A. rubripes*	x	
Gadwall	*A. strepera*	x	
Wood duck	*Aix sponsa*	x	x
Lesser scaup	*Aythya affinis*	x	
Redhead	*A. americana*	x	
Ring-necked duck	*A. collaris*	x	x
Greater scaup	*A. marila*	x	
Canvasback	*A. valisineria*	x	
Oldsquaw	*Clangula hyemalis*	x	
White-winged scoter	*Melanitta fusca*	x	

Common name	Scientific name	Distribution TX	Distribution OK
Black scoter	M. nigra	x	
Surf scoter	M. perspicillata	x	
Common goldeneye	Bucephala clangula	x	
Bufflehead	B. albeola	x	
Hooded merganser	Lophodytes cucullatus	x	
Common merganser	Mergus merganser	x	
Red-breasted merganser	M. serrator	x	
Ruddy duck	Oxyura jamaicensis	x	
Black vulture	Coragyps atratus	x	x
Turkey vulture	Cathartes aura	x	
American swallow-tailed kite	Elanoides forficatus	x	x
Mississippi kite	Ictinia mississippiensis	x	
Sharp-shinned hawk	Accipiter striatus	x	x
Cooper's hawk	A. cooperii	x	x
Red-tailed hawk	Buteo jamaicensis	x	x
Rough-legged hawk	B. lagopus	x	
Red-shouldered hawk	B. lineatus	x	x
Broad-winged hawk	B. platypterus	x	x
Swainson's hawk	B. swainsoni	x	
Northern harrier	Circus cyaneus	x	x
Golden eagle	Aquila chrysaetos	x	x
Bald eagle	Haliaeetus leucocephalus	x	x
Osprey	Pandion haliaetus	x	x
Merlin	Falco columbarius	x	x
Peregrine falcon	F. peregrinus	x	x
Eastern turkey	Meleagris gallopavo	x	x
King rail	Rallus elegans	x	
Virginia rail	R. limicola	x	
Northern bobwhite	Colinus virginianus	x	x
Sora	Porzana carolina	x	
Yellow rail	Coturnicops noveboracensis	x	
Purple gallinule	Porphyrula martinica	x	x
Common moorhen (Common gallinule)	Gallinula chloropus	x	
American coot	Fulica americana	x	
Sandhill crane	Grus canadensis	x	
Whooping crane	G. americana	x	
Black-bellied plover	Pluvialis squatarola	x	
Lesser golden-plover (American golden-plover)	P. dominica	x	
Snowy plover	Charadrius alexandrinus	x	
Piping plover	C. melodus	x	
Semipalmated plover	C. semipalmatus	x	
Killdeer	C. vociferus	x	
Wilson's plover	C. wilsonia	x	
American avocet	Recurvirostra americana	x	

Common name	Scientific name	Distribution TX	OK
Greater yellowlegs	*Tringa melanoleuca*	x	
Lesser yellowlegs	*T. flavipes*	x	
Solitary sandpiper	*T. solitaria*	x	
Willet	*Catoptrophorus semipalmatus*	x	
Spotted sandpiper	*Actitis macularia*	x	
Whimbrel (Hudsonian curlew)	*Numenius phaeopus*	x	
Long-billed curlew	*N. americanus*	x	
Upland plover	*Bartramia longicauda*	x	
Hudsonian godwit	*Limosa haemastica*	x	
Marbled godwit	*L. fedoa*	x	
Ruddy turnstone	*Arenaria interpres*	x	
Red knot	*Calidris canutus*	x	
Sanderling	*C. alba*	x	
Dunlin (red-backed sandpiper)	*C. alpina*	x	
Baird's sandpiper	*C. bairdii*	x	
White-rumped sandpiper	*C. fuscicollis*	x	
Stilt sandpiper	*C. himantopus*	x	
Western sandpiper	*C. mauri*	x	
Pectoral sandpiper	*C. melanotos*	x	
Least sandpiper	*C. minutilla*	x	
Semipalmated sandpiper	*C. pusilla*	x	
Short-billed dowitcher	*Limnodromus griseus*	x	
Long-billed dowitcher	*L. scolopaceus*	x	
Common snipe	*Gallinago gallinago*	x	
American woodcock	*Scolopax minor*	x	x
Wilson's phalarope	*Phalaropus tricolor*	x	
Red phalarope	*P. fulicaria*	x	
Red-necked phalarope	*P. lobatus*	x	
Herring gull	*Larus argentatus*	x	
Laughing gull	*L. atricilla*	x	
Ring-billed gull	*L. delawarensis*	x	
Bonaparte's gull	*L. philadelphia*	x	
Franklin's gull	*L. pipixcan*	x	
Least tern	*Sterna antillarum*	x	x
Caspian tern	*S. caspia*	x	
Forster's tern	*S. forsteri*	x	
Common tern	*S. hirundo*	x	
Black tern	*Chilidonias niger*	x	
Mourning dove	*Zenaida macroura*	x	x
Yellow-billed cuckoo	*Coccyzus americanus*	x	x
Black-billed cuckoo	*C. erythropthalmus*	x	x
Common barn-owl	*Tyto alba*	x	x
Eastern screech-owl	*Otus asio*	x	x
Great horned owl	*Bubo virginianus*	x	x
Barred owl	*Strix varia*	x	x

Appendix G. (Continued)

Common name	Scientific name	Distribution TX	Distribution OK
Short-eared owl	Asio flammeus	x	
Long-eared owl	A. otus	x	x
Chuck-will's-widow	Caprimulgus carolinensis	x	x
Whip-poor-will	C. vociferus	x	
Chimney swift	Chaetura pelagica	x	x
Black-chinned hummingbird	Archilochus alexandri	x	
Ruby-throated hummingbird	A. colubris	x	x
Rufous hummingbird	Selasphorus rufus	x	
Belted kingfisher	Caryle alcyon	x	x
Yellow-bellied sapsucker	Sphyrapicus varius	x	
Northern flicker	Colaptes auratus	x	x
Pileated woodpecker	Dryocopus pileatus	x	x
Red-bellied woodpecker	Melanerpes carolinus	x	x
Red-headed woodpecker	M. erythrocephalus	x	x
Red-cockaded woodpecker	Picoides borealis	x	x
Downy woodpecker	P. pubescens	x	x
Hairy woodpecker	P. villosus	x	x
Eastern kingbird	Tyrannus tyrannus	x	x
Great crested flycatcher	Myiarchus crinitus	x	x
Eastern phoebe	Sayornis phoebe	x	x
Alder flycatcher	Empidonax alnorum	x	
Yellow-bellied flycatcher	E. flaviventris	x	
Least flycatcher	E. minimus	x	x
Willow flycatcher	E. traillii	x	x
Acadian flycatcher	E. virescens	x	x
Olive-sided flycatcher	Contopus borealis	x	
Eastern wood-pewee	C. virens	x	x
Vermilion flycatcher	Pyrocephalus rubinus	x	
Purple martin	Progne subis	x	
Tree swallow	Tachycineta bicolor	x	x
Bank swallow	Riparia riparia	x	x
Barn swallow	Hirundo rustica	x	
Cliff swallow	H. pyrrhonata	x	x
Southern rough-winged swallow	Stelgidopteryx ruficollis	x	x
Northern rough-winged swallow	S. serripennis	x	
Blue jay	Cyanocitta cristata	x	x
American crow	Corvus brachyrhynchos	x	x
Fish crow	C. ossifragus	x	x
Tufted titmouse	Parus bicolor	x	x
Carolina chickadee	P. carolinensis	x	x
Red-breasted nuthatch	Sitta canadensis	x	x
White-breasted nuthatch	S. carolinensis	x	x
Brown-headed nuthatch	S. pusilla	x	
Brown creeper	Certhia americana	x	
House wren	Troglodytes aedon	x	x

Appendix G. (Continued)

Common name	Scientific name	Distribution TX	OK
Winter wren	*T. troglodytes*	x	x
Bewick's wren	*Thryomanes bewickii*	x	x
Carolina wren	*Thryothorus ludovicianus*	x	x
Marsh wren	*Cistothorus palustris*	x	
Sedge wren	*C. platensis*	x	
Northern mockingbird	*Mimus polyglottos*	x	x
Gray catbird	*Dumetella carolinensis*	x	x
Brown thrasher	*Toxostoma rufum*	x	x
American robin	*Turdus migratorius*	x	x
Wood thrush	*Hylocichla mustelina*	x	x
Veery	*Catharus fuscescens*	x	x
Hermit thrush	*C. guttatus*	x	x
Gray-cheeked thrush	*C. minimus*	x	
Swainson's thrush	*C. ustulatus*	x	x
Eastern bluebird	*Sialis sialis*	x	x
Blue-gray gnatcatcher	*Polioptila caerulea*	x	x
Ruby-crowned kinglet	*Regulus calendula*	x	x
Golden-crowned kinglet	*R. satrapa*	x	
Water pipit	*Anthus spinoletta*	x	
Sprague's pipit	*A. spragueii*	x	
Cedar waxwing	*Bombycilla cedrorum*	x	x
Bell's vireo	*Vireo bellii*	x	x
Yellow-throated vireo	*V. flavifrons*	x	x
Warbling vireo	*V. gilvus*	x	x
White-eyed vireo	*V. griseus*	x	x
Red-eyed vireo	*V. olivaceus*	x	x
Philadelphia vireo	*V. philadelphicus*	x	x
Solitary vireo	*V. soltarius*	x	x
Black-and-white warbler	*Mniotilta varia*	x	x
Prothonotary warbler	*Protonotaria citrea*	x	x
Swainson's warbler	*Limnothlypis swainsonii*	x	x
Worm-eating warbler	*Helmitheros vermivorus*	x	x
Bachman's warbler	*Vermivora bachmanii*	x	
Orange-crowned warbler	*V. celata*	x	x
Golden-winged warbler	*V. chrysoptera*	x	x
Tennessee warbler	*V. peregrina*	x	x
Blue-winged warbler	*V. pinus*	x	x
Nashville warbler	*V. ruficapilla*	x	x
Northern parula	*Parula americana*	x	x
Black-throated blue warbler	*Dendroica caerulescens*	x	x
Bay-breasted warbler	*D. castanea*	x	x
Cerulean warbler	*D. cerulea*	x	x
Yellow-rumped warbler	*D. coronata*	x	x
Yellow-throated warbler	*D. dominica*	x	x
Blackburnian warbler	*D. fusca*	x	x

Appendix G. (Continued)

Common name	Scientific name	Distribution TX	OK
Magnolia warbler	*D. magnolia*	x	x
Black-throated gray warbler	*D. nigrescens*	x	
Palm warbler	*D. palmarum*	x	x
Chestnut-sided warbler	*D. pensylvanica*	x	x
Yellow warbler	*D. petechia*	x	x
Pine warbler	*D. pinus*	x	
Blackpoll warbler	*D. striata*	x	x
Cape May warbler	*D. tigrina*	x	x
Black-throated green warbler	*D. virens*	x	x
Ovenbird	*Seiurus aurocapillus*	x	x
Louisiana waterthrush	*S. motacilla*	x	x
Northern waterthrush	*S. noveboracensis*	x	x
Connecticut warbler	*Oporornis agilis*	x	
Kentucky warbler	*O. formosus*	x	x
Mourning warbler	*O. philadelphia*	x	
Common yellowthroat	*Geothlypis trichas*	x	x
Yellow-breasted chat	*Icteria virens*		x
Canada warbler	*Wilsonia canadensis*		x
Hooded warbler	*W. citrina*	x	x
Wilson's warbler	*W. pusilla*	x	x
American redstart	*Setophaga ruticilla*	x	x
Northern oriole	*Icterus galbula*	x	x
Orchard oriole	*I. spurius*	x	x
House Sparrow	*Passer domesticus*	x	x
Bobolink	*Dolichonyx oryzivorus*	x	
Red-winged blackbird	*Agelaius phoeniceus*	x	x
Yellow-headed blackbird	*Xanthocephalus xanthocephalus*	x	
Rusty blackbird	*Euphagus carolinus*	x	x
Brewer's blackbird	*E. cyanocephalus*	x	
Boat-tailed grackle	*Quiscalus major*	x	
Great-tailed grackle	*Q. mexicanus*	x	x
Common grackle	*Q. quiscula*	x	x
Brown-headed cowbird	*Molothrus ater*	x	x
Western tanager	*Piranga ludoviciana*	x	
Scarlet tanager	*P. olivacea*	x	x
Summer tanager	*P. rubra*	x	x
Northern cardinal	*Cardinalis cardinalis*	x	x
Rose-breasted grosbeak	*Pheucticus ludovicianus*	x	x
Black-headed grosbeck	*P. melanocephalus*	x	
Blue grosbeak	*Guiraca caerulea*	x	x
Painted bunting	*Passerina ciris*	x	x
Indigo bunting	*P. cyanea*	x	x
Evening grosbeck	*Coccothraustes vespertina*		x
Purple finch	*Carpodacus purpureus*	x	x
Red crossbill	*Loxia curvirostra*	x	

Appendix G. (Continued)

Common name	Scientific name	Distribution TX	OK
Pine siskin	*Carduelis pinus*	x	
American goldfinch	*C. tristis*	x	x
Green-tailed towhee	*Pipilo chlorurus*	x	
Rufous-sided towhee	*P. erythrophtalmus*	x	x
Sharp-tailed sparrow	*Ammodramus caudacutus*	x	
Henslow's sparrow	*A. henslowii*	x	
Le Conte's sparrow	*A. leconteii*	x	x
Dark-eyed junco	*Junco hyemalis*	x	x
White-throated sparrow	*Zonotrichia albicollis*	x	x
White-crowned sparrow	*Z. leucophrys*	x	x
Harris' sparrow	*Z. querula*	x	x
Fox sparrow	*Passerella iliaca*	x	x
Savannah sparrow	*Passerculus sandwichensis*	x	
Swamp sparrow	*Melospiza georgiana*	x	x
Lincoln's sparrow	*M. lincolnii*	x	x
Song sparrow	*M. melodia*	x	x
American tree sparrow	*Spizella arborea*	x	
Clay-colored sparrow	*S. pallida*	x	
Chipping sparrow	*S. passerina*	x	
MAMMALS			
Virginia opossum	*Didelphis virginiana*	x	x
Northern shorttail shrew	*Blarina brevicauda*		x
Southern shorttail shrew	*B. carolinensis*	x	x
Least shrew	*Cryptotis parva*	x	x
Southeastern shrew	*Sorex longirostris*		x
Eastern mole	*Scalopus aquaticus*	x	x
Southeastern myotis	*Myotis austroriparius*	x	x
Gray bat	*M. grisescens*		x
Keen's myotis	*M. keeni*		x
Little brown myotis	*M. lucifugus*		x
Indiana bat	*M. sodalis*		x
Small-footed myotis	*M. leibii*		x
Silver-haired bat	*Lasionycteris noctivagans*	x	x
Eastern pipistrelle	*Pipistrellus subflavus*	x	x
Red bat	*Lasiurus borealis*	x	x
Hoary bat	*L. cinereus*	x	x
Northern yellow bat	*L. intermedius*	x	
Seminole bat	*L. seminolus*	x	x
Big brown bat	*Eptesicus fuscus*	x	x
Evening bat	*Nycticeius humeralis*	x	x
Brazilian free-tailed bat	*Tadarida brasiliensis*	x	
Rafinesque's big-eared bat	*Plecotus rafinesquii*	x	x

Appendix G. (Concluded)

Common name	Scientific name	Distribution TX	OK
Ozark big-eared bat	P. towndsendii ingens		x
Black bear	Ursus americanus		x
Raccoon	Procyon lotor	x	x
Long-tailed weasel	Mustela frenata	x	x
Mink	M. vison	x	x
River otter	Lutra canadensis	x	x
Badger	Taxidea taxus	x	
Eastern spotted skunk	Spilogale putorius	x	x
Striped skunk	Mephitis mephitis	x	x
Hog-nosed skunk	Conepatus mesoleucus	x	
Coyote	Canis latrans	x	x
Red fox	Vulpes vulpes	x	x
Gray fox	Urocyon cinereoargenteus	x	x
Ringtail cat	Bassariscus astutus	x	
Bobcat	Lynx rufus	x	x
Cougar	Felis concolor	x	x
Eastern chipmunk	Tamias straiatus		x
Gray squirrel	Sciurus carolinensis	x	x
Fox squirrel	S. niger	x	x
Southern flying squirrel	Glaucomys volans	x	x
Attwater's pocket gopher	Geomys attwateri	x	
Plains pocket gopher	G. bursarius	x	
Beaver	Castor canadensis	x	x
Fulvous harvest mouse	Reithrodontomys fulvescens	x	x
Eastern harvest mouse	R. humulis		x
Brush mouse	Peromyscus boylei		x
Cotton mouse	P. gossypinus	x	x
White-footed mouse	P. leucopus	x	x
Golden mouse	Ochrotomys nuttali	x	x
Eastern woodrat	Neotoma floridana	x	x
Marsh rice rat	Oryzomys palustris	x	x
Woodland vole	Pitymys pinetorum	x	
Muskrat	Ondatra zibethicus	x	x
Nutria	Myocastor coypus	x	x
Swamp rabbit	Sylvilagus aquaticus	x	x
Eastern cottontail	S. floridanus	x	x
Feral hog	Sus scrofa	x	
White-tailed deer	Odocoileus virginianus	x	x
Nine-banded armadillo	Dasypus novemcinctus	x	x

APPENDIX H. FAUNA OF SPECIAL CONCERN IN EASTERN OKLAHOMA (from Brabander et al. 1985)

Appendix H. Fauna of special concern in eastern Oklahoma (from Brabander et al. 1985).

Species	Scientific name	Remarks/characteristics
Fish (endangered)		
Shovelnose sturgeon	*Scaphirynchus platorynchus*	Spawn in smaller streams in spring
Ironcolor shiner	*Notropis chalybaeus*	Closely associated with floodplain wetlands
Arkansas darter	*Etheostoma cragini*	Utilizes spring-fed streams
Scaleyhead darter	*E. fusiforme barrattii*	Oxbow wetlands very important
Leopard darter	*Percina pantherina*	Utilizes pool/riffle habitats of Little River system
Chain pickerel	*Esox niger*	Found in quiet water with macrophytic development
Alabama shad	*Alosa alabamae*	Inhabits larger, clear streams
Mooneye	*Hiodon tergisus*	Requires clear waters of larger streams
Bigeye chub	*Hybopsis amblops*	Prefers clear, moderate gradient streams
Fish (rare)		
Pallid shiner	*Notropis amnis*	Utilizes clear, larger streams
Blackspot shiner	*N. atrocaudalis*	Found in lower portions of Little River
River shiner	*N. blennius*	Inhabits larger rivers of study area
Peppered shiner	*N. perpallidus*	Found in lower reaches of tributary streams of the Little and Kiamichi systems
Spotfin shiner	*N. spilopterus*	Known only from Illinois River in Oklahoma
Bluntface shiner	*N. camurus*	Inhabits clear, gravel-bottomed streams in northeast Oklahoma
Tailight shiner	*N. maculatus*	Found in oxbow and floodplain wetlands
Kiamichi shiner	*N. ortenburgeri*	Utilizes clear, moderate-sized streams
Mountain madtom	*Noturus eleutherus*	Found in clear, large, swift streams of Little River system
Neosho madtom	*N. placidus*	Inhabits gravel bars of Neosho and Illinois River systems
Ozark cavefish	*Amblyopsis rosae*	Utilize caves in northeast Oklahoma
Crystal darter	*Ammocrypta asprella*	Inhabits clear, sandy streams of Little River system
Goldstripe darter	*Etheostoma parvipinne*	Found in spring-fed streams with macrophyte development
Least darter	*E. microperca*	Inhabits clear, vegetated streams
Blackside darter	*Percina maculata*	Utilizes deep riffles of clear streams
Longnose darter	*P. nasuta*	Restricted to Lee Creek in Oklahoma
Highfin carpsucker	*Carpiodes velifer*	Prefers larger, clear streams
Blue sucker	*Cycleptus elongatus*	Utilize deep, swift streams, tailwaters
Shorthead redhorse	*Moxostoma macrolepidotum*	Clear, gravel-bottomed streams used
Brown bullhead	*Ictalurus nebulosus*	Found in quiet waters of Little River system
Yellow bass	*Morone mississippiensis*	Spawns over sand and gravel in Little River system
Goldeye	*Hiodon alosoides*	Inhabits larger rivers of east and southeast Oklahoma

Appendix H. (Continued)

Species	Scientific name	Remarks/characteristics
Amphibians (rare)		
Ringed salamander	Ambystoma annulatum	Utilize pools and shallow lakes
Four-toed salamander	Hemidactylium scutatum	Occurs only in sphagnum bogs
Amphiuma	Amphiuma means	Occurs in sloughs and bayous of Red River drainage
Oklahoma salamander	Eurycea tynerensis	Found in clear, rubble bottomed streams
Mole salamander	Ambystoma talpoideum	Utilize crayfish burrows in southeast Oklahoma
Grotto salamander	Typhlotriton spelaeus	Associated with cave habitats
Dwarf salamander	Eurycea quadridigitata	Utilizes floodplain wetlands
Lesser siren	Siren intermedia	Aquatic species, utilizes backwater and floodplain wetlands
Hurter's spadefoot	Scaphiopus holbrooki hurteri	Inhabits BLH habitat
Green tree frog	Hyla cinerea	Occurs in floodplain wetlands of Red River system
Gopher frog	Rana areolata	Often utilizes crayfish burrows
Pickerel frog	R. palustris	Utilizes floodplain wetlands in extreme eastern Oklahoma
Reptiles (endangered)		
American alligator	Alligator mississippiensis	Utilizes floodplain wetlands in extreme southeastern Oklahoma
Reptiles (rare)		
Scarlet snake	Cemophora coccinea	Confined to old-growth timber
Mississippi map turtle	Graptemys kohni	Rivers, lakes and sloughs with mud buttoms
Mud snake	Farancia abacura	Occurs in floodplain wetlands
Smooth earth snake	Virginia valeriae	Utilizes disturbed area in or near BLH
Southern painted turtle	Chrysemys picta dorsalis	Found in coastal plains in Red River drainages
Birds (endangered)		
American swallow-tailed kite	Elanoides forficatus	Found in floodplain wetlands, streams
Bald eagle	Haliaeetus leucocephalus	Nests near large streams, wetland habitats
Red-cockaded woodpecker	Picoides borealis	Normally inhabits shortleaf pine habitat but may occasionally be found in riparian habitat
Anhinga	Anhinga anhinga	Utilize floodplain wetlands
Birds (rare)		
Purple gallinule	Porphyrula martinica	Found in floodplain wetlands in extreme southern Oklahoma

Appendix H. (Concluded)

Species	Scientific name	Remarks/characteristics
Mammals (endangered)		
Gray bat	*Myotis grisescens*	Feeds along streams in BLH habitat
Indiana bat	*M. sodalis*	Utilizes cave habitat, feeds along streams
Swamp rabbit	*Sylvilagus aquaticus*	Found exclusively in BLH habitat
River otter	*Lutra canadensis*	Utilizes streams bordering BLH habitat
Cougar	*Felis concolor*	Hunts in BLH habitat
Mammals (rare)		
Ozark big-eared bat	*Plecotus townsendii ingens*	Favors limestone caves, feeds along streams
Eastern big-eared bat	*P. rafinesquii*	Roosts in hollow trees, feeds along streams
Southeastern myotis	*Myotis austroriparius*	Closely associated with water in feeding, roosts in hollow trees
Little brown myotis	*M. lucifugus*	Known only from Beaver's Bend Park
Eastern harvest mouse	*Reithnodontomys humulis*	Inhabits floodplain marshes
Golden mouse	*Ochrotomys nuttalli*	Found in dense BLH habitat
Rice rat	*Oryzomys palustris*	Utilizes floodplain wetlands
Southeastern shrew	*Sorex longirostris*	Found in floodplain wetlands
Seminole bat	*Lasiurus seminolus*	Forest species utilizing BLH habitat

APPENDIX I. FAUNA OF SPECIAL CONCERN IN EASTERN TEXAS

Appendix I. Fauna of special concern in eastern Texas.

Scientific and common name[a]	East Texas location	Habitat	Authority[b]	Comments
INVERTEBRATES				
Vertigo oralis	Brazos County	Terrestrial	Neck 1984	Peripheral. Known throughout southeastern U.S.
V. oscarlana	Austin and Ball Counties	Leaf-letter microhabitat	Neck 1984	Peripheral. County records lacking for the study area, but presence is possible since this species occurs throughout the southeast.
Strobilops labyrinthica	Harris County	Terrestrial	Neck 1984	Peripheral. Found throughout eastern U.S. to Great Plains and Canada.
S. hubbardi	Ellis County	Terrestrial	Neck 1984	Peripheral. Coastal plain of the southeast.
Succinea unicolor	Panola County	Terrestrial	Neck 1984	Peripheral. Ranges over much of southeastern U.S.
Mesomphix globosus	Four counties in Deep East Texas	Terrestrial	Neck 1984	Peripheral. Southeastern U.S.
Ventridens intertextus	Four counties in southeast Texas	Terrestrial	Neck 1984	Peripheral. Occurs from Southern Canada and Eastern U.S.
Stenotrema stenotrema	Two locations in Newton County	Terrestrial	Neck 1984	Peripheral. Occurs over most of southeast U.S.
Mesodon inflectus	Angelina, Newton, Red River, Morris, and Orange Counties	Open, hardwood forests	Neck 1984	Peripheral. Occurs in midwest and southeast U.S.
Triodopsis divesta	Harrison County	Terrestrial	Neck 1984	One Texas population and in Arkansas, Kansas, Louisiana, Oklahoma, and Missouri
Pomacea paludosa	Harris County	Freshwater	Neck 1984	No recent Texas records. Also found in Florida and Georgia.

Appendix I. (Continued)

Scientific and common name[a]	East Texas location	Habitat	Authority[b]	Comments
Fusconaia askew	Sabine, Neches, Trinity, and San Jacinto River Systems	Freshwater	Neck 1984	Locally common, but status over entire range is not clear.
F. lananensis	West to San Jacinto River	Freshwater	Neck 1984	Recommended for rare and endangered status.
Pleurobema riddelli	West to San Jacinto River	Freshwater	Neck 1984	Endangered status recommended.
Quadrula quadrula	Neches River and tributaries	Freshwater	Neck 1984	Widespread. Mississippi drainage, Great Lakes, Red River (North Dakota), and various Gulf drainages.
Lampsilis satura	Sabine/Neches, Trinity and San Jacinto River drainages	Freshwater	Neck 1984	Also found in western Louisiana.
Potamilus amphichaenus	Sabine River drainage	Freshwater	Neck 1984	May also occur in Brazos River.
Truncilla donaciformis	East and Central Texas	Freshwater	Neck 1984	Found in a large portion of the Mississippi River drainage.
FISHES				
Icthyomyzon castaneus Chestnut lamprey	Northeast Texas		TNHP	Peripheral species.
Polyodon spathula Paddlefish	Red and Sabine Rivers, formerly Trinity	Large rivers	TNHP TPWD-E* TOES-T*	Threatened by reservoirs. Depleted.
Scaphirynchus platorynchus Shovelnose sturgeon	Red River	Large rivers	TPWD-E* TOES-T*	Threatened by reservoirs and diversions. Depleted.

Appendix I. (Continued)

Scientific and common name[a]	East Texas location	Habitat	Authority[b]	Comments
Hybognathus hayi Cypress minnow	Northeast Texas		TNHP	Peripheral.
Notropis bairdi Red River shiner	Northcentral Texas Red River		TNHP	Restricted. Endemic to Red River Valley.
N. buccula Smalleye shiner	S. Blacklands		TNHP	Endemic.
N. chalybaeus Ironcolor shiner	Deep East Texas		TNHP	Peripheral.
N. hubbsi Bluehead shiner	Northeast Texas		TNHP	Peripheral.
N. maculatus Tailight shiner	Northeast Texas		TNHP	Peripheral.
N. oxyrhynchus Sharpnose shiner	Western-East Texas		TNHP	Endemic.
N. sabinae Sabine shiner	Deep East Texas Extreme Northeast Coast		TNHP	Limited distribution.
Phenacobius mirabilis Suckermouth minnow	East Texas		TNHP	Limited distribution.
Cycleptus elongatus Blue sucker	East Texas		TNHP, TPWD-PN*	Depleted.
Erimyzon oblongus Creek chubsucker	East Texas		TNHP	Depleted.
Maxostoma poecilurum Blacktail redhorse	East Texas		TNHP	Limited distribution.
Etheostoma asprigene Mud darter	Deep East Texas		TNHP	Peripheral.
E. histrio Harlequin darter	Deep East Texas		TNHP	Peripheral.
E. parvipinne Goldstripe darter	East Texas		TNHP	Peripheral.

Appendix I. (Continued)

Scientific and common name[a]	East Texas location	Habitat	Authority[b]	Comments
Percina shumardi River darter	East Texas		TNHP, TPWD-PN*	Limited distribution.
Ammocrypta clara Western sand darter	East Texas		TNHP, TPWD-PN*	Limited distribution.
AMPHIBIANS				
Ambystoma talpoideum Mole salamander	Jasper and Nacogdoches Counties	Burrows in lowland woodlands	TNHP, TPWD-PH*, TOES-WL*	Peripheral.
Rana grylio Pig frog	Hardin and Newton Counties	Strongly aquatic, edges of lakes, marshes, and swamps	TNHP	Peripheral.
REPTILES				
Alligator mississippiensis American alligator	East Texas	Marshes, swamps, rivers, lakes	TNHP, TOES-T*, USFWS-T*	Increasing. Once threatened with extirpation.
Graptemys pseudogeographica sabinensis Sabine map turtle	East Texas	Rivers, streams, swamps	TNHP	Limited distribution.
Phrynosoma cornutum Texas horned lizard	East Texas	Dry, sandy areas	TOES-T*, TPWD-PN*	Declining. Pesticide usage and commercial exploitation.
Carphophis amoenus Western worm snake	Bowie and Red Counties	Moist earth	TNHP	Peripheral.
Cemophora coccinea Scarlet snake	Scattered Counties in East Texas	In or near soils suitable for burrowing (sand and loam)	TNHP	Peripheral.
Pituophis melanoleucus ruthveni Louisiana pine snake	East Texas	Longleaf pinewoods, sandy soils	TNHP, TOES-T* TPWD-PN*	Extremely limited distribution. Urbanization threats.

Appendix I. (Continued)

Scientific and common name[a]	East Texas location	Habitat	Authority[b]	Comments
Lampropeltis triangulum annulata Louisiana milk snake	East Texas	Longleaf pinewoodss, sandy soils	TNHP, TOES-T* TPWD-PN*	Extremely limited distribution. Urbanization threats.
Storeria occipitomaculata Redbelly snake	East Texas	Woods, floodplains, and bogs	TNHP	Limited distribution.
BIRDS				
Plegadis chihi White-faced ibis	East Texas	Coastal marshes, inland marshes, and swamps	TOES-T*, TPWD-PN*	Migrant.
Ajala ajaja Roseate spoonbill	Southeast Texas	Coastal marshes, inlands marshes, and swamps	TNHP	Migrant.
Mycteria americana Wood stork	East Texas	Swamps, bottomland lakes	TPWD-PN*	Formerly nesting. Migrant.
Dendrocygna bicolor Fulvous whistling-duck	Southeast Texas	Freshwater marshes and prairies	TOES-T*	Migrant.
Pandion haliaetus Osprey	East Texas	Open water, wetlands	TNHP, TPWD-PN*	Nesting? Migrant.
Elanoides forficatas American swallow-tailed kite	Southeast Texas	Bottomlands	TNHP, TOES-T*, TPWD-PN*	Formerly nesting and perhaps now rarely.
Haliaeetas leucocephalus Bald eagle	East Texas	Bottomlands, lakes, large rivers	TNHP, TOES-E*, TPWD-E*, USFWS-E*	Rare nesting species. More common in winter.
Aquila chrysaetos Golden eagle	East Texas	Hilly County and open country	TOES-T*	Winter transient.
Falco peregrinus Peregrine falcon	East Texas	Various habitats	TNHP, TOES-E*, TPWD-E*, USFWS-E*	Migrant.
F. columbarius Merlin	East Texas	Open country	TOES-T*	Migrant.

Appendix I. (Continued)

Scientific and common name[a]	East Texas location	Habitat	Authority[b]	Comments
Grus americana Whopping crane	East Texas	Coastal areas, fields, agricultural areas, wetlands in migration	TNHP, TOES-E*	Scattered migrants in western section.
Sterna antillarum Least tern	Red River and possibly other rivers	Inland river	TNHP, TOES-E*,	Declining populations.
Picoides borealis Red-cockaded woodpecker	East Texas	Mature, open pine, and occasionally hardwood forests	TNHP, TOES-E*, TPWD-E*, USFWS-E*	Restricted habitat. Permanent resident in East Texas.
Campephilus principalis Ivory-billed woodpecker	East Texas	Mature, hardwood riverbottom forests	TNHP, TOES-E*, TPWD-E*, USFWS-E*	Probably extinct. One of last occurrences in Big Thicket.
Corvus ossifragus Fish crow	Southeast Texas	Rivers	TNHP	Peripheral.
Vermivora bachmanii Bachman's warbler	East Texas	Mature bottomland forests	TNHP, TPWD-E*, USFWS-E*	Formerly in Texas?
Helmitheros vermivorus Worm-eating warbler	East Texas	Dry wooded hills, undergrowth ravines, oak-pine woodlands	TNHP	Rare and restricted nesting in Texas. Peripheral.
Limnothlypis swainsonii Swainson's warbler	East Texas	Swamps, bogs, stream bottoms	TNHP	Rare and restricted nester in Texas. Peripheral.
Aimophila aestivalis Bachman's sparrow	East Texas	Open pine or oakwoods, brushy pastures	TNHP	Rare and restricted nester in Texas. Peripheral.
Ammodramus henslowii Henslow's sparrow	East Texas	Weedy field, wet meadows, and wet prairies	TNHP	Rare and restricted nester in Texas. Peripheral.

Appendix I. (Concluded)

Scientific and common name[a]	East Texas location	Habitat	Authority[b]	Comments
MAMMALS				
Myotis austroriparius Southeastern myotis	Eastern tier of counties	Ponds and streams	TNHP, TPWD-PN*	Peripheral. Very limited in Texas.
Plecotus rafinesquii Eastern big-eared bat	Extreme East Texas	Buildings, cisterns, and wells in oak-pine and longleaf pine regions	TNHP, TPWD-PN*	Peripheral. Very limited in Texas.
Reithrodontomys humilis Eastern harvest mouse	East Texas	Fallow fields and ecotones between grasses and forests	TNHP	Limited distribution. Peripheral.
Ursus americanus Black bear	East Texas	Forests, including bottomlands	TNHP, TOES-T*	Formerly common, now extirpated.
Lutra canadensis River otter	East Texas	Marshes, rivers, streams	TNHP, TOES-T*	Believed to be increasing. Threatened by stream modifications.

[a] Sources:

Neck 1984; Texas Organization for Endangered Species 1984; Texas Parks and Wildlife Department 1978a,b; U.S. Fish and Wildlife Service 1980; Wahl 1984.

[b] Authority codes:

THNP = Texas Natural Heritage Program
TOES = Texas Organization for Endangered Species
TPWD = Texas Parks and Wildlife Department
USFWS = U.S. Fish and Wildlife Service
E* = Endangered
T* = Threatened
PN* = Protected Non-game
WL* = Watch List

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16. Abstract (Limit: 200 words)

Bottomland hardwoods are dynamic, productive systems that depend on intermittent flooding and moving water for maintenance of structure and function. This report focuses on the bottomland hardwoods of eastern Texas and Oklahoma, serving as an introduction and entry to the literature concerning their functions and values. The report begins with a review of the major functions of bottomland hardwoods followed by a section focused on the bottomlands of eastern Texas and Oklahoma. Considerable attention is given to structural characteristics in this section, in order to provide contrasts with bottomland hardwood ecosystems in other areas. The final section, on economic valuation of the functions of bottomland hardwoods, is introduced by a discussion of general concepts of value and the types of human values associated with bottomland hardwoods. Selected methods for quantifying these values are then presented, followed by a discussion and several examples of specific valuations. The text of the report is supplemented by a computerized bibliographic data base of relevant articles. Diskettes containing the data base files are available, on request, for use on selected microcomputer data base management systems.

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APPENDIX A. DESCRIPTION OF WETLAND VALUES DATA BASE

The U.S. Fish and Wildlife Service has developed a computerized data on the attributes and functions of wetlands that are valuable to man. data base consists of an annotated bibliography that pulls together informa contained in the diverse literature concerning the functions and value wetlands. The full data base contains over 5,000 entries and has developed on a mainframe computer under the MANAGE (Shumate 1982) data management system. A complete description of the data base is given in St (1986). Information regarding access to the complete data base may be obta from the data base administrator:

National Wetlands Inventory
Wetland Values Data Base Administrator
U.S. Fish and Wildlife Service
Suite 217, Dade Building
9620 Executive Center Drive
St. Petersburg, FL 33702

Each bibliographic entry in the data base is called a record. record includes the following information: author, year, title, sou abstract (up to 2,100 characters), subject or wetland value, relevant hydro (from the U.S. Geological Survey/Water Resource Council hydrologic unit ma ecoregion (according to Bailey 1980), U.S. Army Corps of Engineers Distr landform (as defined by Hammond 1964), location, and wetland type (follo the Cowardin et al. 1979 classification). Ecoregion, landform, and hydrol unit maps are summarized in Bailey and Cushwa (1982). The contents o example record are given in Figure A-1.

A subset of the Wetland Values Data Base containing references pertai to bottomland hardwoods is available for use on a microcompter in conjunc with this report. The information is structured to be used under the QUICK microcomputer data base management software, which is highly compatible the mainframe MANAGE software used for the full data base. QUICKTEXT run a variety of microcomputers and is available from the Office of Confer Services at Colorado State University under a cooperative agreement with U.S. Fish and Wildlife Service (see Appendix B).

The bottomland hardwoods entries from the Wetland Values Data Base be provided on a series of diskettes, each containing an ASCII data file a well-defined format. A complete description of the fields and poss entries will also be included. Procedures for loading these files in single data base under QUICKTEXT are quite simple and are describe documentation provided with the data (see Appendix B). Programs or proced could also be developed to access the information directly or to load it some other data base management software by individual users.