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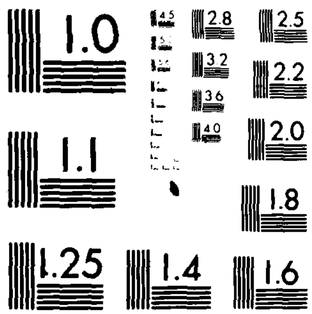

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IMPACTS OF FLOODING REGIME MODIFICATION ON WILDLIFE HABITATS OF BOTTOMLAND HARDWOOD FORESTS IN THE LOWER MISSISSIPPI VALLEY

by

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This report is a literature review concerning the impacts of flooding regime modification on bottomland hardwood forest wildlife habitats of the lower Mississippi Valley. Documented effects on forest vegetation and wildlife populations are described.

The composition and structure of the bottomland forest are an important determinant of the quality and type of wildlife habitat available. These

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forest characteristics are, in turn, largely influenced by the flooding regime. In general, overstory diversity and perennial understory diversity and productivity are lowest in near-permanently flooded habitats and increase in areas flooded less frequently and for shorter periods of time. Nonflooded areas are often, but not always, less diverse and productive than infrequently flooded areas. A permanent change in flooding regime is likely to cause a gradual change in composition and structure, resulting in forest characteristics similar to those normally found under such hydrologic conditions. Tree growth, regional habitat diversity, and land clearance patterns may also be influenced by modifications to the hydrologic regime.

Bottomland forests of the study area are considered productive wildlife habitat due to a variety of factors including high soil fertility, abundant moisture, and the diversity and abundance of wildlife food and cover. Diversity of vegetation, especially in regard to food supply, is considered extremely important to most species of wildlife in bottomland hardwoods. Certain wildlife species occurring in bottomland forests are largely dependent on substrate moisture and the structure and composition of plant communities, while others are highly mobile and tolerant of a variety of conditions and habitat changes. Therefore, modifications in the magnitude, frequency, and duration of flooding are expected to bring about a wide variety of impacts on different species.

Impacts of flooding regime modifications are discussed for mammals, birds, reptiles, and amphibians. Aquatic and semiaquatic species are generally adversely affected by flood reduction and are benefitted by normal flooding conditions. Species that are principally terrestrial may be severely impacted by major flooding events, but they may respond more to secondary influences such as land clearing and logging. Where known, both direct and indirect impacts of flooding regime modifications are discussed by species or species groups occurring in the study area.

PREFACE

This report was prepared at the request of the U. S. Army Engineer Division, Lower Mississippi Valley, Vicksburg, Miss.

Authors of this report were Mr. Charles V. Klimas, Botanist, Mr. Chester O. Martin, Wildlife Biologist, and Mr. James W. Teaford, Biologist, all of the Environmental Laboratory (EL), U. S. Army Engineer Waterways Experiment Station (WES). Much of the literature reviewed herein was located and initially evaluated by Dr. James W. Webb, Texas A&M University, College Station. Ms. Jennifer Buchanan, EL, provided valuable assistance in locating and cataloguing additional materials. Manuscript review was provided by Ms. Dorothy P. Booth, EL, Ms. L. Jean Hunt, EL, and Dr. Kenneth T. Ridlehuber, Texas A&M University, College Station.

Work was performed under the technical leadership and supervision of Mr. Hollis H. Allen, Team Leader, Revegetation and Habitat Development Team, EL; and under the general supervision of Dr. Hanley K. Smith, Ecologist, Wetland and Terrestrial Habitat Group, EL, Dr. Conrad J. Kirby, Chief, Environmental Resources Division, EL, and Dr. John Harrison, Chief, EL.

Commanders and Directors of WES during the preparation and publication of this report were COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. Technical Director was Mr. Fred Brown.

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CONTENTS

IMPACTS OF FLOODING REGIME MODIFICATION ON WILDLIFE HABITATS OF BOTTOMLAND FORESTS IN THE LOWER MISSISSIPPI VALLEY

PART I: INTRODUCTION

1. This report summarizes information concerning wildlife habitats in bottomland hardwood forests of the lower Mississippi Valley, with special reference to the effects of altering floodplain hydrology. The first section concerns plant communities and includes discussion of their flood-related structural and compositional characteristics and considerations in predicting community traits following hydrologic alteration. The remainder of the document regards wildlife of the floodplain ecosystem. Particular emphasis is placed on the habitat requirements of wildlife species with respect to flooding regime and forest community type.

2. The literature reviewed, published prior to spring 1981, primarily described research performed within the lower Mississippi Valley, although studies conducted outside the study region are included where pertinent. Effects on fish and invertebrate populations are included in this review only where they relate to other wildlife species. Nomenclature follows the original authors in most cases; in some instances common and scientific names of plants have been rectified using Radford et al. (1964), Fernald (1970), or other sources as noted.

PART II: THE STUDY AREA

3. Bottomland hardwood forests of the lower Mississippi Valley are contained within the Mississippi Alluvial Plain Section of the Coastal Plain Province of Thornbury (1965). The alluvial valley of the Mississippi extends from near Cape Girardeau, Missouri, to the head of the Atchafalaya River; deltaic plain predominates south of this point. The alluvial valley is bounded by loess-covered valley walls and ranges in width from 200 km near Helena, Arkansas, to 40 km near Natchez, Mississippi. A number of intervalley ridges are present within the alluvial valley, the largest being Crowley's Ridge in northeastern Arkansas and southeastern Missouri (Thornbury 1965).

4. Soils of the region are primarily Inceptisols and are most commonly Aquepts. These soils are very poorly to somewhat poorly drained, generally fine textured, and often characterized by the presence of montmorillonitic clays. The principal exceptions to this general description are the sandy soils of certain river shoreline areas (Smith et al. 1973). The alluvial plains are level to gently undulating and are marked by low natural levees and abandoned meanders (Daniels et al. 1973).

5. Climatically, the study area ranges from almost continental in the north, with moderate winters and hot summers, to semi-tropical at the extreme south, with hot sultry summers and mild winters. Mean annual temperatures and rainfall range from 14.9°C and 122 cm in the north to 21.1°C and 163 cm, respectively, in the south. The distribution of rainfall is variable, resulting in frequent soil moisture deficits between May and October and surplus moisture during winter and early spring months. There are an average of 200 frost-free days in the north and 310 frost-free days in the south (Brown et al., undated).

6. Forests of the region are classified as the Mississippi Alluvial Plain Section of the Southeastern Evergreen Forest Region of Braun (1950) and as the Southern Floodplain Forest of Kuchler (1964).

PART III: VEGETATION

General Characteristics

7. It is generally accepted that water regime is the dominant environmental influence in floodplain habitats (Bedinger 1978, Huffman and Forsythe 1981). Although other factors, such as soil type and past management history, have an influence on plant community composition, structure, and distribution (Putnam 1951), most authors discuss bottomland hardwood forests with respect to relative flooding. However, studies detailing specific flooding regimes and associated plant communities are rare. Two systems for expressing these relationships have been adapted to provide a basis for further discussion (Tables 1 and 2). These systems are general and include types found throughout much of the Mississippi Valley.

8. Putnam (1951) discussed the distribution of bottomland forest types with reference to soil texture and topographic features, such as first bottoms, terrace flats, and low ridges (Table 1). Although flooding regimes associated with each forest type were not described, it was implied that site characteristics were directly indicative of flooding and drainage conditions. This system was inclusive of most alluvial bottomland forests of the south and was organized into eight major forest types regarded by the author as management units.

9. Huffman and Forsythe (1981) developed a classification for bottomland hardwood forests in relation to soil moisture and hydrologic regimes (Table 2). They referenced forest cover types to flooding regime categories ranging from permanent saturation or inundation to rarely flooded. Hydrology was expressed in terms of both frequency and duration.

10. The systems presented in Tables 1 and 2 are not inclusive for all cover types found within the Mississippi Alluvial Valley. For example, pin oak (Quercus palustris) replaces Nuttall oak (Q. nuttallii) in the northern portion of the study area (Fowells 1965), although it is not incorporated into the above tables. For the most part, however,

Table 1

Southern Bottomland Forest Types and their Major Characteristics (After Putnam 1951)*

Type	Characteristic Species	Occurrence by Site	General Features	Common Variations in Type
Sweetgum-water oaks	**Sweetgum **Water oak **Nuttall oak **Willow oak **Soft elm **Hackberry **Green ash Overcup oak Sweet pecan Bitter pecan Cedar elm Cottonwood Diamondleaf oak Laurel oak Red maple Honey locust Persimmon	General in first bottoms except deep sloughs, swamps, fronts, and poorest flat sites. Also on terrace flats	Most widely distributed type	(a) Predominantly sweetgum: on well-drained first bottom ridges and pervious silty clays on terrace flats. (b) Predominantly water oaks: on heavier soils on first bottom ridges and better drained flats on terraces. Nuttall oak dominates on well-drained first bottom flats. Willow oak prevails on first bottom ridges and poorly drained terrace flats, i.e. pin oak flats; near the Coast laurel oak takes over. (c) Cedar elm-water oaks: On poorly drained, impervious soils on low or indistinct first bottom ridges. Of minor importance on impervious terrace soils
White oaks-red oaks-other hardwoods	**Cow oak **White oak **Delta post oak **Cherrybark oak **Shumard oak **Southern red oak **White ash **Hickory **Black gum **Winged elm Sweetgum Overcup oak Willow oak Water oak Laurel oak Post oak Soft elm Magnolia Yellow poplar Loblolly pine Spruce pine Beech	Best fine, sandy loam soils on first bottom ridges and all ridges on the terraces. Type extends on first bottom ridges to a few peculiar well-drained soils other than sandy loam	Second only to sweetgum-water oaks type in area	(a) Predominantly white oaks: on the most matured terrace soils. (b) Pine-hardwood: in very limited situations; most common with loblolly on terraces, but also with spruce on ridges in first bottoms of small streams of the Coastal Plains east of the Mississippi River

(Continued)

* See reference for nomenclature.
** Most important or key species.

(Sheet 1 of 3)

Table 1 (Continued)

Type	Characteristic Species	Occurrence by Site	General Features	Common Variations in Type
Hackberry-elm-ash	**Hackberry **Soft elm **Green ash **Bitter pecan **Willow oak Cedar elm Overcup oak Sweet pecan Water oak Nuttall oak Winged elm White ash Cherrybark oak Blackgum Persimmon Red maple Boxelder	Low ridges, flats, and sloughs in first bottoms and terrace flats and sloughs. Occasionally on new land or fronts. Rarely on badly treated terrace ridges	Temporary type following heavy cutting and fire or succeeding cottonwood. Widely distributed in stands from a few to several hundred acres in size	(a) Pure ash: occasional small stands of pure ash may occur almost anywhere within the type but most notably on moist flats or in shallow sloughs. (b) Pure hackberry: occurs rarely on new land or front sites
Overcup oak-bitter pecan	**Overcup oak **Bitter pecan Willow oak Nuttall oak Soft elm Cedar elm Green ash Hackberry Water locust Persimmon Red maple	Low, poorly drained flats, usually with tight clay soils; sloughs; lowest backwater basins. On low ridges with heavy soils, residual after heavy cutting in sweetgum-water oaks type	Widely distributed with most extensive areas in backwater basins of principal rivers	None
Cottonwood	**Cottonwood **Sweet pecan **Sycamore **Hackberry Willow Green ash Soft elm Silver maple Boxelder	Front land ridges and well-drained flats; rarely on abandoned fields on well-drained ridges in the first bottoms	Pioneer type, characteristic of the fronts of all major streams	None

(Continued)

(Sheet 2 of 3)

Table 1 (Concluded)

Type	Characteristic Species	Occurrence by Site	General Features	Common Variations in Type
Willow	**Willow Cottonwood Green ash Persimmon Water locust Soft elm Cypress Red maple Hackberry	Front land sloughs and low flats; occasionally shallow swamps and deep sloughs throughout first bottoms	Pioneer type on front land	None
Riverfront hardwoods	**Sycamore **Sweet pecan **Green ash **Soft elm **Hackberry Silver maple Cottonwood Willow Water oak Nuttall oak Sweetgum Boxelder River birch	All front lands except deep sloughs and swamps	Transition between cottonwood or willow and the sweetgum-water oaks type. Widely distributed but restricted in extent	None
Cypress-tupelo gum (Cypress-swamp blackgum)	**Cypress **Tupelo gum **Swamp blackgum Willow Swamp cottonwood Red maple Soft elm Water locust Persimmon Overcup oak Bitter pecan Sweetgum Nuttall oak Diamondleaf oak Sweet bay	Cypress-tupelo gum in very low, poorly drained flats, deep sloughs and swamps in first bottoms and terraces. Cypress-swamp blackgum in swamps of the Coastal Plains and river estuaries	Widely distributed in small areas. Extensive areas on lower reaches and estuaries of major streams	(a) Pure cypress: occurs scattered throughout the type. (b) Pure tupelo gum (or swamp blackgum): largely follows clear cutting of cypress

(Sheet 3 of 3)

Table 2

General Summary of Major Lower Mississippi Valley Floodplain Aquatic and Forest Plant Types in Relation to Soil Moisture/Hydrologic Habitat Regimes (After Huffman and Forsythe 1981)*

Soil Moisture/Hydrologic Regime	Aquatic Plant and Forest Types**
	Aquatic Plant Types
I. Permanently saturated or inundated. Soil saturation or inundation by ground or surface water occurs on a permanent basis throughout the growing season of the prevalent vegetation.	Attached-Floating Free-Floating Rooted-Emergent Submerged Plant
	Bottomland Hardwood Forest Types
II. Intermittently exposed. Soil inundation or saturation by surface or groundwater typically exists on a nearly permanent basis throughout the growing season of the prevalent vegetation, except during extreme drought periods.	Bald Cypress (101) Bald Cypress-Water Tupelo (102) Slash Pine-Swamp Tupelo (99) Sweetbay-Swamp Tupelo-Red Maple (104) Water Tupelo (103)
III. Semipermanently inundated or saturated. Soil inundation or saturation by surface or groundwater occurs with detectable intermittent periodicity for a major portion of the growing season of the prevalent vegetation. Typically occurs during the spring and summer months with a frequency ranging from 51 to 100 years per 100 years. The total duration of time for the seasonal event(s) typically exceeds 25 percent of the growing season.	Black Willow (95) Overcup Oak-Water Hickory (96)
IV. Seasonally inundated or saturated. Soil inundation by surface or groundwater typically occurs with detectable intermittent periodicity for 1 to 2 months during the growing season of the prevalent vegetation. Typically occurs up to the beginning of the summer season with a frequency ranging from 51 to 100 years per 100 years. The total duration of time for the seasonal event(s) typically ranges from 12.5 to 25 percent of the growing season.	Cottonwood (63) Laurel Oak-Willow Oak (88: wet site variation) Live Oak (89: wet site variation) Slash Pine (84: wet site variation) Slash Pine-Hardwood (85: wet site variation) Sweetgum-Nuttall Oak-Willow Oak (92) Sycamore-Pecan-American Elm (94)
V. Temporarily inundated or saturated. Soil inundation or saturation by surface or groundwater typically occurs with detectable intermittent periodicity for short periods during the growing season but not totaling more than one month for the entire growing season of the prevalent vegetation. Typical frequency ranges from 11 to 50 years - 1 to 10 years per 100 years. The total duration of time for the seasonal event(s) typically ranges from 2 to 12.5 percent of the growing season.	Beech-Southern Magnolia (90: wet site variation) Loblolly Pine (81: wet site variation) Loblolly Pine - Mixed Hardwood (82: wet site variation) Swamp Chestnut Oak-Cherrybark Oak (91)

* Ordering of each group of forest types is based on maximum tolerance levels recurring over an extended period of years to the soil moisture/hydrologic regimes listed. Forest types may therefore be found associated with less frequently inundated habitats; however, these associations are not shown. No attempt is made to order forest types associated within each category due to the high degree of within-group variability.

** Aquatic plant types adapted from Sculthorpe (1967); forest type number, from Society of American Foresters (1975). See SAF (1975) for nomenclature.

even the extreme northern portion of the region is floristically consistent with forests elsewhere in the Mississippi bottomlands (Robertson et al. 1978). This consistency is not apparent in upland forests adjacent to the Alluvial Plain, however. According to Braun (1950), the study area is bordered by four major forest formations containing numerous forest cover types.

11. Although it is difficult to detail specific relationships between forest types and flooding regimes, certain generalizations can be made concerning community structure as it varies with flooding. Studies in Arkansas (Bedinger 1971), Illinois (Bell 1974, 1980, Bell and del Moral 1977, Adams and Anderson 1980), Oklahoma (Petranka and Holland 1980), Louisiana (Conner and Day 1976), and Texas (Burandt et al. 1977) suggest that overstory species diversity tends to be low in frequently flooded habitats and high in irregularly flooded habitats. Adjacent uplands are often less diverse than the intermediate zone (Adams and Anderson 1980, Bell 1980), although in some situations, unflooded areas may be highest in diversity (Bell and del Moral 1977). Overstory diversity and productivity appear to be strongly related not only to hydrologic regime, but also to successional stage (Terpening et al. 1974, Johnson and Bell 1976, Dabel and Day 1977, Bell 1980).

12. Overstory composition and structure is of greatest concern here as it relates to wildlife food production. The importance of hard mast, especially acorns, as a major food source for various wildlife species has been documented by several authors, and the principal factors that influence mast production are fairly well known (Reid and Goodrum 1957, Collins 1961, Shaw 1971, Harlow et al. 1975). A brief summary of these factors is presented below to illustrate the inherent complexities involved and the difficulty of isolating the influence of increased or reduced flooding on mast production:

a. The diversity of the forest overstory can influence the potential production of hard mast. Over the course of several years, stands with a mixture of species produce a more reliable supply of mast than do stands dominated by one or two species (Collins 1961, Goodrum et al. 1971, U. S. Department of Agriculture (USDA) 1971).

b. Acorn production varies from species to species and from tree to tree within a species. Collins (1961) found that the percentage of trees within a species producing acorns ranged from 51 percent for overcup oak to 84 percent for water oak. Reid and Goodrum (1957) found that acorn production ranged from a low of 54 percent for post oak to a high of 93 percent for water oak. Sharp (1958), Goodrum et al. (1971), and Olson and Boyce (1971) also noted that some individual trees are consistently good producers while others are consistently poor producers.

c. Acorn production is periodic and fluctuates from year to year (Reid and Goodrum 1957, Sharp 1958, Olson and Boyce 1971). These fluctuations generally occur in different phases for the red oak group and the white oak group. Although an occasional complete mast failure does occur in a mixed stand, the red and white oak groups generally complement each other, with acorn production being high in one group when it is low in the other (Collins 1961). In a 12-year study of five Southern Appalachian oak species (Beck 1977), 3 years yielded essentially complete mast failures with production of less than 11.2 kg of sound, well-developed acorns per hectare, while 1 year was a near failure (26 kg/ha). Four years represented moderate production (54-87 kg/ha) and 4 years were "bumper crops" (325-897 kg/ha). In 7 of 12 years, the production of sound, well-developed acorns represented moderate (68 kg/ha) to excellent (897 kg/ha) production when compared with the standard of 112 kg/ha of "sound fresh acorns" reported by Shaw (1971) as necessary for the support of both game and nongame wildlife species at optimum population levels.

d. Reid and Goodrum (1957) found that the bottomland oak species in their study produced more acorns than the upland scrub oaks did. The authors attributed this difference to larger diameters in the bottomland oaks and postulated that mast yields would be comparable in the two groups if considered on the basis of equivalent crown unit area. Collins (1961) found that floodplain oaks yielded more mast than did oaks inhabiting smaller stream bottoms.

e. Olson and Boyce (1971) stated that year-to-year variation in the size of the mast crops they studied was not due to lack of flower formation. The authors noted that both staminate and pistillate flowers were formed every year in abundance on nearly every tree of flowering size and age. The authors stated that climatic factors, such as wind, late frost, prolonged rain, relative humidity, and temperature influenced the formation and development of flowers and the dissemination of pollen. They also noted that the greatest loss of immature fruits occurred because of premature abscission and the highest rate of loss occurred during pollination and fertilization. They were unable to identify the reasons for these losses.

d. Reid and Goodrum (1957) and Collins (1961) noted that the minimum age of substantial acorn production for the various oaks they studied was 25 years. Once acorn production began, the best yields came from those trees with well-developed crowns in the larger diameter classes. Because oak flowers are produced on the current year's twig growth, live branch volume as influenced by total crown surface area is an important factor in total acorn production for an individual tree and for a forest stand (Sharp 1958, Shaw 1971, USDA 1971).

13. The relationship between understory species distribution and flooding regime is not well understood. Maisenhelder (1955) and Halls (1977) gave brief descriptions of site preferences for understory plants of bottomland forests, and Putnam and Bull (1932) provided similar information on some shrub species. Fowells (1965) noted certain understory species if they were characteristic of a site and had indicator value. Floristic studies of specific areas such as those by Noble and Murphy (1974), Conner et al. (1975), Carter (1978), and Montz (1978) and ecological surveys such as those by Shelford (1954), Voigt and Mohlenbrock (1964), Thieret (1971), the U. S. Department of the Interior (USDI) (1975), and Thomson and Anderson (1976) have provided lists of shrub, vine, and herbaceous species associated with specific cover types. Some discussion of understory productivity and diversity as they vary with flooding regime was presented by Conner and Day (1976), Johnson and Bell (1976), and Dabel and Day (1977), while Whittaker (1972) and Odum et al. (1979) presented discussions of theoretical considerations related to overall community productivity and diversity. Based on the above references, the following generalizations concerning the relationship of the understory to flooding are presented:

a. Overall understory productivity and diversity are usually lowest in near-permanently flooded forest habitats, are highest in rarely flooded habitats, and are intermediate to high in most unflooded forest areas adjacent to floodplains.

b. Shrubs occur throughout the bottomlands, and certain species exhibit a degree of affinity for particular flood zones. Species such as buttonbush (Cephalanthus occidentalis) and swamp privet (Forestiera acuminata) are generally restricted to areas of regular inundation while species such as pawpaw (Asimina triloba) and spicebush (Lindera spp.) are typical of drier sites.

c. Vines are not generally as restricted in distribution as shrubs, although their relative abundance will vary depending on the flooding regime. Species such as peppervine (Ampelopsis arborea), trumpet creeper (Campsis radicans), and poison ivy (Rhus radicans) are often present in all but near-permanently flooded areas. Vine density and diversity are generally lowest in areas of regular, prolonged flooding.

d. Herbaceous species are relatively unknown with respect to their distribution in bottomlands, although some studies have identified species that appear to be restricted to particular zones. Generally, perennial herbaceous cover and diversity diminish as flooding increases; the distribution of annuals is less restricted, but is dependent on varying conditions from year to year.

e. In most cases, particularly with respect to vines and herbs, density, cover, and to some extent composition are more closely related to light availability than to flooding conditions.

Effects of Reduced Flooding

General

14. Flood-control activities have had their greatest impact on bottomland hardwood forests by making land clearing and conversion to row crops feasible. Recent estimates indicate that bottomland forests within the Mississippi Alluvial Plain have decreased from approximately 4.8 million ha in 1937 to approximately 2.1 million ha in 1978 (MacDonald et al. 1979). Many authors (see for example Viosca 1928, Wharton 1970, Yancy 1970, Korte and Fredrickson 1977a, Fredrickson 1978) have commented on the implications of this habitat loss to wildlife populations, attributing population declines, and in some cases species extinctions, at least in part to loss or exploitation of bottomland forest stands.

15. For a detailed discussion of the magnitude of forest land losses to agriculture and the relationship of this process to flood protection, the reader is referred to MacDonald et al. (1979). For the

purposes of this report, two major facets of this topic should be noted:

- a. The pattern of land conversion has resulted in massive losses of infrequently flooded forest types, with the principal remaining forests being riverfront and regularly flooded types in batture lands and sumps (Sternitzke 1976, Hodgkins et al. 1979).
- b. Remaining forest stands vary in size and surroundings, thus individual stand characteristics such as water supply, nearby agricultural crops, and distance to other forested lands may be of increasing importance in the evaluation of wildlife habitat on any given site (Fredrickson 1978).

16. Work by Broadfoot (1964, 1967, 1973), Broadfoot and Williston (1973), and others demonstrated that many bottomland hardwood species exhibit markedly increased diameter growth when additional water is made available through flooding, raised water tables, or irrigation. Broadfoot and Williston (1973) stated that bottomland trees can use about twice the amount of water provided by normal growing season rainfall and that growth is reduced with any lesser amount. It is therefore reasonable to assume that flood reduction may be expected to reduce tree growth if it reduces the amount of water available during the growing season. In fact, the extent to which growth will be reduced may be estimated for selected species if accurate hydrologic predictions are available, since site index tables (Baker and Broadfoot 1979) incorporate flood duration and water table depth into calculations of tree growth rates.

17. A related impact of flood reduction on growth concerns the disruption of nutrient exchange or subsidy between forested floodplains and adjacent ecosystems. Numerous authors (e.g., Wharton 1970, 1971, Conner and Day 1976) have commented on the exchange of nutrients between wetland ecosystems, and Mitsch et al. (1979) suggested that cypress growth in a southern Illinois swamp may be dependent on phosphorus subsidies resulting from overflow flooding. Whether flooding provides essential nutrients on less frequently flooded sites is not apparent from the literature examined in this review.

18. Some tree mortality may occur during periods of extreme drought if water tables are lowered through flood protection measures

(Putnam et al. 1960). Broadfoot and Toole (1958) suggested that drainage contributed to lowering of the water table and subsequent drought mortality in lowland hardwood species in the early 1950's. Boyce (1961) indicated that drought may contribute to a number of disease and growth problems in trees. Generally, however, bottomland species are relatively tolerant of dry conditions (Fowells 1965), thus existing mature trees may not be critically stressed under occasional drought (Putnam et al. 1960). Seedlings and smaller trees, however, are likely to be more sensitive (Boyce 1961).

19. No information on the direct effects of reduced flooding on mast production was located in the literature, but two indirect influences were alluded to. First, Bedinger (1971) and Bell (1980) noted an increase in tree species diversity and richness from frequently flooded sites to infrequently flooded sites. For a given forest stand, if a shift to a more diverse overstory species composition does indeed occur as a result of flood reduction, it is reasonable to assume that mast production would become more stable over time as the variety of mast producing species increases (Collins 1961, Goodrum et al. 1971, USDA 1971). The second possible influence of reduced flooding on mast production would be related to the potential increase in the incidence of soil moisture stresses. Tree growth may be reduced if the amount of water available to the tree during the growing season is inadequate (Broadfoot and Williston 1973). If these moisture stresses are severe enough to cause branch and twig mortality in the tree crown (Broadfoot and Toole 1958), a reduction in mast production will result (Sharp 1958).

Case studies

20. St. Francis River/Mingo Swamp. Fredrickson (1979) conducted a 1-year study on channelized, drained, "control," and greentree reservoir areas near the St. Francis River, Missouri. Results of the greentree reservoir study will be discussed later in this report. All study sites were in bottomland areas characterized by typical lowland vegetation including species such as overcup oak (*Quercus lyrata*), pin oak, bald cypress (*Taxodium distichum*), water tupelo (*Nyssa aquatica*), and water locust (*Gleditsia aquatica*). Study sites included an area

ditched and drained prior to 1920,* an area along a section of the river leveed prior to 1929, an area along a section channelized prior to 1968, and an area along a section channelized during the year prior to the study. These sites where flooding had been reduced were compared to unchannelized, unleveed control areas that were in successional stages similar to their hydrologically altered counterparts. Vegetation sampling for composition, structure, and growth and an evaluation of hydrologic regimes were conducted for characterization and comparison of the sites.

21. The immediate impact of channelization of the St. Francis River was clearing of the forested lands. Conversion to farmland occurred on 78 percent of the forested area along channelized sections compared to only 7 percent on unchannelized sections. Plant community surveys of the leveed and channelized study sites provided the following general results:

a. Leveed area. Woody species diversity was somewhat higher in the early successional unchannelized area than in the leveed area. Dominant tree species were very different in the two areas, with box elder (*Acer negundo*) and American hornbeam (*Carpinus caroliniana*) predominating in the unchannelized area while river birch (*Betula nigra*), red maple (*Acer rubrum*), two species of ash, and black willow (*Salix nigra*) were important on the leveed site. Herb diversity was much lower in the leveed area than in the unchannelized area.

b. Recently channelized area. The recently channelized area also showed less tree and herb diversity when compared to the same early successional unchannelized area used as a control for the leveed site. However, more shrub species were encountered in this area. Green ash (*Fraxinus pennsylvanica*), box elder, river birch, and overcup oak were the dominant tree species.

c. Older channelized area. Tree, shrub, and herbaceous species diversities were all lower on the older channelized site when compared to the late successional unchannelized control area. Compositional differences in the canopy tree stratum were striking, with sweetgum

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* L. Fredrickson (Gaylord Memorial Lab, University of Missouri-Columbia, Puxico, Missouri) personal communication (Nov 1980).

(Liquidambar styraciflua), shellbark hickory (Carya laciniosa), and shagbark hickory (C. ovata) dominating in the control while American hornbeam and silver maple (Acer saccharinum) were most important on the channelized site.

22. In general (and contrary to the pattern in certain natural systems studied by Bell (1980) and others), Fredrickson found overall species diversity to be lower in leveed and channelized (drier) sites than in unchannelized areas. However, it is difficult to assess the degree to which differences between these paired study sites are attributable to altered hydrology. Differences in canopy tree composition are marked, even between the recently channelized areas and the control site, suggesting that stand conditions may not have been similar prior to flooding regime modification. Fredrickson (1980a) suggests that various factors other than flooding regime may account for observed differences and similarities on these sites, including soil types, forest composition, local rainfall, and management.

23. Observed differences between the drained and control sites, both of which are located in Mingo Swamp, appear to be more directly attributable to hydrologic modification since canopy composition and other factors suggest that initial stand conditions were reasonably similar. The control area experienced normal, frequent flooding, while the drained site was subjected to only shallow flooding over a limited area, with most of the area remaining free of standing water during the growing season. Monthly mean surface soil moisture was significantly higher during the growing season for the control site than for the drained area.

24. Overall woody species diversity was higher for trees, shrubs, and seedlings in the drained area than in the control. In particular, pawpaw, hackberry (Celtis occidentalis), red mulberry (Morus rubra), and winged elm (Ulmus alata) were restricted to the drained area. In comparison with the control area, tree species composition showed a distinctly drier character, with overcup oak much reduced in importance and southern red (Quercus falcata) and Shumard oaks (Q. shumardii) increased. Diversity of herbaceous species was not significantly different between

the two areas, but densities of herbs, seedlings, and shrubs were consistently higher in the drained area.

25. Stand basal area was similar in the drained and control sites, but growth rates of selected species varied between the two areas. Mean annual basal area increment of unsuppressed trees for a 30-year period was much lower on the drained area for red maple, Shumard oak, and pin oak. Sweetgum growth was similar on the two sites, but overcup oak made better growth on the control site. Willow oak growth was nearly five times greater on the drained site than on the control.

26. Luxapalila River. Arner et al. (1976) conducted a study of channelization effects on the Luxapalila River, located in eastern Mississippi and western Alabama. Fish and wildlife populations, invertebrates, and water quality were examined in each of three segments of the river: an unchannelized area, a segment channelized over 52 years earlier, and an area channelized in 1973. Vegetation was sampled only in the unchannelized and older channelized areas.

27. Dominant woody species differed greatly between the two areas where they were studied, with sweetgum, river birch, and red maple being important in the unchannelized segment while water oak (*Quercus nigra*), American hornbeam, and deciduous holly (*Ilex decidua*) were the major species in the channelized portion. Shrub species composition was also dissimilar: the channelized area had highest frequencies of privet (*Ligustrum sinense*), Virginia willow (*Itea virginica*), and elderberry (*Sambucus canadensis*) while in the unchannelized area, switch cane (*Arundinaria gigantea*), blueberry (*Vaccinium* spp.), and sebastian bush (*Sebastiana fruticosa*) were encountered most frequently. Herbaceous species recorded in both segments were similar, but density of herbaceous plants was significantly greater in the unchannelized segment.

Effects of Increased Flooding

General

28. It is reported by some authors that increases in flood frequency or duration take place in conjunction with flood-control projects

through construction of impoundments (Yeager 1949, Hall and Smith 1955), in the batture lands confined between the levees (Gunter 1956), in areas where drainage from backwater flooding is impeded (Wharton 1971), and where projects do not function as designed due to lack of maintenance or beaver activity (Thompson and Miller 1979). The majority of the available literature on this subject is concerned with observations of individual severe flooding events (Brown 1929, Kennedy and Krinard 1974, Noble and Murphy 1975) and with field and laboratory studies of flood tolerance in tree species (e.g., Yeager 1949; Hosner 1958, 1959, 1960; Bell and Johnson 1974). Very little work has been done with respect to minor long-term increases in flooding; most published information on this type of impact concerns dormant-season flooding of greentree reservoirs (e.g., Minckler and McDermott 1960, Fredrickson 1979).

29. The impacts of prolonged increased flooding are severe and rapid with widespread tree mortality being conspicuous within a few years. It is believed that the critical stress suffered by these plants arises primarily from depletion of oxygen in the flooded soil (Whitlow and Harris 1979), which causes complex changes in soil chemistry and nutrient availability (Ponnamperuma 1972). The ability of a plant to withstand flooded conditions depends partly on the presence of specialized anatomical structures and physiological processes (Hook 1968, Hook et al. 1971, Hook and Brown 1972, 1973) but also is related to the characteristics of the flooding regime, size and age of the plant, type of substrate, and other factors (Whitlow and Harris 1979).

30. In a review of the literature concerning flood tolerance in plants, Whitlow and Harris (1979) devised a relative mature-tree tolerance classification of 60 tree and shrub species of the lower Mississippi Valley. This system is adapted in Table 3; and a tabular summary of the research on which the classification is based, also from Whitlow and Harris (1979), is presented in Appendix A. Of the species classified as very tolerant, such as baldcypress, overcup oak, water tupelo, and water hickory, nearly all are commonly found in areas of regular prolonged flooding. Many of the species which are widespread in bottomland forests, such as sweetgum, water oak, and American elm, are ranked

Table 3

Relative Flood Tolerance of Selected Trees and Shrubs in the Lower Mississippi Valley (After Whitlow and Harris 1979)

Common Name	Scientific Name
	Very Tolerant*
Water hickory	Carya aquatica
Pecan	C. illinoensis
Buttonbush	Cephalanthus occidentalis
Swamp privet	Forestiera acuminata
Green ash	Fraxinus pennsylvanica
Water locust	Gleditsia aquatica
Deciduous holly	Ilex decidua
Water tupelo	Nyssa aquatica
Water elm	Planera aquatica
Overcup oak	Quercus lyrata
Nuttall oak	Q. nuttallii
Black willow	Salix nigra
Bald cypress	Taxodium distichum
	Tolerant**
Red Maple	Acer rubrum
Sugarberry	Celtis laevigata
Hackberry	C. occidentalis
Persimmon	Diospyros virginiana
White ash	Fraxinus americana
Shingle oak	Quercus imbricaria
Pin oak	Q. palustris

(Continued)

* Able to survive deep, prolonged flooding for more than 1 year.
** Able to survive deep flooding for one growing season, with significant mortality occurring if flooding is repeated the following year.

(Sheet 1 of 3)

Table 3 (Continued)

Common Name	Scientific Name
	Tolerant (Continued)
Sweetgum	*Liquidambar styraciflua*
Cottonwood	*Populus deltoides*
	Somewhat Tolerant*
Box elder	*Acer negundo*
Silver maple	*A. saccharinum*
Hazel alder	*Alnus rugosa*
River birch	*Betula nigra*
Hawthorn	*Crataegus mollis*
Honey locust	*Gleditsia triacanthos*
American holly	*Ilex opaca*
Black gum	*Nyssa sylvatica*
Sycamore	*Platanus occidentalis*
Swamp white oak	*Quercus bicolor*
Spanish oak	*Q. falcata*
Bur oak	*Q. macrocarpa*
Water oak	*Q. nigra*
Willow oak	*Q. phellos*
Winged elm	*Ulmus alata*
American elm	*U. americana*
Red elm	*U. rubra*

(Continued)

* Able to survive flooding or saturated soils for 30 consecutive days during the growing season.

(Sheet 2 of 3)

Table 3 (Concluded)

Common Name	Scientific Name
	Intolerant*
Ironwood	*Carpinus caroliniana*
Bitternut hickory	*Carya cordiformis*
Shellbark hickory	*C. lacinosa*
Shagbark hickory	*C. ovata*
Mockernut hickory	*C. tomentosa*
Redbud	*Cercis canadensis*
Flowering dogwood	*Cornus florida*
Kentucky coffee tree	*Gymnocladus dioica*
Black walnut	*Juglans nigra*
Shortleaf pine	*Pinus echinata*
Loblolly pine	*P. taeda*
Wild plum	*Prunus americana*
Black cherry	*P. serotina*
White oak	*Quercus alba*
Blackjack oak	*Q. marilandica*
Red oak	*Q. rubra*
Shumard oak	*Q. shumardii*
Post oak	*Q. stellata*
Black oak	*Q. velutina*
Sassafras	*Sassafras albidum*

* Unable to survive more than a few days of flooding during the growing season without significant mortality.

(Sheet 3 of 3)

as tolerant or somewhat tolerant, but species in both of these categories are generally found to be sensitive to long-term increases in growing-season flooding. Species normally found on upland or well-drained sites, such as white oak and black oak, suffer significant mortality if subjected to any flooding of more than a few days during the growing season.

31. Results of studies of seedling mortality under flooded conditions are included in Appendix A and are generally consistent with the rated flood tolerance of mature trees of the same species. However, as Broadfoot and Williston (1973) point out, seedlings of most species are particularly susceptible to flooding if completely submerged; although species that are adapted to regular, deep flooding, such as green ash, water hickory, and overcup oak, tend to leaf out later than other species, and their seedlings are thus better able to survive early growing-season flooding. Seedlings are also more susceptible than mature trees to sedimentation, although some adaptation may be seen in this respect also, with riverfront types (cottonwood, black willow) and deep swamp species (bald cypress, water tupelo) being more tolerant than other species.

32. Yeager: Illinois. Yeager (1949) studied the effects of increased flooding and raised water tables on bottomland forest stands influenced by the construction of Alton Dam in Illinois. Many of the species of the area are common in lower Mississippi Valley hardwood stands; and the comprehensive nature of the study, where a variety of effects were monitored over an 8-year period, makes it of considerable interest here.

33. With a rise of about 91 cm in average summer water stage, all flooded tree species in every size class exhibited almost total mortality within 8 years, and many succumbed much sooner. Pin oak suffered 100 percent mortality within 3 years in flooded areas, while white ash proved surprisingly tolerant, with a few individuals still producing trunk sprouts after 8 years. Other species died at differential rates generally reflecting the flood tolerances presented in Table 3. Three shrub species were evaluated and these also showed differential responses

to flooding. Buttonbush was most tolerant, with 40 percent or more survival except in deeply flooded areas. Swamp privet was severely affected, but some survivors remained in shallowly (less than 61 cm) flooded areas after 8 years. Deciduous holly suffered complete mortality within 4 years.

34. The raising of the water table showed a similar pattern with regard to species stress, but the effects were less pronounced and were restricted primarily to areas where the soil surface was saturated. In areas where the water table was raised but did not reach the soil surface, only pin oak suffered significant mortality during the study.

35. Hall and Smith: Tennessee. Hall and Smith (1955) observed effects of increased periodic flooding associated with a malaria control dewatering project in Tennessee. Uncleared or partially cleared bottomland forests were subjected to significant growing-season flooding during 4 of the first 7 years of project operation, after which woody plant mortality was evaluated. Of the 39 woody species examined, all were killed in areas where root crowns were inundated for more than 54 percent of the growing season. Survival in areas subjected to less flooding varied among species, with those typical of very wet sites (e.g., water elm, black willow, overcup oak, buttonbush) surviving best. In general, survival among all species corresponded well with the relative tolerances given in Table 3.

36. Mississippi River: 1927, 1973. A limited amount of information is available concerning the effects two individual severe flooding events, the Mississippi River floods of 1927 and 1973. Brown (1929) surveyed an area near Baton Rouge, Louisiana, that had been submerged for approximately 3 months by the 1927 flood. Although no preflood inventory was available for comparison, it is interesting to note that species of *Ampelopsis*, *Smilax*, *Rhus*, and *Rubus* all were present after the water receded. Noble and Murphy (1975) compared 1973 postflood understory composition to data they had collected earlier on the same site in Tensas Parish, Louisiana. Prolonged flooding killed or defoliated the understory, but cover was regained quickly. Only 6 of the 42 major understory species were completely eliminated by the flood, and

only 1 of these (Ulmus americana) was a woody perennial. Both Brown (1929) and Noble and Murphy (1975) reported significant mortality of hardwood seedlings. Kennedy and Krinard (1974), in a survey of impacts of the 1973 flood, also reported substantial mortality in seedlings of a variety of species, but survival was good among trees more than 1 year old and flooded during only the first 2 months of the growing season. Thus, it appears that individual severe floods may affect understory structure and composition for short periods but have no significant effect on mature woody plants.

37. Noncatastrophic floods (growing season). Minor increases in growing-season flooding have received only limited attention. Broadfoot (1967) studied tree growth in artifically flooded bottomland sites (sweetgum-ash-oak) near Greenville, Mississippi. Shallow impoundments were flooded in the spring (until 1 July) for 4 years, then sapling-sized and larger trees were evaluated for growth. Flooding increased growth in canopy trees of all species, with a 90 percent increase for cottonwood, green ash, and sweetgum. Oaks, American elm, and hackberry responded less markedly to impoundment, but the average increase in radial growth was 52 percent for all species combined. Although no formal survey of reproduction or understory effects was reported, the author noted that Nuttall oak, hackberry, and honey locust were able to initiate new reproduction during the study period, and that poison ivy suffered a sharp decrease in abundance. Broadfoot (1973) found similar increases in growth correlated with raised water tables in hardwood stands in Alabama and Florida. After 5 years of raised water tables, significantly higher growth rates were documented in a number of species including longleaf pine, sweetgum, southern red oak, and water oak. However, on sandy soils and where sediment had been deposited around trees, stand growth was not improved or was decreasing.

38. Broadfoot and Williston (1973) also related increased diameter growth of dominant tree species to normal flooding. They reported that, in the Steele Bayou Sump and Yazoo River Backwater area near Vicksburg, Mississippi, the dominant native species benefitted appreciably in terms of growth from the effects of flooding. In flood years,

diameter growth of these trees was 50 to 100 percent greater than in nonflood years, and green ash responded to spring flooding lasting through August with 80 percent greater than normal diameter growth.

39. The studies described above dealt with minor or short-term flood increases in irregularly flooded hardwood stands. Flood increases in near-permanently flooded habitats may have a detrimental effect on swamp species. In a cypress swamp in southern Illinois, water levels raised by beaver activity apparently caused a dramatic reduction in growth for cypress (Mitsch et al. 1979) and killed several acres of (unidentified) hardwoods (Anderson and White 1970). The adverse effects of prolonged flooding on cypress and swamp and water tupelo seedling establishment and growth have been well documented (Demaree 1932, Shunk 1939, Applequist 1959, Kennedy 1970). In addition, studies by Hook et al. (1970) and Harms (1973) demonstrated that growth of swamp and water tupelo seedlings may be particularly depressed by stagnant floodwaters.

40. Noncatastrophic floods (dormant season). Some information is available concerning increased dormant-season flooding as imposed in greentree reservoirs. Fredrickson's (1979) study of channelization and drainage effects in southeastern Missouri included an analysis of the effects of such impoundments. A greentree reservoir area, subjected to fall flooding and prone to minor flooding during high rainfall periods, was compared to a nearby bottomland area relatively unaffected by flood-control efforts. The greentree area had been under a fall flooding schedule for 20 years at the time of the study.*

41. Overall diversity of trees, shrubs, and herbs was very similar between the two sites, although there were several more shrub species and two fewer herb species in the impounded area. The relative-importance ranking of the four major tree species was the same on both sites. Relative sapling abundance differed between the two sites, with red maple, sweetgum, and red elm being most common on the control area, and persimmon, red elm, buttonbush, and stiff dogwood (*Cornus foemina*)

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* Ibid.

most abundant in the impounded area. Tree densities and stand basal areas were not significantly different between the impounded and control areas. However, individual species growth rates were somewhat different between the two sites. Mean annual basal area increment of unsuppressed trees was lower on the periodically impounded area for red maple, Shumard oak,and sweetgum, but was greater for pin oak and willow oak. Overcup oak growth on the impounded area was more than twice that on the control. In the seedling stratum, Southern red oak, ash, and buttonbush were important in the impounded area along with the red maple and elm that were important on the control. Herb densities varied seasonally on both sites, being higher in May than in July, but were generally higher in the impounded area than the control area at both times. In summarizing his work, Fredrickson (1979) concluded that establishment of greentree reservoirs slowly alters the plant community to one typical of a wetter site.

42. Thomson and Anderson (1976), in an ecological investigation of a greentree reservoir in southern Illinois, found that regeneration of dominant overstory species was generally not occurring. Pin oak, cherrybark oak, and shagbark hickory were not well represented as seedlings or saplings in the stands where they dominated. Green ash, red maple, and red elm were often the principal tree species in the understory. The authors did not speculate on the relationship between these changes and the altered flooding regime, but suggested that intolerance to shade was probably the prime reason for lack of regeneration of pin and cherrybark oaks.

43. Broadfoot (1958) surveyed 16 greentree reservoirs in Mississippi and Arkansas and found that when properly managed, these impoundments increased tree growth, reduced fire danger, and appeared to have no effect on acorn and seedling production. However, under continuous flooding, growth was reduced, acorn production ceased after 1 year, and widespread mortality occurred within 4 years. In contrast to Broadfoot's (1958) generalization concerning improved tree growth in greentree reservoirs, a study in Missouri suggested that growth may, in fact, be reduced. Analysis of 20 years of growth data from a pin oak dominated

greentree reservoir in southeastern Missouri indicated that tree growth had been reduced by approximately 10 percent when compared to normally flooded areas nearby.*

44. Brakage (1966), in a discussion of mast production, stated that annual winter flooding is detrimental to stand regeneration, but that it results in a higher percentage of sound acorns by reducing insect depredation. Interim reports on a long-term study of pin oak acorn production in a greentree reservoir in southeast Missouri were published by Minckler and McDermott (1960), Merz and Brakhage (1964), and Minckler and Janes (1965); McQuilkin and Musbach (1977) summarized the study after 14 years of data had been collected. McQuilkin and Musbach (1977) reported no significant difference in the production of sound, fully developed acorns between the greentree reservoir, flooded in the dormant season, and a control site flooded normally 1-4 times per year for 2-10 days per flood. It should be noted that the earlier reports from this study, especially Minckler and McDermott (1960), showed quite different results based on shorter periods of study.

45. Francis (1980) found that dormant-season flooding of a greentree reservoir in the Delta National Forest of Mississippi reduced the production of sound Nuttall oak acorns on the greentree site when compared with a normally flooded site. In considering the work reported by Francis (1980), it should be noted that 2 years of the study were mast failures and the results were based on only 3 years of actual acorn production data. Thus, the short-term nature of the study should be taken into account in assessing its applicability, particularly in light of the misleading results obtained by Minckler and McDermott (1960) over a similarly short period of data collection. Despite the results reported by Minckler and McDermott (1960) and Francis (1980), an increase in dormant-season flooding does not appear to cause any significant change in sound, fully developed acorn production from that yielded by a normally flooded site of the same forest type and general geographic area.

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* R. Rogers (Mensurationist, USDA Forest Service North Central Forest Experiment Station, Columbia, Missouri), personal communication (April 1981).

46. Tree mortality has not been reported in the literature in connection with dormant-season flooding of specific greentree reservoirs. However, these areas may be particularly susceptible to flooding mortality if not dewatered prior to or early in the growing season (Broadfoot 1958). Greentree reservoirs in southeastern Missouri suffered differential damage due to the 1973 flood; one impoundment that was not drawn down early in the growing season experienced significant mortality when floodwaters (replenished by rain) remained until late July, while a similar greentree reservoir nearby was dewatered in early spring and did not show the same problem.*

47. There is some evidence that the incidence of certain insect and disease problems may be related to water management in impoundments such as greentree reservoirs (McCracken and Solomon 1980). Ambrosia beetle populations, root rots, and other problems may increase in stands where water is held too long in the spring and stress results; the authors also suggested that soil mycorrhizal populations may be altered. They stated, however, that strict adherence to recommended flooding/drainage dates should avoid the imposition of inordinate stress. One soil-related problem has also been noted that has implications for greentree reservoir site selection. An impoundment in southeastern Missouri has suffered mature tree mortality associated with high sodium soils disrupted during construction and leached by dormant-season flooding.**

Considerations in Predicting Plant Community Change in Response to Flooding Regime Alteration

General

48. As indicated by the preceding review, certain characteristics of bottomland forests are adequately known to allow limited generalizations regarding forest composition and structure as related to flooding.

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* L. Fredrickson, personal communication, ibid.

** J. Baker (Principal Silviculturist, Forestry Sciences Laboratory, Monticello, Ark.), personal communication (Dec 1980).

In most cases where authors have provided detailed descriptions of bottomland forest types, the occurrence of those types has been related, often indirectly, to flooding. Shelford (1954) regarded various forest types as representing successional stages from aquatic to upland. Others (Braun 1950, Putnam 1951) discussed plant communities with respect to topography, with the various land types reflecting flooding and drainage conditions. Recent investigations (Bedinger 1971, 1978, Huffman 1980) have established correlations between flooding regimes and certain forest types independent of other variables. Thus, relatively mature bottomland forest types have been satisfactorily shown to be distributed primarily in relation to flooding. The question of concern here, however, is whether these known relationships can be extrapolated to situations where the flooding regime has been altered, thus allowing prediction of the rate and pattern of change and the eventual forest structure and composition on a given altered site.

49. Flooding and water availability impose stresses on plants that limit the distribution of species in fairly specific ways. Seedlings of many commercially important tree species have been experimentally tested for flood tolerance (Hosner 1958, 1960; Hosner and Boyce 1962; Dickson et al. 1965), and field observations of all size classes of these and other species provide a relatively good understanding of tolerance limits for many common bottomland trees (Table 3). Thus, if the flooding regime of a particular site is changed to a known degree, the common tree species capable of germinating and surviving under the new flooding conditions can usually be easily determined. However, the actual eventual forest composition will be dependent on a number of factors other than simple flood tolerance, as discussed below.

50. Given that a change in flooding of known magnitude will occur and that the tree species capable of reproducing under the altered conditions are known, three questions must be satisfactorily addressed in order to predict habitat conditions:

a. To what degree and at what rate will the existing forest succumb to the change?

b. If a radical change in forest composition is anticipated, what intervening developmental stages will occur before a relatively stable cover type is established?

c. Given the cover types that might become established under the projected flooding regime, which are most likely to occur under the soil conditions, management practices, and other pertinent factors that characterize the site?

Impacts on existing stands

51. Increased flooding. The rate and extent of decline of an existing forest is most easily predicted in situations where extreme increases in flooding are anticipated. Studies by Yeager (1949) and Hall and Smith (1955) demonstrated that nearly total mortality may be expected within a decade when forests are subjected to greatly increased or prolonged flooding. Substantial losses will occur within a few years. One possible exception to this generalization is the near-permanently flooded swamp; no evidence has been located that suggests that mature trees in cypress-tupelo swamps will suffer mortality under increased flooding conditions. It should be noted that the situations referred to above concern growing-season floods of increased magnitude and duration. Should a site be subjected to deeper floodwaters, but without a significantly increased growing-season duration, prediction of mature tree mortality is less clear.

52. Minor increases in growing-season flooding should not quickly cause significant mature tree mortality in regularly inundated environments, since existing trees in these areas will be species capable of withstanding such conditions. However, stresses may be imposed that would result in long-term decay of a stand through increased susceptibility to windthrow and disease. Dormant-season flooding (greentree reservoir) of bottomland forests has not been shown to result in overstory mortality except when the prescribed pre-growing-season drawdown did not occur.

53. Mortality from minor increases in growing-season flooding may be expected to be greatest in habitats that previously received only occasional short-duration flooding or none at all. The driest bottomland habitats include species (such as yellow poplar) incapable of

tolerating more than a few days of flooding, thus a patchwork of dead trees might be apparent in such an area within a few years after hydrologic change. Even significantly raised water tables may be expected to cause differential mortality in such areas.

54. Another factor related to increased flooding is increased sedimentation, which may drastically intensify tree mortality. Where sediments are deeply deposited by floodwaters, many tree species show deleterious effects in a short time. This problem appears to be relatively unimportant in riverfront cover types (particularly willow).

55. Although information on understory response to increases in flooding is limited primarily to extreme cases, it is reasonable to assume that the pattern of response would be similar to that outlined for tree species, with almost total losses under severe conditions and less drastic, differential mortality from minor changes. However, any increase in flooding that produces prolonged, total immersion of low-growing plants will result in massive losses at any point along the flood gradient. The effects of sedimentation on understory plants has not received significant attention in the literature, but one study (Howard and Penfound 1942) indicated that herbaceous plants and low shrubs are much more susceptible than vines.

56. Decreased flooding. Mature tree mortality associated with decreases in flooding has been reported where drainage has intensified the effects of severe drought. However, most bottomland tree species appear to be capable of withstanding drier conditions than those in which they typically reach optimum importance in the forest. Growth may be expected to decline for most species whenever water availability falls below optimum, but as long as water is available within the rooting zone, mortality should not occur. Sites which might be particularly susceptible to devastation by occasional severe drought include those where soils are extremely sandy and droughty; where deep rooting is impeded by an impervious soil layer; and where accumulation of sodium and potassium salts or extremely fine-textured soils reduce water availability. Tree species that have demonstrated susceptibility to drought damage are cottonwood; sweetgum; black willow; and to a lesser extent

red oaks (especially Nuttall), elms, green ash and sycamore. The literature available for this review gives no indication of the response of existing understory vegetation to flood reduction or drought.

Succession, management, and eventual composition

57. Alteration of the flooding regime in a bottomland forest constitutes a disturbance; thus predicting the eventual composition and structure of such a forest community (including its wildlife component) is a question of predicting successional trends. A great many authors (e.g. Gleason 1939, Whittaker 1953, Drury and Nisbet 1973, Daubenmire 1976) have discussed the difficulties of formulating simplistic successional pathways or of relating community development to a single environmental factor. The nature of the disturbance, its periodicity and severity (Cattelino et al. 1979), and the characteristics of the stressed or invading organisms themselves (Wells 1976) all have a bearing on rate and direction of change. The addition of factors other than hydrologic change (such as various methods of timber harvesting; differential browsing pressure; or gradually changing sediment, pesticide, or nutrient loads) further complicates the matter. However, certain generalizations are justified based on the literature reviewed in this report.

58. The rate of compositional change in a hardwood stand where flooding has been altered is highly dependent on the rate of decline of the existing overstory. Unless advanced reproduction of appropriate species is present, large canopy openings created by mature tree mortality will usually be colonized by shade-intolerant species, and stand development will proceed through a series of sequential stages similar to those outlined by Shelford (1954) and Hosner and Minckler (1963). In areas where flooding becomes deep and prolonged causing severe overstory mortality, open water may persist or stand development may be arrested at some early stage (e.g., buttonbush or willow) until sedimentation raises the substrate elevation or conditions occur which facilitate reproduction of swamp species. Changes in stands where the canopy remains closed (i.e., without significant overstory mortality) may be very gradual, particularly if species appropriate to the altered site

conditions are not already present on the site or if seed sources are not available in the vicinity.

59. The problem of appropriate seed sources is most important where flooding has been reduced sufficiently to curtail "floating in" of the heavier seeded species such as oaks. Windborne propagules, such as those of willow and cottonwood, are likely to be available on most sites, but acorns and other nuts must be transported to any site where parent trees do not occur. Thus, *distance to seed sources may be critical* in determining stand development rates. In cases where flood alterations are minor, seedlings and saplings of appropriate species may be present on the site and could provide a relatively rapid transition to a new, fairly stable stand composition. However, it has been demonstrated that smaller sized trees are also most sensitive to flood alterations; thus they cannot be expected to persist if substantial changes, particularly increases, are effected.

60. The variety of possible developmental rates and successional pathways may be illustrated through examination of a few site-specific studies. Thompson and Anderson's (1976) study in southern Illinois provides an example of succession on a former "swamp" site (presumably cypress-tupelo) where permanent drainage has occurred. More than 60 years after alteration of the hydrologic regime, the site was still dominated by the relatively pioneer species, black willow. Assuming the area was not logged or farmed in the interim (the authors make no specific mention of such activity on the site), it appears likely that the swamp species persisted for some time and that stand decay then proceeded rapidly enough to promote invasion by black willow. Regardless of the origin of the black willow, the current stand composition provides clues to its future development. Green ash, which is well represented in intermediate size classes, will evidently assume dominance after the willow. Pin oak is the principal species in the smallest size classes and may be expected to replace green ash in time, unless it is eliminated through shading. Since both green ash and pin oak are relatively intolerant of shade, it is reasonable to expect that other species not yet important in the stand will eventually assume dominance

if the stand remains undisturbed. Thus, it appears that approximately a century will be required to establish an acorn-producing cover type (pin oak) on this drained swamp site at the northern limits of the study area and that more time will be required to achieve a stable, self-reproducing cover type.

61. In contrast to this slow process, stand development on newly formed land at the southern extreme of the study area seems to proceed rather quickly. Review of aerial photography of the Atchafalaya River basin (USDI 1976) showed relatively rapid stand replacement resulting from sedimentation. One site showed a shift from cypress/willow/tupelo in 1930 to mature willow in 1952 to "mixed hardwoods" (specific composition not indicated) in 1973. Thus, a process taking about 100 years in Illinois has occurred in just 40 years in Louisiana. Whether more rapid change is characteristic of sedimentation areas or whether other site characteristics are of primary importance could not be determined from the data presented. However, it seems likely that differences in growth rates associated with longer growing seasons will result in accelerated stand development in southern portions of the study region.

62. Inference of developmental trends is more difficult in matched-pair studies such as those by Arner et al. (1976) and Fredrickson (1979). Although the authors apparently attempted to choose sites believed to be of similar initial composition, it is possible that initial differences were present or that differential management otherwise affected current composition in ways that reduced stand comparability. However, Fredrickson concluded that an area operated as a greentree reservoir in southeastern Missouri was beginning to show a "wetter" character after 20 years of dormant-season flooding. This type of slow change may be typical in areas where canopy trees are not killed by changes in flooding regime.

63. The classic successional sequence from new land to mature forest described by Shelford (1954) provides some insight into the time required for community development. Although discussed from the point of view of land-building resulting in increasing elevation, Shelford's system also incorporates aspects of shade tolerance and pioneer/climax

species characteristics. He estimates that in excess of two centuries are required for plant community development to proceed from willow-dominated to the point where elms, oaks, and hickories begin to assume importance.

64. Timber management effects in bottomland forests may be evident long after a site has been thinned or harvested. For example, in comparing an old-growth bottomland forest in southern Illinois to an adjacent secondary stand harvested about 75 years prior to their study, Robertson et al. (1978) found differences in size-class distributions, shrub and overstory composition, and stand regeneration strategies apparently attributable to the prior disturbance. The type of harvesting method used also seemed to have had an effect on composition of the secondary stand; the absence of highly shade-intolerent species suggested that clearing was selective and did not result in the creation of large openings in the forest. Thus, more than 75 years after a noncatastrophic timber harvest, stand conditions were still markedly dissimilar from those typical of the site and flooding regime, as represented by the old-growth stand.

65. Another example of the effects of timber harvesting may be seen in some of the hackberry- or sugarberry-dominated stands found throughout the study area. According to Putnam (1951) and Shelford (1954), these stands may often be the result of severe or repeated disturbance, including selective removal of more commercially valuable tree species. Since Celtis spp. occur in a great many forest types across a wide range of flooding regimes (Fowells 1965), and thus may persist following hydrologic alteration, the potential for these species to increase in importance is great where other species are eliminated through cutting, or through mortality due to alteration of hydrology or other causes.

66. Johnson and Bell (1976) studied long-term effects of flooding and disturbance caused by disease and timber harvesting. Floodplain, transition zone, and upland forests adjacent to the Sangamon River in east-central Illinois were sampled to determine plant biomass and net primary production of three strata in three flood-frequency zones.

Total aboveground biomass was estimated to be 290.0 t/ha in the lower floodplain, 142.1 t/ha in the transition zone, and 234.2 t/ha in the upland. The percentage of these totals accounted for by herbaceous and shrub species was 0.4 percent (1.3 t/ha), 4.9 percent (7.0 t/ha), and 3.0 percent (7.2 t/ha), respectively. Estimated total net primary production was 12.5 t/ha/yr in the floodplain, 8.0 t/ha/yr in the transition zone, and 10.9 t/ha/yr in the upland. Seven tree species were encountered in the floodplain, with silver maple being dominant. The transition zone had 16 tree species, with hackberry and shingle oak (Quercus imbricaria) being the principal components. The upland area was strongly dominated by white oak, although 13 other tree species were represented. Johnson and Bell speculated that two disturbance factors contributed to the patterns observed. Selective logging was conducted throughout the area prior to 1890, and the upland forest still shows the effects of this activity due to its slow growth rate. The floodplain forest, however, with its high moisture availability, has almost completely recovered from this prior disturbance. The transition zone, which is believed to have been dominated by American elm prior to the 1950's, showed the effects of Dutch elm disease and phloem necrosis in a low tree biomass and a correspondingly high percentage of shrub and herbaceous production. Thus, disturbances over the course of a century continued to have an impact not only on community composition but on standing crop and net primary productivity of the ecosystem, and recovery of the various flood zones and forest strata is affected differentially by flood frequency as it influences growth rate.

67. Timber management effects on stand development are difficult to summarize due to the great variety of management systems used. Johnson (1978) pointed out that at least 40 species grow to commercial size in southeastern bottomlands and that management systems employed may range from careful thinning and stand manipulation to simple diameter-limit cuts or high-grading. In natural stands tree reproduction is dependent on a number of factors, but release from shading is critical for most important species, while hackberry, mulberry, elm, and hickories may survive well under shading (Putnam 1951, Hosner and

Minckler 1963). Thus, stand composition will be highly dependent on the kind and intensity of continuing management employed.

68. Factors other than timber harvests will also have a bearing on stand development. Putnam (1951) pointed out that regeneration in swamps will occur only in the rare year or succession of years when favorable flooding conditions exist. Huffman (1980) identified a similar seedling sensitivity to flooding regime on drier sites flooded for short periods. Thus, bottomland sites that are suitable in every way for the development of certain tree species may not support those species for years if flooding conditions are inappropriate. Other factors that may influence regeneration include fire, cattle grazing, and vine or shrub competition (Putnam 1951).

69. Assuming a group of species have successfully established on a given altered site and are capable of surviving the flooding regime, which will be most successful and persist or assume dominance? Since light is critical to so many bottomland species (Putnam 1951), this factor will probably be the prime determinant (other than flooding) of eventual composition. In heavily shaded stands, only a small number of species are likely to be successful, as described above. However, in open areas, competition for canopy positions will be dependent on the rate of height growth of each species (unless undesirable species are regularly thinned from the stand). Therefore, the best means of predicting the success of a species on such a site is probably the site index, which uses soil/site factors to predict growth rate of selected species. Site index studies are available for the more commercially valuable bottomland species (Baker and Broadfoot 1979). On sites where flooding has been reduced sufficiently to promote the establishment of upland forest types, regional site index studies should be used since upland forests adjacent to bottomlands vary considerably in composition along the Mississippi Alluvial Plain (Braun 1950). In general, predicting the eventual cover type to establish following flood alteration will be least difficult in zones which will be regularly or near-permanently flooded (e.g., overcup oak-bitter pecan, cypress-tupelo).

70. The influence of factors such as those discussed above may

produce conditions dissimilar to what might be expected on a site based on flood alteration alone. For example, Fredrickson (1979) found higher densities of herbaceous plants within a greentree reservoir than outside the impoundment, which is inconsistent with the general pattern of less ground cover on more flooded sites. Similarly, herbaceous and woody species diversity was sometimes lower in areas where flooding had been reduced than in areas experiencing uncontrolled flooding, again in contrast to the "expected" situation. Clearly, then, the generalized trends described earlier are not strong and may well be altered or reversed depending on individual site characteristics, including management history.

71. The above discussion is concerned primarily with the determination of eventual forest composition on a site where the flooding regime has been altered. However, it is clear that intervening developmental stages may occur (or persist, under management) that will have a bearing on wildlife habitat. The importance of stand condition in the assessment of wildlife habitat was demonstrated by Hopkins and Darden (1975). In an evaluation of eleven forest stands near Vicksburg, Mississippi, they found wide variation in habitat quality within forest types depending on stand condition. For example, in overcup oak-water hickory forests, poison ivy was the principal summer browse species in all stand conditions except immature poletimber, where it was entirely absent. In American elm-green ash stands, poison ivy was the most important browse species in immature poletimber and mature sawtimber, but was absent from immature sawtimber stands and was less important than trumpet vine in sparse sawtimber. Another study conducted in the same area (Bourland 1978) found that three site preparation treatments designed to promote hardwood regeneration differed greatly with respect to seedling density and composition (and with respect to passerine bird usage and deer food abundance). Other examples are available, but the point is clear: the successional stage/stand condition may well be of greater importance in determining the quality of wildlife habitat than the general characteristics of the cover type as a whole. This is especially important as it relates to shrub and herbaceous production, which is clearly related to the amount of light penetration.

PART IV: WILDLIFE

General Characteristics

72. The dependence of alluvial systems and their associated fauna on fluctuating water levels and periodic pulses of water flow has been addressed in several studies, including Fredrickson (1978) and Weller (1978). According to Weller (1978), water movement through a region may reduce the establishment and survival of vegetation important as cover and food for wildlife, but periodic flooding provides new nutrients and flushes out detritus needed by adjacent areas. The importance of fluctuating water levels through various elevations and vegetative zones in the Mississippi Delta was discussed by Fredrickson (1978), who emphasized that not only were plant establishment and growth controlled largely by water, but aquatic and semiaquatic invertebrate foods were also dependent upon water level changes induced by flooding. Fredrickson (1978) additionally stated that such pulsations through a system make food readily available to a variety of animals and that both plant and animal communities have a characteristic distribution within these systems that is related to flood duration, frequency, and water depth.

73. The status of bottomland hardwoods in relation to wildlife in the lower Mississippi Valley floodplain has been discussed by several authors (Yancey 1970, Glasgow and Noble 1971, Fredrickson 1978). Yancey (1970) asserted that these bottomland regions were among the most productive game and fish habitats on the North American continent due largely to the variety of mast-producing plants that provide essential wildlife foods on a year-round basis. Glasgow and Noble (1971), in a report on bottomland hardwoods of the coastal plain of Louisiana and Mississippi, stated that reasons for high wildlife production in this area were high soil fertility, abundant moisture, quality and quantity of wildlife foods, good escape cover, low incidence of fire, and the general accessibility of agricultural food crops.

74. Wildlife populations are dependent on various factors and conditions including food, cover, water, competition, predation, and

type and intensity of human activity. Certain species are largely dependent upon soils, moisture, and the structure and composition of plant communities, whereas others are highly mobile and tolerant of a variety of conditions and habitat changes. According to Fredrickson (1978), certain species of wildlife make seasonal shifts into different hardwood zones to escape flooding, to forage, or to hibernate. Modifications to bottomland hardwoods cited by Glasgow and Noble (1971) as generally affecting wildlife included logging, burning, grazing, flood control, ditching, construction and management of greentree reservoirs, beaver activity, and agriculture.

75. Modifications in the magnitude, frequency, and duration of flooding are expected to bring about a wide variety of impacts on different species depending upon their ability to tolerate both direct and indirect changes to the flooding regimes. Impacts of flooding regime modifications are addressed on a case-by-case basis (by species and/or groups of species) in the following sections. The habitat requirements of certain species are also discussed in order to provide baseline information for understanding indirect impacts of water level changes.

Mammals

76. Approximately 70 species of mammals have been reported from the lower Mississippi Valley study area (Table 4), the majority of which are known to occur in a variety of habitats. Several species, however, have a definite preference for bottomland hardwoods and wooded swamps. The following narrative provides information on habitat preferences and impacts of flooding regime modifications on game and commercial mammals and nongame species. Key species and groups such as raccoons, squirrels, rabbits, and white-tailed deer are discussed individually.

Game and commercial species: General

77. Faunal status. Principal game species and furbearers of bottomland hardwoods of the region include the swamp rabbit (*Sylvilagus aquaticus*), eastern cottontail (*S. floridanus*), gray squirrel (*Sciurus carolinensis*), fox squirrel (*S. niger*), beaver (*Castor canadensis*),

Table 4

Mammals of Actual or Probable Occurrence in Generalized Habitat Types of the Lower Mississippi Valley Study Area, Southern *Illinois* to South *Louisiana*

Species	Habitat Types: Marshlands	Lakes, Ponds	Rivers, Streams, Bayous	Swamps, Sloughs	Wooded Bottomland	Wooded Uplands	Grasslands, Shrubland, Open Terrain
Opossums							
Virginia opossum (Didelphis virginiana)	+*			+	++	++	++**
Shrews and Moles							
Southeastern shrew (Sorex longirostris)	+			++	++	+	+
Short-tailed shrew (Blarina brevicauda)					+	+	+
Least shrew (Cryptotis parva)	+					+	++
Eastern mole (Scalopus aquaticus)					+	++ (sandy, moist)	+ (moist)
Bats							
Little brown myotis (Myotis lucifugus)	The majority of bats require permanent water sources (ponds, lakes, slow-moving streams) for drinking and foraging					+	+ (crevices, dwellings)
Southeastern myotis (Myotis austroriparius)						+	+ (caves, structures)
Gray myotis (Myotis grisescens)							+ (caves)
Keen's myotis (Myotis keenii)						+	+ (caves)
Indiana myotis (Myotis sodalis)							+ (caves)
Small-footed myotis (Myotis leibii)							+ (crevices, canyons)
Silver-haired bat (Lasionycteris noctivagans)					+	+	+ (edge)
Eastern pipestrelle (Pipistrellus subflavus)					+	+ (open)	+ (caves, crevices, dwellings)
Big brown bat (Eptesicus fuscus)						++	+ (crevices, dwellings)
Red bat (Lasiurus borealis)					+	++	+
Seminole bat (Lasiurus seminolus)					+	+	+
Hoary bat (Lasiurus cinereus)						+	
Northern yellow bat (Lasiurus intermedius)					+	+	+
Evening bat (Nycticeius humeralis)					+	+	+ (dwellings)
Rafinesque's big-eared bat (Plecotus rafinesquii)						+	+
Townsend's big-eared bat (Plecotus townsendii)						+	+ (caves, dwellings)
Brazilian free-tailed bat (Tadarida brasiliensis)						+	+ (caves, dwellings)
Armadillos							
Nine-banded armadillo (Dasypus novemcinctus)				+	+	++	++
Hares and Rabbits							
Eastern cottontail (Sylvilagus floridanus)					+	+	++
Swamp rabbit (Sylvilagus aquaticus)	++		+	+	++		

(Continued)

* + = reported occurrence in habitat type.
** ++ = known preference for habitat type.

Table 4 (Concluded)

Species	Habitat Types: Marshlands	Lakes, Ponds	Rivers, Streams, Bayous	Swamps, Sloughs	Wooded Bottomland	Wooded Uplands	Grasslands, Shrubland, Open Terrain
Rodents							
Eastern chipmunk (*Tamias striatus*)					+	++	+
Woodchuck (*Marmota monax*)						+ (edge)	+
Gray squirrel (*Sciurus carolinensis*)				++	++	++	
Fox squirrel (*Sciurus niger*)				+	+	++	+ (edge)
Southern flying squirrel (*Glaucomys volans*)				+	+	+	
Plains pocket gopher (*Geomys bursarius*)						+	++
Hispid pocket mouse (*Perognathus hispidus*)							++
Beaver (*Castor canadensis*)	+	++	++	++	+		
Marsh rice rat (*Oryzomys palustris*)	++				+	+	+ (moist)
Western harvest mouse (*Reithrodontomys megalatis*)	+						++
Eastern harvest mouse (*Reithrodontomys humulis*)							++
Fulvous harvest mouse (*Reithrodontomys fulvescens*)					+ (edge)	+ (borders)	++
Deer mouse (*Peromyscus maniculatus*)						+	++
White-footed mouse (*Peromyscus leucopus*)					++	++	+
Cotton mouse (*Peromyscus gossypinus*)				++	++	++	+ (edge)
Golden mouse (*Ochrotomys nuttalli*)				+	+	++	+
Hispid cotton rat (*Sigmodon hispidus*)	+					+	++
Eastern woodrat (*Neotoma floridana*)	+			+	++	++	+
Prairie vole (*Microtus ochrogaster*)							++
Woodland vole (*Microtus pinetorum*)					+	++	+ (edge)
Muskrat (*Ondatra zibethicus*)	++	++	++	+	+		
Southern bog lemming (*Synaptomys cooperi*)				+	+ (damp woods with ground litter)	+	+ (moist)
Black rat (*Rattus rattus*)	+				+	+	+
Norway rat (*Rattus norvegicus*)					+	+	+
House mouse (*Mus musculus*)					+	+	+
Meadow jumping mouse (*Zapus hudsonius*)						+ (edge)	++
Nutria (*Myocastor coypus*)	++	+	+	+	+ (edge)		
Carnivores							
Coyote (*Canis latrans*)	+				+ (edge)	+ (edge)	++
Red wolf (*Canis rufus*) - extinct or nearly so	+			+	+	+	+
Red fox (*Vulpes vulpes*)	+				+ (edge)	++ (edge)	+
Gray fox (*Urocyon cinereoargenteus*)					+ (edge)	++	+
Black bear (*Ursus americana*)				+	+	+	+
Ringtail (*Bassariscus astutus*)					+	+	++
Raccoon (*Procyon lotor*)	++	+	+	++	++	+	+
Long-tailed weasel (*Mustela frenata*)	+				+	+	+
Mink (*Mustela vison*)	++	+	+	++	++	+	+
Eastern spotted skunk (*Spilogale putorius*)					+	+	++
Striped skunk (*Mephitis mephitis*)					+	+	++
River otter (*Lutra canadensis*)	++	+	++	++	+	+ (edge)	
Cougar (*Felis concolor*)				+	+	+	+
Bobcat (*Felis rufus*)	+			+	++	++	++
Hoofed Mammals							
Wild boar (*Sus scrofa*)				+	+	+	+
White-tailed deer (*Odocoileus virginianus*)	+			+	++	++	+

muskrat (Ondatra zibethicus), nutria (Myocastor coypus), opossum (Didelphis virginiana), raccoon (Procyon lotor), mink (Mustela vison), river otter (Lutra canadensis), bobcat (Felis rufus), and white-tailed deer (Odocoileus virginianus). According to Chabreck (1978), wetlands are an important component of the habitat used by many furbearers, but few species are limited to this environment. Commercially important species reported as spending a large portion of their time in wetlands were beaver, mink, muskrat, nutria, and river otter (Chabreck 1978). Fredrickson (1978) stated that river otter and beaver were the most aquatic mammals in lowland hardwoods and that both species occurred near permanent water. Mink were reported to concentrate their activities near water, whereas raccoons wandered over a larger area that might include both permanent water and uplands. Swamp rabbit, deer, bobcat, and gray fox (Urocyon cinereoargenteus) were also said to occur in bottomlands but concentrated their use when flooding was not in progress (Fredrickson 1978).

78. Upland furbearers occasionally found in bottomland situations include the coyote (Canis latrans), red fox (Vulpes vulpes), gray fox, and skunks. Although primarily upland species, both the striped skunk (Mephitis mephitis) and spotted skunk (Spilogale putorius) were reported by Lowery (1974) to occasionally eat frogs, salamanders, and crayfish. According to Schitoskey and Linden (1978), animals normally considered upland species may be forced to adapt to lowland regions where uplands are developed for agriculture or other human use. Yeager (1949) found that increased flooding limited areas suitable for ground dens for terrestrial mammals such as skunks and foxes.

79. Few studies were located that compared the relative values of habitats for game and commercial mammals in bottomland regions of the Southeast. Although not conducted in the lower Mississippi Valley study area, an applicable study by McKeever (1959) reported the relative abundance of furbearers and small game mammals in bottomland hardwoods of Georgia and Florida compared with adjacent habitat types. Habitats were ranked in descending order of value (based on percentage catch of all species) as follows: pine-hardwoods, cultivated area, bottomland

hardwoods, tall weeds-broomsedge, upland hardwoods, and pine. Species occurring in bottomland hardwoods were the opossum, eastern cottontail, fox squirrel, gray squirrel, raccoon, striped skunk, spotted skunk, and bobcat (Table 5, compiled from McKeever 1959), but many species were common in a variety of habitats. McKeever (1959) stated that vegetative life form was a dominant factor controlling the distribution of many species.

80. Several studies have compared habitat preferences of game and commercial species in the Atchafalaya Basin Floodway, Louisiana. Nichols and Chabreck (1973) compared harvest data for swamp and marsh regions in the basin and found that mean harvest values from the two habitats were not significantly different for muskrat, nutria, and otter; however, mink and raccoon harvest means were significantly higher in the swamp. Harvest data were also presented for different vegetation types (cypress-tupelo, cottonwood-willow-sycamore, and bottomland hardwoods) within the swamp region which produced a large portion of the total income from nutria, mink, and raccoon. Cypress-tupelo areas were the swamp type preferred by trappers. Muskrat and nutria harvest means were higher in cypress-tupelo, and mink, raccoon and otter harvest means were greater in bottomland hardwoods (Nichols and Chabreck 1973). Yancey (1970) also reported that mink, otter, and raccoon thrived in tupelo-cypress brakes and sloughs.

81. Mullins (1978) conducted a survey of game mammals and furbearers in three major forest types (cypress-tupelo, cottonwood-willow-sycamore, and bottomland hardwoods) in the Atchafalaya River Basin. Bottomland hardwood regions were characterized by sweetgum, hackberry, ash, and elm. Results of track and night counts pertinent to this report are summarized from Mullins (1978) as follows: deer and bobcat were significantly more abundant in bottomland hardwoods, but bobcat tracks occurred more often on spoil elevations than on natural elevations; beaver and swamp rabbit abundance was significantly greater in cottonwood-willow-sycamore, whereas mink and nutria populations were greater in cypress-typelo. No significant differences occurred in squirrel densities among forest types, and natural elevations had

Table 5

Trapping Success and Percent Catch of Medium-Sized Mammals in Six Habitat Types in the Southeastern United States (Southwestern Georgia and Northwestern Florida). Numbers in Parentheses Show Percent Trapping Success. (After McKeever 1959)

Species*	Habitat Type					
	Cultivated Area	Tallweeds-Broomsedge	Pine	Pine-Hardwoods	Upland Hardwood	Bottomland Hardwoods
Opossum	49 (1.9%)	468 (2.4%)	30 (1.4%)	117 (3.4%)	7 (1.5%)	93 (3.3%)
Eastern cottontail	39 (1.5%)	221 (1.1%)	12 (0.6%)	41 (1.2%)	5 (1.1%)	24 (0.8%)
Marsh rabbit	--	3 (0.02%)	--	1 (0.03%)	--	4 (0.14%)
Fox squirrel	3 (0.12%)	57 (0.3%)	8 (0.4%)	5 (0.15%)	1 (0.2%)	2 (0.07%)
Gray fox	28 (1.1%)	105 (0.5%)	4 (0.2%)	13 (0.4%)	5 (1.1%)	5 (0.2%)
Red fox	10 (0.4%)	16 (0.1%)	2 (0.1%)	--	--	--
Raccoon	65 (2.6%)	490 (2.5%)	16 (0.8%)	76 (2.2%)	11 (2.4%)	90 (3.2%)
Striped skunk	36 (1.4%)	235 (1.2%)	33 (1.6%)	78 (2.3%)	5 (1.1%)	16 (0.6%)
Spotted skunk	2 (0.08%)	5 (0.03%)	--	1 (0.03%)	--	2 (0.07%)
River otter	--	1 (0.005%)	--	1 (0.03%)	--	--
Bobcat	1 (0.04%)	22 (0.1%)	18 (0.9%)	34 (1.0%)	4 (0.9%)	21 (0.7%)
House cat	13 (0.5%)	24 (0.1%)	5 (0.2%)	5 (0.5%)	--	--
Total	246 (9.7%)	1,647 (8.3%)	128 (6.2%)	372 (10.9%)	38 (8.3%)	257 (9.1%)
No. Trap nights	2,541	19,788	2,096	3,430	457	2,833

* The long-tailed weasel and gray squirrel also occurred in the region but were not subject to censusing by method used. The marsh rabbit does not occur in the lower Mississippi Valley study area.

significantly higher squirrel occurrence than spoil elevations in the cypress-tupelo forest type.

82. According to USDI (1976), track count surveys of fur and game mammals in the above forest types of the Atchafalaya Basin showed that the highest relative numbers of animals occurred in cypress-tupelo forests compared with bottomland hardwoods and cottonwood-willow-sycamore. A reexamination of the USDI data (shown in Table 6), however, indicated that a reversal of their conclusions may, in fact, be the case. Tracks counted per effective observation effort showed that bottomland hardwoods supported a comparatively greater number of mammals, with the least numbers occurring in cypress-tupelo. USDI (1976) also stated that preliminary night-lighting data indicated that population trends appeared to substantiate results of their track counts. An examination of tables provided by USDI (1976), however, also showed that bottomland hardwoods supported the greatest number of species followed by cottonwood-willow-sycamore (based on counts per effort).

83. Impacts of flooding regime modifications. Channelization is generally reported to be detrimental to game and commercial species because of the removal of streamside vegetation and resultant deterioration of habitat quality. Fredrickson (1979) reported that after channelization riparian habitat is nonexistent along new channels and species such as river otter, mink, beaver, and muskrat disappear. Both leveed and backwater cutoffs, however, were said to provide good habitat for these species. Arner et al. (1976) compared furbearer use of unchannelized, old channelized (over 52 years), and newly channelized segments of the Luxapalila River, Mississippi and Alabama, over a 3-year period (Table 7). Results of the study showed that muskrat and beaver were far more numerous in unchannelized segments, and otter were found only in the unchannelized region. Raccoon occurred commonly in both unchannelized and old channelized segments, and mink appeared most common in old channelized regions. Furbearers recorded on newly channelized segments were invariably located at the mouths of feeder streams leading into unchannelized areas (Arner et al. 1976).

84. Few studies were located which related directly to impacts of

Table 6

Furbearers and Game Mammals Indicated by Track Counts on Standardized plots in the Atchafalaya Basin, Louisiana, July 1976 (After USDI 1976). Analysis of Counts Based on Effective Observation Effort*

	Cypress-Tupelo (48 Plots Observed; 10 Erased by Rain)		Cottonwood-Willow-Sycamore (16 Plots Observed; 9 Erased by Rain)		Bottomland Hardwoods (16 Plots Observed; 5 Erased by Rain)	
	On Spoil	Off Spoil	On Spoil	Off Spoil	On Spoil	Off Spoil
Raccoon	4	3	1	0	2	2
Mink	3	10	0	0	0	0
Bobcat	0	0	1	0	3	3
Opossum	0	0	1	1	0	0
Swamp rabbit	8	6	1	2	1	0
Beaver	1	0	0	0	0	0
Nutria	3	2	0	0	0	0
Muskrat	0	2	0	0	0	0
Fox squirrel	0	1	0	0	0	1
Gray squirrel	0	0	0	0	2	0
White-tailed deer	0	0	1	1	3	2
	19	24	5	4	11	8
	43		9		19	
* Effective observations (assuming plots erased by rain were not included)	38		7		11	
Tracks counted per effective observation effort.	1.13		1.29		1.73	

Table 7

Summary of Furbearer Counts During 25 Night Float Trips (Feb 1975-Apr 1976) and Track Counts (Oct 1974-Aug 1975) Along the Luxapalila River, Mississippi and Alabama (After Arner et al. 1976)

Habitat	Furbearer Counts				
	Beaver	Mink	Muskrat	Raccoon	Otter
Old Channelized Segments					
Night Counts = Total + (Number/mile) Total distance = 60.5 mi	21 (0.347)	2 (0.033)	1 (0.017)	9 (0.149)	0.0
Track Counts = Number Check days/count	4.86	13.60	0.0	2.43	0.0
Unchannelized Segments					
Night Counts = Total + (Number/mile) Total distance = 36.0 mi	40 (1.11)	0.0	17 (0.472)	9 (0.250)	0.0
Track Counts = Number Check days/count	6.80	4.86	68.00	2.19	68.00
Newly Channelized Segments					
Night Counts = Total + (Number/mile) Total distance = 12.6 mi	8 (0.635)	0.0	5 (0.397)	1 (0.079)	0.0
Track Counts = None recorded					

flooding on the overall game and commercial mammal fauna of sites within the lower Mississippi Valley region. Early studies by Yeager and Anderson (1944) and Yeager (1949) addressed impacts of seasonal and permanent flooding on mammal populations of bottomland hardwoods in Illinois. Seasonal flooding resulted in no noticeable change in mink populations; minor effects to fox squirrel, raccoon, and opossum; and highly detrimental impacts to cottontail, woodchuck (Mormata manax), and muskrat populations (Yeager and Anderson 1944). Permanent flooding brought about more serious changes to species such as opossum and squirrels, but did not seriously affect raccoon and mink populations (Yeager 1949). Muskrat were initially affected but showed substantial recovery due to stabilized water levels created by permanent impoundment. Additional impacts of flooding are addressed on a species-by-species basis in the following accounts.

Rabbits (*Sylvilagus floridanus* and *S. aquaticus*)

85. Habitat requirements. The eastern cottontail and swamp rabbit are found in various bottomland situations throughout the lower Mississippi Valley. The cottontail prefers open brush, forest edge, or well-drained streamsides (Schwartz and Schwartz 1959, Davis 1974, Lowery 1974), but according to Glasgow and Noble (1971), the species has invaded lowlands in force with the conversion of many bottomland areas to agriculture. Hopkins and Darden (1975) reported that in the Delta National Forest, Mississippi, the quantity and quality of cover in the sweetgum-Nuttall oak-willow oak forest type (sparse and immature sawtimber classes) provided good cottontail habitat and was distinctly better than the overcup oak-water hickory forest type. Sparse sawtimber and immature poletimber classes of the sugarberry-American elm-green ash forest type also supported good populations. Cottontails required from about 1 to 4 ha per animal in forest types of the Delta National Forest (Hopkins and Darden 1975) compared with ideal agricultural habitat which can support 5 to 7 animals per ha (USDA 1971).

86. The swamp rabbit is a representative species of poorly drained bottomland hardwoods, swamps, and coastal marshlands (Schwartz

and Schwartz 1959, USDA 1971, Lowery 1974, Fredrickson 1978). Lowery (1974) stated that swamp rabbits were particularly abundant in Louisiana where canal banks and chenieres (wooded ridges) provided cover. Fredrickson (1978) reported that the densest populations in Missouri occurred where forests were disturbed and provided small natural openings. Heuer and Perry (1976) examined the relative abundance of swamp rabbits in bottomland hardwoods (hackberry-ash-sweetgum-elm), cypress-tupelo, and cottonwood-willow-sycamore habitats in the Atchafalaya River Basin and found that populations varied significantly by overstory type with highest densities in bottomland hardwoods and lowest in cypress-tupelo. USDI (1976), however, reported swamp rabbits to be common in cypress-tupelo during dry years. Hopkins and Darden (1975) found that swamp rabbit populations were only average (about 4 to 8 ha per animal) in sweetgum-Nuttall oak-willow oak, sugarberry-American elm-green ash, and overcup oak-water hickory forests in the Delta National Forest, Mississippi. The highest carrying capacities occurred primarily in sparse sawtimber stands of these forest types. The authors, however, stated that an important consideration for evaluating swamp rabbit habitat is the availability of permanent water edge, which was not taken into account in determining carrying capacity in their study. Additional habitat and natural history information is provided in Toll et al. (1960), Korte (1975), and Korte and Fredrickson (1977b).

87. Studies by Calhoun (1941) in Tennessee and Lowe (1958) in Georgia indicated a distinct delineation of swamp rabbit and cottontail ranges where both species occurred, but Toll et al. (1960) found a gradation from cottontail to swamp rabbit ranges with a broad band of overlap in disturbed bottomland hardwoods of Missouri. Only swamp rabbits were captured in deep wooded swamps, but both species occurred in a wide transition belt; cottontails were generally trapped farther from open water, but there were occasional exceptions (Toll et al. 1960). Glasgow and Noble (1971) reported that although the swamp rabbit has historically been considered the dominant rabbit of bottomland regions, both it and the cottontail are now found in almost equal numbers in bottomlands of the deep South. Davis (1974) also reported that both

species occupied creek and river bottoms in about equal numbers at a site along the Brazos River in eastern Texas, but stated that only cottontails were found in the uplands.

88. Impacts of flooding regime modifications. The swamp rabbit prefers lowland hardwoods and marshes and is expected to be detrimentally affected by significant reductions in water levels in Mississippi River bottomlands. Yancey (1970) estimated an average annual decline in carrying capacity of around 56,000 animals from 1961 to 1968 in north Louisiana bottomlands based on clearing of hardwoods and associated drainage practices.

89. Reduced flooding may bring about invasion of swamp rabbit habitat and competition for food and cover by the cottontail which prefers dryer sites. This shift of species should not affect total rabbit numbers but could eliminate local populations of the swamp rabbit. Several authors have commented on the detrimental impacts of heavy rains and flooding on swamp rabbits, especially during the breeding and nesting seasons (Conaway et al. 1960, Martinson et al. 1961, Schwartz and Schwartz 1959, Lowery 1974). Toll et al. (1960) reported that swamp rabbits were forced onto roadways and high ridges during a 2-month spring flood in Mingo Swamp, Missouri, and Heuer and Perry (1976) stated that cypress-tupelo provided only marginal swamp rabbit habitat due to frequent and prolonged flooding. Fredrickson (1978), however, reported that flooding could also create new habitat by killing large trees, thus providing openings and downed timber. Fredrickson (1978) additionally stated that although the immediate effects of flooding may greatly reduce rabbit production, the long-term effects of flooding provide benefits to the species.

90. Reduced flooding should be generally beneficial to cottontails if adequate food and cover remains available. Flooding of bottomland regions is potentially detrimental to local populations of cottontails on a short-term basis; however, long-term production should not be severely affected because of the species' high reproductive potential and generally adequate brood stock in surrounding uplands.

Squirrels (Sciurus carolinensis and S. niger)

91. Habitat requirements. Both the gray and fox squirrel occur in woodland habitats throughout much of the lower Mississippi Valley. The USDA (1971) reported that the gray squirrel in southern forests was typical of hardwoods and mixed pine-hardwoods and preferred stands with a moderately dense to dense understory of vines. Lowery (1974) stated that gray squirrels were abundant in virtually all wooded areas in Louisiana, whereas Schwartz and Schwartz (1959) found that in Missouri they preferred dense hardwood forests with a brushy understory along river bluffs or bottomlands and occurred to a lesser extent in other timbered areas. Goff (1952) reported that the gray squirrel was the predominant squirrel in floodplain communities of Illinois, and Redmond (1953) found bottomland hardwoods to be the most important habitat in Mississippi but noted daily movements of squirrels between mixed upland hardwoods and bottomland sites. Goodrum (1937, 1940) ranked the following forest types in decreasing order of preference for gray squirrel in eastern Texas: (1) hammocks, where the principal vegetation is white oak and water oak with magnolia, linden, sweetgum, and holly; (2) poorly drained bottomlands with pin, evergreen and overcup oaks, elms, bitter pecan, black gum, cypress, and ash; (3) well-drained bottomlands with post and red oaks, hackberry, gum bumelia (Bumelia lanuginosa), and pecan; and (4) uplands dominated by the pine-oak-hickory association which is not subject to overflow.

92. The fox squirrel occurs in a variety of forest types but generally prefers more upland forests with less ground cover than that used by the gray squirrel. Schwartz and Schwartz (1959) found that fox and gray squirrels occupied approximately the same habitats in Missouri but added that fox squirrels were more common along higher ridges. Goff (1952) also reported that the fox squirrel replaced the gray in upland timber of Illinois, but Yeager and Anderson (1944) found that fox squirrels were present in all timbered areas of a leveed bottomland lake in Illinois. Lowery (1974) stated that fox squirrels were common to abundant throughout nearly all wooded portions of Louisiana but that

preferred habitat was rather open situations in hardwood forests or in tracts of mixed hardwoods and pine. Conversely, subspecies of the fox squirrel in the Atchafalaya Basin and adjacent regions in southern Louisiana occurred in deep swamps of cypress, tupelo, bitter pecan, and other hardwoods (Lowery 1974).

93. Glasgow and Noble (1971) stated that bottomland hardwood forests were the most productive habitat for both fox and gray squirrels in Louisiana and Mississippi. These authors additionally stated that bottomland hardwoods have become more important to squirrels in the last 20 years because of the extensive conversion of upland forests from mixed pine-hardwoods to pure pine stands in the Southeast. Bateman (1959) also found that in Louisiana squirrels were more abundant along creek and river bottomlands than in uplands, but large numbers were also reported in upland forests with preferred seed-bearing trees. Heuer and Perry (1976) compared the relative abundance of gray and fox squirrels in three predominant overstory forest types (bottomland hardwoods, cypress-tupelo, and cottonwood-willow-sycamore) in the Atchafalaya River Basin and found that squirrel abundance was significantly greater in bottomland hardwoods (hackberry-ash-sweetgum-elm), but no significant differences were noted between the other forest types. They also found no significant differences between the counts of fox and gray squirrels. Hopkins and Darden (1975) determined the carrying capacity for squirrels (gray and fox combined) based on the availability of dens and food in 3 forest type-stand condition classes in the Delta National Forest, Mississippi. The sugarberry-American elm-green ash type provided the greatest number of dens per ha (6.2), slightly exceeding that of the overcup oak-water hickory forest (5.4 dens per ha). The overcup oak-water hickory type had the highest calculated carrying capacity for squirrels but was predicted to support an unstable population because of the high dependence on overcup oak production; the diversity of mast producing species was expected to provide for stable squirrel populations in the sugarberry-American elm-green ash type. The sweetgum-Nuttall oak-willow oak type provided the least number of dens per ha and least carrying capacity for squirrels (Hopkins and Darden 1975).

94. Several authors have emphasized the importance of the fall mast crop, den trees, and habitat diversity to the production of both gray and fox squirrel populations (Uhlig 1956, Sharp 1960, Smith and Barkalow 1967, USDA 1971, Nixon et al. 1975, Short 1976, Perry et al. 1977). Glasgow and Noble (1971) stated that heterogenous bottomland forests with ample mast production managed on a sawlog rotation system provided excellent squirrel habitat in the south. Bateman (1959) discussed the dependence of squirrels on high-use hardwood species such as beech, black and tupelo gum, hickories, locust, pecan, and oaks (white, red, and water or pin oak groups).

95. Impacts of flooding regime modifications. Several authors have indicated that flood-control projects and drainage of bottomlands have contributed to the reduction of preferred squirrel habitat in southern regions (Yancey 1970, USDA 1971, Davis 1974). Yancey (1970) estimated an average annual loss of habitat for approximately 145,000 squirrels (based on a carrying capacity of 3.2 squirrels per ha) in north Louisiana bottomlands from drainage practices and associated clearing of hardwoods. Goodrum (1940) also observed a decline in gray squirrel populations following drainage of bottomland hardwoods in eastern Texas.

96. Yeager and Anderson (1944) reported that fall and winter flooding did not drive fox squirrels from timbered stands of a leveed bottomland lake in Illinois although inundation during two peak floods was 1.5 m or more. Movement during flood periods was said to be arboreal or by logs and floating debris (Yeager and Anderson 1944). Frederickson (1978) also stated that squirrels were not affected by flooding because of their arboreal habits. Perry et al. (1977), however, noted that gray squirrels of low swampy areas in North Carolina may shift their activities to higher sites with increases in stream depths. Yeager (1949), in a study of permanent impoundment of a timbered region in Illinois, found that although gray squirrels were originally predominant in river bottomlands, the death of large tracts of flooded timber and consequent creation of open areas resulted in fox squirrels becoming the dominant squirrel species.

97. Reduced flooding of hardwood bottomlands and the subsequent clearing of large tracts of land for agricultural purposes that is likely to follow will be detrimental to populations of both gray and fox squirrels. Where clearing does not occur with reduced flooding, squirrel populations will be most affected by changes in the abundance and diversity of mast producing vegetation. An analysis of studies by Bedinger (1971) and Bell (1980) indicated that the greatest overstory richness and diversity in bottomland forests occurred in infrequently flooded zones compared with frequently flooded areas. Bell (1980) also found that overstory richness and diversity was slightly less in unflooded upland forests than in infrequently flooded zones. Fredrickson (1979, 1980) showed that bottomland forests on the landside of levees and those subjected to drainage responded similarly by increasing in diversity and developing more herbaceous ground cover. Fredrickson (1980) also reported that reduced flooding from drainage would result in a gradual shift of forest vegetation toward species typical of drier sites. In light of these studies, squirrel populations would be expected to be more stable in infrequently flooded zones and could benefit from decreased flooding of frequently inundated sites. It is possible, however, that reduced flooding throughout a site could produce a more homogeneous forest cover, thus decreasing overall community diversity. An increase in herbaceous ground cover and understory vegetation would be beneficial to gray squirrels but could be detrimental to fox squirrels.

Beaver (*Castor canadensis*),
Muskrat (*Ondatra zibethicus*),
and Nutria (*Myocastor coypus*)

98. Habitat requirements. Beaver are generally found along streams, rivers, marshes, and lakes (Schwartz and Schwartz 1959), and in Louisiana they occur most often along slow-flowing, sluggish streams or bayous (Lowery 1974). Wooded swamps and flooded timberland are also preferred habitat throughout much of their range. Dwellings may be lodges or burrows in streambanks. Beaver are primarily bark eaters and show various preferences depending on location and availability of plant

species. Woody species commonly used include black willow, cottonwood, sweetgum, loblolly pine, silverbell (*Halesia* sp.), sweetbay (*Magnolia virginiana*), and American hornbeam (Chabreck 1958, Schwartz and Schwartz 1959, Davis 1974, and Lowery 1974). Beaver may take corn when available (Schwartz and Schwartz 1959) and seasonally consume large quantities of oak mast, shrubs, and a variety of aquatic vegetation (Schwartz and Schwartz 1959, Lowery 1974). Marsh beaver are known to feed on emergent plant rootstocks (Weller 1978).

99. Muskrat are most abundant in emergent wetlands with stable water levels which permit house building (Chabreck 1978), but they also inhabit other areas where high banks are available for burrowing and den construction (O'Neil 1949). According to Dosier (1953), muskrat habitat may be divided into the following categories: 1) small streams, riverbanks, creeks, ponds, lakes, and canals; 2) swamps; and 3) marshes. According to Palmisano (1972), mixed communities of three-cornered bulrush (*Scirpus olneyi*) and marshhay cordgrass (*Spartina patens*) are the preferred habitat on the northern Gulf Coast. Greatest populations occur in Louisiana in brackish and intermediate marshes supporting dense stands of three-cornered bulrush (O'Neil 1949, Chabreck 1972, 1978), but the muskrat also ranges inland where rice is grown and occurs along bayous and lakes throughout much of the state (Lowery 1974). Dozier (1953) reported that habitat conditions for muskrat were generally poor in timbered lowlands even though escape cover was plentiful. Muskrat houses are generally constructed in marsh regions, but bank burrows are characteristic of the north-central states, including the northern portion of the lower Mississippi Valley. Diet depends largely on availability (Schwartz and Schwartz 1959), with rootstocks and stems of bulrush, cattail, sedges, and other wetland vegetation being preferred (Bellrose and Brown 1941, Schwartz and Schwartz 1959). Muskrats inhabiting freshwater lakes, rice fields, and bayous north of coastal marshes feed more on animal matter including clams, crayfish, fish, frogs, reptiles, and young birds (O'Neil 1949).

100. The nutria inhabits a wide variety of wetland environments (Chabreck 1978), with peak production generally occurring in fresh and

intermediate marshes (Palmisano 1971). Nichols and Chabreck (1973), however, found that nutria were commonly harvested in both marsh and swamplands in the Atchafalaya River Basin. Nutria feed on a variety of aquatic and semiaquatic vegetation and also consume shellfish along the coast (Davis 1974). Additional habitat information may be found in Atwood (1950), Swank and Petrides (1954), and Nichols and Chabreck (1973).

101. Impacts of flooding regime modifications. The importance of beavers in changing water levels and affecting vegetation and habitat conditions by their dam-building activities has been discussed by Frederickson (1978) and others. According to Schwartz and Schwartz (1959), beaver in Missouri tend to construct dens in streambanks because flooding and fluctuating water levels make lodges impractical. They additionally stated that during droughts, beavers living in lodges may abandon these homes and move to deeper pools where they establish houses in banks. Beavers are highly dependent on seasonally flooded bottomlands throughout much of their range and would be greatly affected by significant decreases in water levels. Little has been reported on the impacts of water level changes to nutria, but droughts and severe flooding are expected to be detrimental to local populations. Seasonal flooding of normal intensity should not adversely affect the species.

102. The detrimental impacts of both low waters and flooding to muskrat populations have been discussed in several studies (Errington 1937, 1939, 1961, Bellrose and Brown 1941, Bellrose and Low 1943, Bellrose 1945, Schwartz and Schwartz 1959). Schwartz and Schwartz (1959) reported a general decline in Missouri populations due to habitat deterioration following drainage. Flooding and water level rises have been reported to cause high mortality of muskrats, especially in young animals (Errington 1937, Schwartz and Schwartz 1959). Yeager and Anderson (1944) found muskrats to be adversely affected by fall and winter floods in a leveed timber bottomland in Illinois; October and February floods resulted in approximately 1.5-m rises in water levels which covered practically all houses and bank dens and caused hundreds of muskrats to take refuge along levees, in willows, and on logs and

other floating debris where heavy mortality apparently occurred from predation and other factors. Predation and total mortality was greater during the fall flood than the winter flood (Yeager and Anderson 1944). Yeager (1949), however, reported that among mammals, muskrats showed the greatest adaptability to conditions induced by permanent flooding of a timbered river bottom at the junction of the Mississippi and Illinois rivers. Two continuous years of severe flooding (1943 and 1944) and a lesser flood in 1945 apparently depleted their numbers, but there was evidence of substantial recovery by October 1946 (Yeager 1949).

Opossum (*Didelphis virginiana*)

103. Habitat requirements. The opossum frequents a wide variety of habitats including prairies, marshes, and farmlands but is typically found along streams, swamps, and deciduous woodlands near water (Schwartz and Schwartz 1959, Davis 1974, McManus 1974). Den sites include hollow trees, logs, woodpiles, rocky outcroppings, and man-made dwellings. Food-habit studies show that the opossum is a highly opportunistic omnivore with the bulk of its diet consisting of animal matter such as insects, rodents, and carrion; plant foods include fruits of pokeberry, mulberry, hackberry, greenbrier, grape, pawpaw, and persimmon, which are primarily consumed in the fall and winter (Lay 1942, Schwartz and Schwartz 1959, Stieglitz and Klimstra 1962, McManus 1970).

104. Impacts of flooding regime modifications. The opossum is a capable swimmer (Doutt 1954, Moore 1955, McManus 1970) and could apparently escape rising floodwaters. Flooding, however, would drive animals from terrestrial den sites. Yeager and Anderson (1944) found that fall and winter flooding of a leveed bottomland in Illinois drove a large number of opossums from lowland timber stands and concentrated them on nearby levees. Yeager (1949) also reported that opossums were apparently evicted from timbered bottomlands by permanent flooding.

105. Although the opossum occurs commonly in seasonally flooded bottomlands, reduced flooding is not expected to be detrimental to the species. Reduced flooding could, in fact, be beneficial by decreasing the incidence of inundated den sites and by increasing habitat for

ground-dwelling insects and other food items.

Raccoon (*Procyon lotor*)

106. Habitat requirements. Raccoons occur in a variety of habitats but are most abundant in coastal swamps, marshes, and bottomland hardwoods (USDA 1971). McKeever (1959) reported that catch per trap night was greatest in bottomland hardwoods; intermediate in cultivated fields, weeds and broomsedge, and upland hardwoods; slightly lower in mixed pine-hardwood; and lowest in pine forest. Caldwell (1963, cited by Johnson 1970) rated the following habitat from best to poorest for raccoons: swamps, farmlands, hammocks, sandhills, and flatwoods. The USDA (1971) rated the following habitats for raccoons in southern states, shown in descending order of preference: bottomland hardwoods, marshes, tall weeds and broomsedge, upland hardwood, pine hardwood, and pine.

107. Johnson (1970) stated that although the raccoon was a very adaptable species, habitat deficiencies were a major limiting factor in many areas. The most critical limiting factors in Alabama were late winter food and refuge and den trees (Johnson 1970). Johnson also reported that beaver activities were highly beneficial to raccoons by providing aquatic foods and dead trees for denning. According to USDA (1971), ground or tree dens are used for shelter and escape, but tree dens are preferred for raising young. Davis (1974) stated that raccoons seldom occurred far from water, a condition which appeared to have a greater influence on their distribution than any particular type of vegetation. Johnson (1970) reported that movement patterns were generally along water courses, but animals often migrated considerable distances from their normal range to take advantage of available food supplies. Additional habitat information may be found in Hamilton (1936), Yeager and Rennels (1943), Baker et al. (1945), Cabalka et al. (1953), Mech et al. (1966), Berner and Gysel (1967), and Johnson (1970).

108. The omnivorous feeding habits of raccoons have been discussed in many studies. Acorns, beechnuts, and pecans are staples from late fall to early spring, especially in areas lacking wetlands which would normally provide aquatic food items, and corn is heavily used when

available (USDA 1971). Johnson (1970) found that acorns were essential for getting raccoons through the winter in good condition unless planted foods were available, and Baker et al. (1945) reported that acorns averaged more than half the total volume of the winter diet of raccoons in eastern Texas. Grape, persimmon, greenbrier, blackberry, sugarberry, possum-haw, rattan, cherry, wild plum, privet, eastern redcedar, hawthorns, crabapple, apple, dogwood, serviceberry, blueberry, and other fruits are taken seasonally (USDA 1971). Animal foods include crayfish, clams, insects, earthworms, arthropods, amphibians and reptiles, fish, small mammals, muskrats, rabbits, and ground-nesting birds and their eggs (USDA 1971, Schwartz and Schwartz 1959). According to Baker et al. (1945) and Johnson (1970), the most important animal foods are crayfish and insects.

109. Impacts of flooding regime modifications. Yeager and Anderson (1944) found that fall and winter flooding in Illinois did not seriously affect raccoons occurring in timbered bottomland. These authors reported that during October flooding, raccoons denned in flooded woods in both tree cavities and muskrat houses built at flood stage; during February, primary concentrations occurred on a levee bordered by heavy timber, but considerable numbers also found retreats under brush piles and in ground dens. Yeager (1949) also reported that raccoons, with some fluctuations in their numbers, also remained common-to-abundant in a timbered bottomland in Illinois that was flooded permanently following impoundment. Nichols and Chabreck (1973), however, stated that deep spring flooding in swamps of the Atchafalaya River Basin probably had damaging effects on raccoon populations.

110. Although the raccoon occurs in a variety of habitats, densest populations are apparently found in wet timbered areas (McKeever 1959, Caldwell 1963, Johnson 1970). A drying out of bottomland hardwoods through reduced flooding is, therefore, expected to have an overall adverse effect on raccoon populations. Results of decreased flooding would be especially detrimental with a reduction in the availability of important aquatic food items such as crayfish and clams.

Mink (Mustela vison) and
River Otter (Lutra canadensis)

111. Habitat requirements. The mink occurs in a variety of wetland habitats but may select dens in adjacent uplands (Schwartz and Schwartz 1959, Chabreck 1978). The species is closely associated with waterways and lakes, with smaller streams preferred to large rivers (Davis 1974), and the presence of permanent water is a basic requirement (Schwartz and Schwartz 1959). Standing timber adjacent to water is attractive to the species but is not a necessity (Schwartz and Schwartz 1959). Lowery (1974) reported that minks were particularly abundant in tupelo swamps along the Mississippi River and Atchafalaya Basin in Louisiana, as well as in freshwater-to-brackish marshes. Den sites include burrows in banks of streams, retreats beneath tree roots near water, debris piles along streams, and muskrat houses. The availability of den sites and crayfish populations was considered a probable factor for high mink populations in swamp regions (Nichols and Chabreck 1973). Food items include fish, frogs, clams, mussels, snakes, crabs, crayfish, rodents, rabbits, and occasionally birds (Schwartz and Schwartz 1959, Davis 1974, Lowery 1974) with the favorite food perhaps being crayfish (Lowery 1974).

112. The river otter is essentially aquatic, occurring along streams, rivers, and lakes that are frequently but not always bordered by timber (Schwartz and Schwartz 1959, Davis 1974, Chabreck 1978). Otters are notably common in coastal areas in marshes and brackish waters and along bayous (Lowery 1974, Davis 1974). Optimum habitats reported by Wilson (1959) include outer banks, sounds, marsh, swamp, coastal rivers, and inlets and bays bordered by marsh, bogs, or swamp. Nichols and Chabreck (1973) reported that mean harvest results were nearly identical when compared between swamplands and marshes of the Atchafalaya Basin. Dens include hollow cypress trees, logs, and banks of streams. Foods include fish and shellfish (major items), frogs, turtles, snakes, salamanders, crabs, clams, earthworms, and aquatic insects; waterfowl, other birds, muskrats, and various small mammals are occasionally taken (Schwartz and Schwartz 1959, Wilson 1959, Davis 1974, Lowery 1974).

113. Impacts of flooding regime modifications. General impacts of channelization to mink and otter populations were discussed by Arner et al. (1976) and Fredrickson (1979). The destruction of riparian habitat occurring with channelization initially eliminates these species, but older leveed areas and backwater cutoffs provide good habitat (Frederickson 1979). Arner et al. (1976) also reported that minks occurred in old channelized segments of river systems, but otters were recorded only along natural regions. Fredrickson (1979), however, stated that in Missouri the otter does well within leveed areas and is probably more abundant there than in any other area. Yeager and Anderson (1944) reported that minks were not affected by fall and winter flooding of a timbered bottomland in Illinois, and Yeager (1949) also found that the species remained common to abundant in permanently flooded bottomlands. Although normal flooding is not expected to affect river otter populations, Wilson (1959) noted losses of otter yields in North Carolina due to extensive flooding following hurricanes.

114. Reduced flooding in bottomland hardwoods is expected to be highly detrimental to populations of mink and river otter because of their high preference for wetland habitats. These species are dependent upon the availability of aquatic and semiaquatic foods such as fish, crayfish, mollusks, amphibians, and aquatic insects. Drying out of wet bottomlands and the resulting transition to upland habitat types will eliminate many of the life requirements for these species.

Bobcat (*Felis rufus*)

115. Habitat requirements. The bobcat occurs in a variety of forest habitats, brushlands, and open terrain throughout much of the United States. Although little appears to be published about the species in the study area, Lowery (1974) stated that the bobcat occurs in nearly all heavily wooded terrain and maintains appreciable numbers throughout the bottomland hardwoods along the Mississippi River. Hall and Newsome (1976), in a study of bobcats in bottomland hardwoods of southern Louisiana, found that the mid-successional seral stages (consisting of saplings, vines, and briars) characteristic of cutover areas

were important to bobcats in supplying cover and a maximum supply of prey species. Dense woods were also cited as favorite hunting areas for some individuals.

116. Impacts of flooding regime modifications. Cowan (1971) implied that agriculture and timber practices have had little effect on the general abundance of bobcat in North America, and Hall and Newsome (1976) also indicated that logging activities had little impact on bobcat movements in southern Louisiana. Jenkins (1971), however, reported that the species has been drastically reduced by urban expansion and intensive farming. Although little information appears available on the effects of flooding regime modifications on the bobcat, it is expected that reduced flooding in itself would have little impact on populations. Normal flooding probably brings about only temporary impacts because of the mobility and arboreal habit of the species.

White-tailed deer
(*Odocoileus virginianus*)

117. Habitat requirements. According to the USDA Forest Service (1971), the white-tailed deer is an adaptable, widely distributed species which occurs in a variety of forest and nonforested habitats. The importance of bottomland hardwood forests for deer, especially in the lower Mississippi Valley and adjacent regions, has been discussed by numerous authors (Stransky 1969, Yancey 1970, Glasgow and Noble 1971, Murphy and Noble 1972, Pearson and Sternitzke 1976, Zwank et al. 1979). Glasgow and Noble (1971) reported that bottomland hardwoods supported a higher deer carrying capacity than any other forest type in the Southeast and perhaps in the nation. General estimates of deer-carrying capacity for various forest types were provided by Glasgow and Noble (1971) as follows: longleaf-slash pine (1 deer/12-14 ha), loblolly-shortleaf pine-upland hardwoods (1 deer/10-12 ha), and upland hardwoods (1 deer/7-8 ha); whereas many bottomland hardwoods in the lower Mississippi Valley were said to carry 1 deer/4-5 ha, with some stands supporting 1 deer/2 ha where agricultural crops were readily available (Noble 1961, Glasgow and Noble 1971). Yancey (1969) estimated an average

carrying capacity of 1 deer/8 ha in north Louisiana bottomland hardwoods under standard selective logging practices.

118. Several studies have dealt with the importance of available and palatable browse plants to healthy deer populations in bottomland forests (Halls and Ripley 1961, Shaw and Ripley 1966, Pearson and Sternitzke 1976). Pearson and Sternitzke (1976) found that in six major forest types in southwest Louisiana, longleaf-slash pine provided the poorest variety of desirable browse for deer and bottomland hardwood provided the best. Desirability ratings showed that 63 percent of the area of bottomlands provided fair or better deer browse compared with about 55 percent in loblolly-shortleaf pine, oak-pine, and hickory habitats and only 20 percent in longleaf-slash pine. Vines provided more than 40 percent of the cover in bottomland habitats (Pearson and Sternitzke 1976). Studies of the monthly and seasonal availability and use of deer browse plants in periodically flooded bottomland hardwoods of Tensas Parish, Louisiana, and adjacent areas (Noble 1967b, Murphy and Noble 1972, Murphy 1974) showed that dewberry (Rubus spp.), aster (Aster spp.), trumpet creeper, and poison ivy were the most important browse plants. According to Murphy (1974), dewberry, aster, and trumpet creeper totaled 71.2 percent of all browse eaten by deer and 29.9 percent of all available browse; of 154 plant taxa recorded for the area, however, 86 (55.8 percent) were utilized to some extent.

119. USDI (1975, 1976) reported results of deer browse surveys in the Atchafalaya River Basin, Louisiana, and found that the cover-type category they refer to as "bottomland hardwoods" ranked first during summer and winter in relative abundance of deer compared with cottonwood-willow-sycamore (ranked second) and cypress-tupelo habitat (a distant third). A significant positive correlation was found between average vegetative density and average degree of browsing, with density and diversity increasing from cypress-tupelo to cottonwood-willow-sycamore and significantly higher in bottomland hardwoods. Fourteen browse species were reported as used in bottomland hardwoods, with dewberry most preferred and rattan vine and grapevines also receiving high use (USDI

1976). Wigley et al. (1980) compared deer use between cottonwood plantations and native bottomland hardwoods on batture lands of Washington and Bolivar Counties, Mississippi, and found that deer preferred the perimeter between these habitats for both feeding and bedding; the plantation interior ranked second. Although nocturnal use of the plantation ranked second for all seasons, diurnal use of its interior exceeded diurnal use of the native forest only during parturition. Glasgow and Noble (1971), however, stated that apparent use of cottonwoods could be misleading because animals often use plantations as openings but are most dependent on surrounding heterogenous bottomland forests. Glasgow and Noble (1971) reported that young cottonwood plantations provided good cover and tremendous quantities of deer browse but could not support high populations over large areas (4,046 ha or more) or when crown closure occurred; the value of cottonwood monoculture for deer was said to decrease drastically as plantations approached 4 years of age.

120. Several studies have also emphasized the importance of mast and herbaceous food items to deer in bottomland regions. The USDA (1971) stated that southern deer were once thought to be primarily browsers but are now known to consume large quantities of fruits, mushrooms, acorns, nuts, and herbaceous plant materials. Bateman (1959) reported that acorns provided much of the winter deer foods in a Louisiana bottomland region. Acorns were also preferred in uplands but were less plentiful. According to Bateman (1959), more palatable winter browse was available in upland regions compared with bottomlands. Lay (1964, 1965) also discussed the importance of mast-bearing trees, fruiting shrubs, and a variety of herbaceous species to deer in southern forest regions. Rumen analysis of deer in bottomland hardwoods of Tensas Parish, Louisiana, showed that sweet pecan was extremely important in their diet during the fall and winter months and cultivated corn and soybeans were important auxilliary food supplies (Murphy and Noble 1972, Murphy 1974). Hopkins and Darden (1975) estimated deer carrying capacity based on food availability in three forest types of the Delta National Forest, Mississippi, and found that average carrying capacity was similar (approximately 6 ha/deer) for each type. Deer were

heavily dependent on the mast crop in the overcup-hickory forest type, and although carrying capacity was estimated at 6 ha/deer, the absence of browse plants was suspected to provide a relatively unstable deer population (Hopkins and Darden 1975). Winter deer food was said to be fairly stable in the sweetgum-Nuttall oak-willow oak forest type since browse comprised about 70 percent of the available food. Winter browse accounted for about 22 percent of the winter diet in the sugarberry-American elm-green ash forest type, thus making the deer population heavily dependent on mast; the shrub component in this forest type, however, was expected to provide foods in the form of fruits and browse during years of low hard-mast production (Hopkins and Darden 1975).

121. There is apparently tremendous variation in use of food items by deer in bottomland forest habitats depending on availability, preference, and population pressure. The USDA (1971) stated that foods eaten readily in one area may not be taken in another area due to differences in soil types, nutrition, succulence, deer numbers, and plant community composition; it was also suggested that in some situations food availability may be a more important factor than preference. Byford (1969) examined deer movements in a logged floodplain forest in southwestern Alabama and noted shifting of activity within home ranges in response to food availability; but home ranges were not shifted to any great extent to reach a concentrated food supply. Observations indicated that movements were not permanent but suggested a seasonal cycle of activity shifts in relation to food preference or abundance (Byford 1969). The USDA stated that a deer's home range was seldom more than 120 ha during a season but that seasonal (temporary) shifts in range were common if necessary to reach better food or cover or to escape adverse conditions.

122. Impacts of flooding regime modifications. Although the white-tailed deer uses a variety of habitats throughout its range, numerous studies have shown that bottomland hardwoods are capable of supporting higher populations per unit area than adjacent uplands (Stransky 1969, Yancey 1969, Glasgow and Noble 1971). The apparent preference of deer for wooded bottomlands in the lower Mississippi Valley indicates

that the species is not detrimentally affected by normal flooding cycles. Several studies, however, have shown that prolonged flooding during the growing season could affect deer populations by limiting the availability and diversity of forage plants. USDI (1975) reported that high water levels limited understory cover and thereby reduced available browse in bottomland hardwoods and swamps of the Atchafalaya Basin, and Hopkins and Darden (1975) indicated that flooding could be a limiting factor to deer in overcup oak-water hickory forests. Consequently, reduced flooding in near-permanently inundated bottomlands could improve habitat for deer by bringing about an increase in the diversity and density of understory food plants, assuming mast production is not reduced.

Nongame species

123. Faunal status and habitat requirements. Nongame mammals commonly reported from bottomland situations in the lower Mississippi Valley include the armadillo (*Dasypus novemcinctus*), short-tailed shrew (*Blarina brevicauda*), southeastern shrew (*Sorex longirostris*), eastern mole (*Scalopus aquaticus*), eastern chipmunk (*Tamias striatus*), southern flying squirrel (*Glaucomys volans*), marsh rice rat (*Oryzomys palustris*), deer mouse (*Peromyscus maniculatus*), white-footed mouse (*P. leucopus*), cotton mouse (*P. gossypinus*), golden mouse (*Ochrotomys nuttalli*), eastern woodrat (*Neotoma floridana*), and house mouse (*Mus musculus*). Additional species are shown in Table 4. Species with an apparent preference for wooded bottomlands are the southeastern shrew, white-footed mouse, cotton mouse, golden mouse, and eastern woodrat (Dice 1940; Calhoun 1941; McCarley 1954, 1959, 1963; Taylor and McCarley 1963; Gentry et al. 1968; Lowery 1974; Wolfe and Linzey 1977; French 1980; Schmidly et al. 1980).

124. The abundance and distribution of small-mammal populations in relation to habitat variables and vegetative community structure in forested regions have been examined in several recent studies (M'Closkey 1975, M'Closkey and Fieldwick 1975, Dueser and Shugart 1978, Morris 1979). Factors reported to affect species composition and densities in forest communities included tree basal area, tree density, foliage height

density and diversity, and soil surface debris. Geier and Best (1980) found significant positive correlations between the abundance of woody plant debris (logs, brushpiles,or stumps) and small-mammal populations in woody riparian habitat but found that deciduous tree cover was not related to species densities.

125. Wetzel (1958) found the following trends to bring about population increases in small mammals in a coal-stripped floodplain in Illinois: better surface drainage and drier soils, increases in older trees and potential home sites providing refuge from floods, increase in invertebrate foods, and an increase in plant food resulting from invasion of trees such as oaks and hickories. Drier soils presented better conditions for tunneling and burrowing by small mammals and more nearly optimum habitat for invertebrates. Blem and Blem (1975), however, found that small-mammal populations in floodplains of Champaign County, Illinois, were consistently greater in density and biomass than were the mammal fauna of adjacent upland forests.

126. Preliminary data on winter trapping of small mammals in the Atchafalaya River Basin indicated that bottomland hardwoods greatly exceeded cottonwood-willow-sycamore and cypress-tupelo habitat in total number of animals and species richness (USDI 1976) (Table 8). Mullins (1978), however, stated that there were no significant differences in small-mammal densities among the above forest types, but densities in frequently flooded cottonwood-willow-sycamore and cypress-typelo forests were significantly greater on disposal mounds than on natural elevations. Johnson et al. (1977) compared rodent populations in cottonwood plantations and natural hardwoods in bottomlands of Huntington and Catfish Points, Bolivar County, Mississippi, and found little significant difference in overall capture data. Natural stands almost exclusively supported mice of the genus *Peromyscus*, whereas cottonwood plantations supported a greater variety of rodents. Greatest differences occurred between natural stands and unthinned cottonwoods (Table 9). According to Johnson et al. (1977), cottonwoods provided a more diversified habitat in the understory, which resulted in a greater diversity of small mammals. Data indicated that ground cover such as log piles, fallen

Table 8

Summary of Snap-Trap Data in Three Bottomland Habitat Types of the Atchafalaya River Basin, Louisiana (After USDI 1976)

Species	Habitat-Catch		
	Bottomland Hardwoods (BH)	Cottonwood-Willow-Sycamore (C-W-S)	Cypress-Tupelo (C-T)
	Winter (Nov 1974 and Sep 1975 to Feb 1976)*		
Peromyscus leucopus	71	11	7
Oryzomys palustris	33	9	--
Sigmodon hispidus	5	--	--
Neotoma floridana	3	--	--
Mus musculus	5	--	--
Blarina brevicanda	2	--	--
Total	119	20	7
	Spring 1976-Traps Set on 15 4-Acre Spoil Plots in the Above Habitat Types**		
Total (no species listed)	33	24	14

* No. trap nights = BH (5,466), C-W-S (5,463), C-T (4,587).
** No. trap nights = 270 per habitat type.

Table 9

Summary of Small-Mammal Trapping in Cottonwood Plantations and Natural Bottomlands Along Batture Lands, Huntington and Catfish Points, Bolivar County, Mississippi (After Johnson et al. 1977)

Species	Catch/Habitat, Location, Year									
	Natural				Unthinned Cottonwood				Thinned Cottonwood	
	Huntington Point		Catfish Point		Huntington Point		Catfish Point		Huntington Point	
	1975-6	1976-7	1975-6	1976-7	1975-6	1976-7	1975-6	1976-7	1975-6	1976-7
Peromyscus spp.	24	23	37	23	3	25	--	12	14	20
Sigmodon hispidus	--	--	--	--	--	--	--	2	1	--
Neotoma floridana	--	--	1	--	--	--	--	--	--	--
Mus musculus	--	--	--	--	--	--	--	1	--	1
Cryptotis parva	--	--	--	--	--	1	--	--	--	5
Microtus pinetorum	--	--	--	--	--	1	--	--	--	--
Blarina brevicanda	--	--	--	--	1	4	1	2	--	2
Total	24	23	38	23	4	31	1	17	15	28

logs, dewberry brambles, and thickets of switch cane contributed to higher small-mammal populations than did the ecotone between cottonwood and natural stands (Johnson et al. 1977).

127. Impacts of flooding regime modifica ns. Geier and Best (1980), in a study of habitat selection by small mammals of riparian communities, reported that habitat disturbances such as stream-channel realignment, clearcuts, fire, and strip mining could affect small-mammal populations and alter community composition. These authors found that small-mammal diversity was greatest in channelized and heavily grazed upland habitats in riparian communities of southwestern Iowa where predominant habitat alterations resulted from grazing, timber removal, and stream-channel realignment. Lower species diversities in other habitat types (wet and dry floodplains, lightly grazed and ungrazed uplands) were thought to be partly attributable to the dominance of two species, the white-footed mouse and eastern chipmunk (Geier and Best 1980).

128. Fredrickson (1979) also found that trapping success for small mammals was highest in drained areas compared with flooded sites in lowland hardwood forests near the St. Francis River, Missouri (Table 10). The greatest trapping success occurred on the driest sites where food and cover were abundant, and the poorest results were on sites with extensive flooding where vegetation was sparse to nonexistent. The white-footed mouse was the most common species trapped; with populations apparently highest on drained sites, almost equally abundant on sites flooded intermittently, and least abundant on leveed sites where flooding occurred regularly over the entire area between the levees. Fredrickson stated, however, that many rodents were caught immediately after flooding if traps were placed on dry sites within areas periodically flooded, and he conjectured that results may have reflected ease of capture rather than abundance. It was determined that seedling, shrub, and herb density were higher on drained areas and therefore provided food and cover for reproduction and escape from predators (Fredrickson 1979). Ellis (1976), reported by Geier and Best (1980), found greater small-mammal species diversity in channelized habitats and attributed this to the presence of grasses; whereas Ferguson (1975),

Table 10

Results of Small-Mammal Trapping in Mingo Swamp and Along the St. Francis River, Missouri, 1975-1976 (From Fredrickson 1979)

Location/Habitat	Catch/Species Peromyscus Sp.	Ochrotomys nuttalli	Mus musculus	Blarina brevicanda	Crypototis parva	Total	No. Trap Nights	Catch/ Night
Mingo Swamp								
Control	20	0	0	0	0	20	2130	0.009
Periodically impounded	32	5	0	1	0	38	2148	0.018
Drained	64	1	1	1	0	67	2145	0.031
St. Francis River								
Forests near channel								
Unchannelized								
Early successional	24	1	0	0	0	25	1071	0.023
Late successional	24	0	0	0	0	24	1080	0.022
Leveed	0	0	0	0	0	0	1061	0.0
Spoil bank								
Recently channelized	5	0	12	0	0	17	1073	0.016
Previously channelized	10	0	11	4	0	25	1079	0.023
Forests away from channel								
Unchannelized								
Early successional	22	0	0	0	0	22	1074	0.02
Late successional	29	0	0	0	0	29	1075	0.027
Recently channelized	21	0	0	0	0	21	1074	0.019
Previously channelized	20	0	0	1	0	21	1077	0.019
Leveed	2	0	0	0	1	3	1075	0.003

also reported by Geier and Best (1980), found lower diversity in areas recently channelized (2 years after channelization) with forbs dominating the herbaceous stratum.

129. Numerous studies have discussed the impacts of flooding on small-mammal populations (Blair 1939, Grinnel 1939, Stickel 1948, McCarley 1959, Hoslett 1961, Ruffer 1961, Turner 1966, Blem and Blem 1975). The majority of these studies dealt primarily with populations of the white-footed mouse, hereafter referred to as *P. leucopus*. Most studies generally concluded that short-term seasonal flooding resulted in minor impacts to small mammals, whereas long-term severe flooding was highly detrimental to most species. However, there were occasional exceptions to this conclusion based on location, forest type and elevation, adjacent cover, species tolerances, and other factors. Pertinent studies are summarized below to provide locality-specific information.

130. Turner (1966) examined the effects of extensive winter and spring flooding on a population of *P. leucopus* in a wooded bottomland of Illinois and reported that the mice either emigrated from the flooded area or were drowned following inundation. Mark-recapture experiments by Turner showed that reinvasion occurred from adjacent areas after subsidence but that recovery of the population was slow. Observations by Blair (1939) also indicated that severe flooding in years of abnormally heavy rainfall adversely affected populations of small terrestrial mammals in floodplains of eastern Oklahoma. Hoslett (1961) surveyed the effects of flooding on the distribution of small mammals in floodplains of northeastern Iowa and found that different species were variously affected by annual spring floods. Several species, such as the meadow vole (*Microtus pennsylvanicus*), thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*) and meadow jumping mouse (*Zapus hudsonius*) were completely absent from the broader floodplain where the frequent, and occasionally severe, floods prevented their establishment. However, species inhabiting narrower floodplains farther up the valleys were only temporarily affected by floods which normally occurred only at the time of spring breakup. *P. leucopus* were captured in both willow-maple associations in the floodplain and in the hillside oak-hickory

association and were thought to escape the effects of flooding by climbing trees. Pocket gophers (Geomys bursarius) apparently migrated from the floodplain prior to inundation, but deer mice crowded on rafts of stubble during high waters and were either reduced in number or locally extirpated (Hoslett 1961). Hoslett (1961) additionally stated that small-mammal populations of the smaller valleys regained their normal size soon after the flood had subsided.

131. The effects of annual small-scale spring flooding on the movements of P. leucopus were examined in a 0.29-ha wooded bottomland in Ohio by Ruffer (1961). The study area was in the beech-maple forest region and was represented by a mixed oak association, including red oak, swamp white oak, and red maple in the overstory and sparse herbaceous vegetation in the understory. Water from surface drainage filled depressed areas of the forest to a maximum depth of about 61 cm for up to several months each spring. Results of the study indicated that flooding did not seem to inhibit movements of P. leucopus within the area nor was it detrimental to their numbers (Ruffer 1961). Conditions on the site, however, were not typical of large forested overflow areas in the lower Mississippi Valley.

132. Blem and Blem (1975) compared upland and floodplain populations of P. leucopus through an annual flooding cycle along a streamside forest in Illinois. The upland forest consisted largely of white oak, black oak, and red oak, with red elm and sassafras important in the understory. Bottomland species were silver maple, honey locust, and sycamore, and there were many decomposing logs and trunks of American elm. During the summer, herbaceous cover was more extensive on the floodplain (81 percent) than in the upland (51 percent). Floods covered the bottomlands to a depth of about 1 m for about 7 days in December and 9 days in May during the study period. It should be noted that such short-duration floods are not typical of the broad river floodplains of the lower Mississippi Valley, but may be expected to occur in response to local rainfall along small tributaries and in sumps. Blem and Blem reported that populations were consistently more dense on bottomland sites although production of young per unit area was similar for the two

forest types. Although flooding caused the disappearance of some floodplain mice for a month or more, the eventual return of many individuals and accompanying turnover of mice in upland woods offset the effects of inundation (Blem and Blem 1975). The authors hypothesized that while flooding may be detrimental to Peromyscus populations on a short-term basis, it appeared likely that during less extreme years the beneficial effects of dense vegetation in lower floodplain strata may offset the disadvantages of periodic inundation. It should be noted, however, that within the lower Mississippi Valley the most frequently inundated floodplain sites do not support a dense understory.

133. Batzli (1977) compared populations of P. leucopus in a floodplain forest and adjacent upland region along the Sangamon River, Illinois, and discussed the influence of flooding on resources available to the species. Both forest types examined were mature, unlogged deciduous forests. Upland dominants were white oak, black oak, red oak, white ash, sugar maple, and mockernut hickory; floodplain dominants were silver maple, bur oak, green ash, sycamore, big shellbark hickory, and hackberry. Batzli found that fluctuations of density were greater in the floodplain because better recruitment in autumn produced higher densities than in the upland, and poor recruitment in winter and spring produced lower densities. Contrary to expectations, floodplain populations provided a small source of recruits for the uplands rather than the reverse (Batzli 1977). Batzli suggested that recruitment patterns and population fluctuations were probably related to food availability, with the best survival of young occurring in autumn after the mast crop had fallen. Poor recruitment in the floodplain was related to extensive flooding. Floodplain populations tended to be more erratic, but densities were not simply related to flooding patterns. Batzli (1977) summarized the influences of flooding to P. leucopus as follows: during flooding the forest floor is not available for foraging or nesting; floods wash away organic matter, rearrange it into scattered piles on the forest floor and cover it with silt; and flooding causes dramatic differences in the flora and therefore seed production, compared to that in the upland. Floodplains appeared to be a more severe and less

predictable habitat than uplands, yet P. leucopus populations were more productive in the floodplain region (Batzli 1977).

134. McCarley (1959) conducted a study of the effects of short-term and long-term flooding on populations of cotton mice and golden mice in eastern Texas. A heavily wooded area on the upper terrace of a floodplain region consisted primarily of water oak and American hornbeam with numerous depressions and drainage pools, but was rarely subject to flooding. Complete inundation of this site for 8 days during a flash flood in April had no apparent impact on mouse populations. A lower terrace of the floodplain had similar vegetative composition but was generally more advanced successionally and had more of an upper canopy consisting mainly of water oak with a correspondingly lesser amount of small woody and herbaceous vegetation on the forest floor. This lower region supported smaller populations of cotton mice and golden mice, was flooded to a depth of approximately 60 cm for a period of 21 days, and had suffered a 70 percent decrease in total rodent populations after floodwaters receded. McCarley (1959) concluded that short-term flooding had no detrimental effects to small-mammal populations, but long-term flooding was apparently detrimental. Schmidly et al (1980) surveyed the small-mammal fauna of various habitats in the Big Thicket National Preserve in east Texas and found little difference in populations based on topography or moisture regimes except where water was an adverse factor due to flooding. Floodplain forest habitats and habitats in corridor regions adjacent to major waterways exhibited moderate trapping success and low species diversity, apparently due to periodic flooding and the resultant decrease in food supply. Only a few species (the cotton mouse, eastern wood rat, and golden mouse) were said to be adapted to the harsh environment of periodically flooded habitats (Schmidly et al. 1980).

135. Impacts of prolonged flooding on small-mammal populations were examined by Hayden and MacCallum (1976) in the floodplain of the lower Mississippi River and adjacent loessial bluff habitats at Grand Gulf, Mississippi. Populations were sampled in loessial bluff forest, bottomland forests, and related field habitats. The two forest habitats were generally inhabited by the same species (short-tailed shrew, cotton

mouse, and golden mouse) with *P. leucopus* additionally found in the bluff forest. Upland and bottomland fields were inhabited by the least shrew (*Cryptotis parva*), short-tailed shrew, fulvous harvest mouse (*Reithrodontomys fulvescens*), cotton mouse, hispid cotton rat (*Sigmodon hispidus*), pine vole (*Microtus pinetorum*), and house mouse, with the marsh rice rat occurring only in the bottomland fields (Hayden and MacCallum 1976). The bottomland region was almost continuously inundated to a maximum depth of about 6 m for 8 months (mid-November to July 1972) during the study. Results of sampling following recession of floodwaters showed that there was no survival of arboreal species such as the cotton mouse and golden mouse over the extended flood period and that the fields were repopulated at a faster rate than woodland areas. The extent of vegetative ground cover appeared to be the key to which species repopulated the previously flooded area, and the house mouse was the dominant repopulating species. Forest ground cover was generally sparse prior to the flood and was completely absent after floodwaters receded (Hayden and MacCallum 1976). Johnson et al. (1977) found that floods played an important role in population fluctuations of small mammals in cottonwood plantations versus natural areas in the Mississippi River Delta. Cottonwoods were devoid of needed cover and showed only small populations the winter following spring floods, but habitat became more favorable for small mammals following seasons without spring flooding. Populations in natural hardwood stands showed little change with or without spring flooding (Johnson et al. 1977).

136. In summary, several studies have indicated that small mammals are more abundant and exhibit greater species diversity on well-drained sites with abundant ground cover compared with periodically inundated bottomlands. However, bottomland hardwoods and adjacent upland forests appear to support similar population densities for certain species. The majority of studies dealing with effects of flooding on small mammals have shown that short-term flooding was not detrimental to most species, but flooding for prolonged periods was highly detrimental to both arboreal and terrestrial species. Lower elevations in bottomland hardwoods are subject to greater inundation and apparently support

the least stable populations of small mammals. Severe long-term flooding often brings about complete eradication of local populations, but reinvasion occurs from adjacent uplands following recession of floodwaters. Repopulation of previously flooded sites is generally slower in woodlands than in field habitats. Reduced flooding is expected to bring about a greater diversity of small mammals but may not increase densities. Reduced flooding will also lessen the frequency of severe flood conditions and will therefore be beneficial to individuals occurring in the lowest elevations of bottomland hardwoods.

Birds

137. Approximately 100 species of birds use bottomland hardwood forests in the lower Mississippi River Valley as breeding and wintering range (Table 11). Information on general habitat preferences and the impacts of flooding regime modifications are presented individually for major game species and collectively for nongame species. Birds that use the area as transitory migrants only are not treated in this report.

Game species: general

138. The principal game birds occurring in the bottomland hardwoods of the lower Mississippi River Valley are the wood duck (*Aix sponsa*), mallard (*Anas platyrhynchos*), hooded merganser (*Lophodytes cucullatus*), wild turkey (*Meleagris gallopavo*), and American woodcock (*Philohela minor*). Although the bobwhite quail (*Colinus virginianus*) is found in extensive openings and along forest edges, it is not considered a typical bottomland hardwood forest species and thus is not treated here. The black duck (*Anas rubripes*), American wigeon (*Anas americana*), green-winged teal (*Anas crecca*), ring-necked duck (*Aythya collaris*), and American coot (*Fulica americana*) may use flooded bottomland hardwood forests on occasion, but they are more typical of other habitats and are not discussed in this report.

Wood duck (*Aix sponsa*)

139. *Habitat requirements.* During the breeding season, wood

Table 11

Seasonal Status of Birds in Bottomland Hardwood Forests in the Lower Mississippi River Valley (Data from Terpening et al. 1974, Dickson 1978, and Peterson 1980)

Species	Status					
	Missouri	Illinois	Arkansas	Tennessee	Mississippi	Louisiana
Anhinga (*Anhinga anhinga*)	B	--	B	B	B	P
Great Blue Heron (*Ardea herodias*)	P	P	P	P	P	P
Green Heron (*Butorides vi-escens*)	B	B	B	B	B	B
Little Blue Heron (*Florida caerulea*)	B	B	B	B	B	B
Cattle Egret (*Bubulcus ibis*)	B	B	B	B	B	B
Great Egret (*Casmerodius albus*)	B	B	B	B	B	P
Snowy Egret (*Egretta thula*)	--	--	B	B	B	P
Black-crowned Night Heron (*Nycticorax nycticorax*)	P	P	P	P	P	P
Yellow-crowned Night Heron (*Nyctanassa violacea*)	B	B	B	B	B	B
Wood Stork (*Mycteria americana*)	SF	--	SF	SF	SF	SF
Mallard (*Anas platyrhynchos*)	W	W	W	W	W	W
Black Duck (*Anas rubripes*)	W	W	W	W	W	W
Wood Duck (*Aix sponsa*)	P	P	P	P	P	P
Hooded Merganser (*Lophodytes cucullatus*)	P	P	P	P	P	P
Turkey Vulture (*Cathartes aura*)	P	B/P	P	P	P	P
Black Vulture (*Coragyps atratus*)	P	P	P	P	P	P
Swallow-tailed Kite (*Elanoides forficatus*)	--	--	--	--	B	B
Mississippi Kite (*Ictinia mississippiensis*)	B	B	B	B	B	B
Sharp-shinned Hawk (*Accipiter striatus*)	P	P	P/W	P	P/W	W
Cooper's Hawk (*Accipiter cooperii*)	P	P	P	P	P	P
Red-tailed Hawk (*Buteo jamaicensis*)	P	P	P	P	P	P
Red-shouldered Hawk (*Buteo lineatus*)	P	P	P	P	P	P
Broad-winged Hawk (*Buteo platypterus*)	B	B	B	B	B	B
Turkey (*Meleagris gallopavo*)	P	P	P	P	P	P
American Coot (*Fulica americana*)	P	B/P	P	P	P	P
American Woodcock (*Philohela minor*)	P	B	P	P	P	P
Yellow-billed Cuckoo (*Coccyzus americanus*)	B	B	B	B	B	B
Black-billed Cuckoo (*Coccyzus erythropthalmus*)	B	B	--	--	--	--
Screech Owl (*Otis asio*)	P	P	P	P	P	P
Great-horned Owl (*Bubo virginianus*)	P	P	P	P	P	P
Barred Owl (*Strix varia*)	P	P	P	P	P	P
Chimney Swift (*Chaetura pelagica*)	B	B	B	B	B	B
Ruby-throated Hummingbird (*Archilochus colubris*)	B	B	B	B	B	B
Belted Kingfisher (*Megaceryle alcyon*)	P	P	P	P	P	P
Common Flicker (*Colaptes auratus*)	P	P	P	P	P	P
Pileated Woodpecker (*Dryocopus pileatus*)	P	P	P	P	P	P
Red-bellied Woodpecker (*Melanerpes carolinus*)	P	P	P	P	P	P
Red-headed Woodpecker (*Melanerpes erythrocephalus*)	P	P	P	P	P	P
Yellow-bellied Sapsucker (*Sphyrapicus varius*)	W	W	W	W	W	W

(Continued)

Note: B = Breeding; W = Wintering; P = Permanent Resident; SF = Summer Foraging; E = Endangered.

(Sheet 1 of 3)

Table 11 (Continued)

Species	Status					
	Missouri	Illinois	Arkansas	Tennessee	Mississippi	Louisiana
Downy Woodpecker (Picoides pubescens)	P	P	P	P	P	P
Hairy Woodpecker (Picoides villosus)	P	P	P	P	P	P
Great-crested Flycatcher (Myiarchus crinitus)	B	B	B	B	B	B
Eastern Phoebe (Sayornis phoebe)	P	B/P	P	P	P/W	W
Eastern Wood Pewee (Contopus virens)	B	B	B	B	B	B
Acadian Flycatcher (Empidonax virescens)	B	B	B	B	B	B
Blue Jay (Cyanocitta cristata)	P	P	P	P	P	P
American Crow (Corvus brachyrhynchos)	P	P	P	P	P	P
Fish Crow (Corvus ossifragus)	B	B	P	P	P	P
Carolina Chickadee (Parus carolinensis)	P	P	P	P	P	P
Black-capped Chickadee (Parus atricapillus)	P	P	--	--	--	--
Tufted Titmouse (Parus bicolor)	P	P	P	P	P	P
White-breasted Nuthatch (Sitta carolinensis)	P	P	P	P	P	P
Brown Creeper (Certhia familiaris)	W	W	W	W	W	W
House Wren (Troglodytes aedon)	B	B	W	--	W	W
Winter Wren (Troglodytes troglodytes)	W	W	W	W	W	W
Bewick's Wren (Thryomanes bewickii)	B/P	B/P	P/W	P	P/W	W
Carolina Wren (Thryothorus ludovicianus)	P	P	P	P	P	P
Northern Mockingbird (Mimus polyglottos)	P	P	P	P	P	P
Gray Catbird (Dumetella carolinensis)	B/P	B	P	P	P	P
Brown Thrasher (Toxostoma rufum)	P	P	P	P	P	P
American Robin (Turdus migratorius)	P	P	P	P	P	P
Wood Thrush (Hylocichla mustelina)	B	B	B	B	B	B
Hermit Thrush (Catharus guttatus)	W	W	W	W	W	W
Blue-gray Gnatcatcher (Polioptila caerulea)	B	B	B	B	B	B/P
Golden-crowned Kinglet (Regulus satrapa)	W	W	W	W	W	W
Ruby-crowned Kinglet (Regulus calendula)	W	W	W	W	W	W
Cedar Waxwing (Bombycilla cedrorum)	W	W	W	W	W	W
Starling (Sturnus vulgaris)	P	P	P	P	P	P
White-eyed Vireo (Vireo griseus)	B	B	B	B	B	B/P
Yellow-throated Vireo (Vireo flavifrons)	B	B	B	B	B	B
Solitary Vireo (Vireo solitarius)	--	--	--	--	W	W
Red-eyed Vireo (Vireo olivaceus)	B	B	B	B	B	B
Warbling Vireo (Vireo gilvus)	B	B	B	B	B	B
Black-and-white Warbler (Mniotilta varia)	B	B	B	B	B	B
Prothonotary Warbler (Protonotaria citrea)	B	B	B	B	B	B
Swainson's Warbler (Limnothlypis swainsonii)	B	B	B	B	B	B
Bachman's Warbler (Vermivora bachmanii)	B?/E	--	B?/E	B?/E	B?/E	B?/E
Orange-crowned Warbler (Vermivora celata)	--	--	-/W	--	-/W	W
Northern Parula Warbler (Parula americana)	B	B	B	B	B	B
Yellow Warbler (Dendroica petechia)	B	B	B/-	B	B/-	--
Yellow-rumped Warbler (Dendroica coronata)	W	W	W	W	W	W
Cerulean Warbler (Dendroica cerulea)	B	B	B	B	B/-	B/-
Yellow-throated Warbler (Dendroica dominica)	B	B	B	B	B	B
Louisiana Waterthrush (Seiurus motacilla)	B	B	B	B	B	B
Kentucky Warbler (Oporornis formosus)	B	B	B	B	B	B
Common Yellowthroat (Geothlypis trichas)	B	B	B/P	B	B/P	P

(Continued)

(Sheet 2 of 3)

Table 11 (Concluded)

Species	Status					
	Missouri	Illinois	Arkansas	Tennessee	Mississippi	Louisiana
Yellow-breasted Chat (*Icteria virens*)	B	B	B	B	B	B
Hooded Warbler (*Wilsonia citrina*)	B	B	B	B	B	B
American Redstart (*Setophaga ruticilla*)	B	B	B	B	B	B
Red-wing Blackbird (*Agelaius phoeniceus*)	P	P	P	P	P	P
Orchard Oriole (*Icterus spurius*)	B	B	B	B	B	B
Northern Oriole (*Icterus galbula*)	B	B	B	B	B	B
Rusty Blackbird (*Euphagus carolinus*)	W	W	W	W	W	W
Common Grackle (*Quiscalus quiscula*)	P	P	P	P	P	P
Brown-headed Cowbird (*Molothrus ater*)	P	P	P	P	P	P
Scarlet Tanager (*Piranga olivacea*)	B	B	B/-	B/-	--	--
Summer Tanager (*Piranga rubra*)	B	B	B	B	B	B
Northern Cardinal (*Cardinalis cardinalis*)	P	P	P	P	P	P
Indigo Bunting (*Passerina cyanea*)	B	B	B	B	B	B
American Goldfinch (*Carduelis tristis*)	P	P	P	P	P/W	W
Rufous-sided Towhee (*Pipilo erythrophthalmus*)	P	P	P	P	P	P/W
Northern Junco (*Junco hyemalis*)	W	W	W	W	W	W
White-throated Sparrow (*Zonotrichia albicollis*)	W	W	W	W	W	W
Fox Sparrow (*Passerella iliaca*)	W	W	W	W	W	W
Swamp Sparrow (*Melospiza georgiana*)	W	W	W	W	W	W

(Sheet 3 of 3)

ducks require habitats that provide food, loafing sites, protective cover, and nesting cavities. These habitats are generally freshwater swamps, sloughs, beaver ponds, and seasonally flooded bottomland hardwoods.

140. Wood ducks use natural and man-made cavities for nesting (Bellrose et al. 1964). Nest sites are generally adjacent to permanent or semipermanent water, although they may be found as far as 1.6 km from water (Bellrose 1976). In oak-gum-cypress forests, the trees most likely to produce nesting cavities are baldcypress, sycamore, silver maple, red maple, ash, blackgum, sweetgum, boxelder, black willow, elm, sugarberry, and oaks of the black oak group (USDA 1971).

141. Optimum brood habitat has been characterized as areas with patchy patterns of emergent cover, such as downed timber and herbaceous or woody plants interlaced with a network of open water passageways. Buttonbush and swamp privet are good examples of this dense, spreading, low growth (Webster and McGilvery 1966). The importance of still and shallow water, logs for loafing, canopy closure along sloughs, and water throughout the nesting season at the proper level was noted by Morrill (1976). Areas with these characteristics provide ample substrate to support invertebrate populations that are important sources of protein and amino acids for breeding hens and their broods (Drobney and Fredrickson 1979).

142. Although large areas of open water seem to be of little value to wood duck broods (Webster and McGilvery 1966), a complex of various wetland types that provides travel corridors can be important to brood survival. Hepp (1977) suggested that the use of wetland corridors in movements from nest sites to brood habitat increased the overall production of wood ducks on his study area. Ridlehuber (1980) stated that lengthy cross-country moves through inferior brood habitat contributed to high brood mortality. In areas where these wetland corridors are available for brood movements, the brood survival is apparently higher than for areas where broods must make overland movements.

143. During the fall and winter, wood ducks use wooded wetlands for food and cover. Acorns are the preferred food and are obtained

primarily in shallowly flooded timber. However, wood ducks also will eat acorns in dry woods and waste grain in fields when preferred feeding sites are lacking (Bellrose 1976). According to Parr et al. (1979), autumn and winter roost sites in southern Illinois were characterized by overhead concealing cover with open water underneath. The above authors observed that during the day, wood ducks were found in buttonbush swamps 75 percent of the time compared with 25 percent in the flooded timber. During the night, wood ducks were located in buttonbush 99 percent of the time. On the basis of over 500 observations, wood ducks were never found in open water (Parr et al. 1979).

144. Impacts of flooding regime modifications. Hankla and Carter (1966) stated that flood control and drainage were detrimental to wood duck populations. Flood control reduces the frequency and duration of floodplain inundation, which in turn reduces the availability of bottomland hardwood mast to wood ducks. Drainage eliminates or directly reduces the extent of many permanent and semipermanent wooded wetlands and reduces the seasonal flooding in bottomland forests.

145. The direct elimination of brood habitat through drainage and reduced flooding will result in decreased brood survival; Ridlehuber (1980) has shown that lengthy movements through inferior brood habitat have contributed to increased brood mortality.

146. Drobney (1977) and Drobney and Fredrickson (1979) noted that during breeding season, the female wood duck shifts to a diet high in invertebrates. Shallowly flooded areas are an important source of these invertebrates which provide the protein and essential amino acids needed by the nesting hen. During late winter and early spring, these areas are especially valuable as deeper waters lack the surface vegetation that would serve as production substrate for invertebrates. Also, the seasonal availability of nonaquatic invertebrates is low at this time.

147. In a greentree reservoir in southern Illinois, Hubert and Krull (1973) found that the greatest number and biomass of aquatic macroinvertebrates were collected about 6 weeks after flooding in the fall. Most of these populations developed in place from species adapted to conditions of temporary waters. Although this study was based on initial

flooding in the fall, it would seem logical to assume that comparable invertebrate populations would develop in a bottomland hardwood forest initially flooded in the late winter and early spring. Thus, the periodic spring flooding of hardwoods may be important to breeding wood ducks since it would likely produce aquatic macroinvertebrates for food. The reduction of flooding may have an adverse impact on the female's nesting success.

148. The most obvious adverse impact of increased flooding would be the loss of nests and eggs to inundation. This would depend on the timing and severity of the flood and the height of the nesting cavity chosen by the wood duck. Overall, this would seem to be of minor consequence due to the irregular occurrence of exceptional floods and the renesting ability of the adult hen. Tree mortality caused by exceptionally high waters or by incomplete drainage of flood waters could provide an additional source of nesting cavities for wood ducks. Fredrickson (1980b) noted that prolonged deep flooding during the growing season killed approximately 7 percent of the oaks on a Missouri site. This mortality included a number of large mature pin oaks and cherrybark oaks scattered throughout the stand. This pattern of scattered dead snags would probably be beneficial to nesting wood ducks. However, dead snags would be available as potential nest sites for only a limited time (probably 5-8 yr on the average) before succumbing to decay or windthrow.

Hooded merganser (*Lophodytes cucullatus*)

149. Habitat requirements. According to Bellrose (1976), the hooded merganser's requirements for natural nesting cavities are quite similar to those of the wood duck. Bellrose reported that hooded mergansers use wood duck boxes for nesting and that wood ducks and mergansers will lay eggs in each other's nests. Hooded mergansers nest in swamps, river bottomlands, beaver ponds, and along wooded streams and lakes. Most hooded merganser nests are adjacent to or near standing water (Morse et al. 1969). Bellrose (1976) reported that merganser broods use rivers or river-related habitat, beaver ponds, and other

types of standing water. Hooded mergansers feed primarily on fishes, crustaceans, and aquatic insects, although Arner, as reported by Bellrose (1976), said they use acorns on the Noxubee National Wildlife Refuge, Mississippi.

150. Impacts of flooding regime modifications. With their dependence on aquatic foods, any decrease in water coverage would affect merganser habitat. Bellrose (1976) reported that hooded merganser numbers were lower than they were earlier in this century. This decline was attributed to the drainage of swamps and river bottomlands. Bellrose further stated that 61 percent of the total population wintered on the Mississippi Flyway. Of this figure, only about 10 percent wintered north of the Ohio River and the Arkansas border. Thus, any reduction in hooded merganser habitat in the lower Mississippi River Valley would be likely to have a significant impact on the overall population. Bellrose (1976) reported that hooded mergansers cannot find adequate food in highly turbid waters. Unless relatively calm clear backwaters are available during floods, the hooded merganser is likely to be adversely affected.

Mallard (*Anas platyrhynchos*)

151. Habitat requirements. The lower Mississippi River Valley is the heart of the mallard wintering area of the Mississippi Flyway. Mallards move into this area in early October of each year. Major concentration areas during the fall migration are: the central Illinois River Valley, Illinois; the Jonesboro and Stuttgart regions of Arkansas; Union and Alexander Counties in southern Illinois; Reelfoot Lake and Lake Isom, Tennessee; the Ouachita River Valley of southern Arkansas and northern Louisiana; and the swamps of southeastern Louisiana (Bellrose 1972). Mallards remain in these general areas throughout the winter and begin their northward migration in early February to early April (Bellrose 1976).

152. The mallard is very adaptable in its feeding and roosting/rafting habits (Jahn and Hunt 1964). Habitat types used include flooded bottomland hardwood forests, freshwater marshes and swamps, open-water

rivers, oxbow lakes and reservoirs, beaver ponds, and flooded dead timber reservoirs. Foods used include natural marsh plants (Bellrose 1976), acorns (Wright 1959), corn (Madson 1964), rice (Horn and Glasgow 1964), and wet soybeans (Bellrose 1976).

153. Although mallards use dead timber reservoirs and deep open-water areas for roosting and rafting, they apparently prefer flooded bottomland hardwoods (Horn and Glasgow 1964). The preference for these flooded woodlands is also indicated by the difficulties encountered in the annual winter waterfowl census. During years when bottomlands are flooded by high waters or local rains, mallard concentrations are found in forests where they are difficult to count (Chamberlain et al. 1972, Benning et al. 1978, and Goldsberry et al. 1980). Rudolph and Hunter (1964) noted the dramatic increase in mallard use of the Noxubee National Wildlife Refuge, Mississippi, after the construction of green-tree reservoirs. Annual estimates of duck numbers and total use days increased from highs of 21,000 and 1.8 million, respectively, before construction to highs of 100,000 and 6 million a few years after construction.

154. Flooded bottomlands also provide food when acorns and other hard mast are available (Hall 1962). Desirable mast tree species are pin oak, water oak, willow oak, cherry bark oak, Nuttall oak, Shumard oak, blackgum, and hickory (Rudolph and Hunter 1964). Mallards feed by tipping up and rarely dive for food. To be available for mallards, food should be within 30 to 45 cm of the water surface. Mallards feed on the feather edge of rising waters but they rarely feed on hardwood mast on dry ground unless it is associated with this edge (Rudolph and Hunter 1964). Wright (1959) found that mallards in Arkansas had almost 3 times more acorns in their diets during a wet year with bottomland flooding than during a dry year with little flooding. In a day-to-day food habits analysis, he noticed an immediate increase in mallard use of acorns as the weather changed from dry to wet.

155. During a typical day, mallards leave the bottomlands at dawn and fly out to grain fields to feed. These flights normally range up to 24 to 40 km one way, but they may be as long as 64 km. The ducks return

to the flooded timber in midday and then fly out again in late afternoon (Bellrose 1976). Late in the day, the mallards return once again to roost in the woods overnight (Hall 1962).

156. Bellrose (1976) considered the mallard's field feeding habit to be a "double-edged sword." Although the large quantities of agricultural waste grain have helped to increase the mallard's survival by reducing nonhunting mortality, the loss of natural wetlands has forced the mallard to depend on this food source. Bellrose believed that as improved crop strains were developed, as harvesting equipment was made more efficient, and as fall plowing was increased, the availability of agricultural waste grain would be reduced, therefore forcing the mallard back to a more natural diet. The mallard population might then be in jeopardy due to the inadequacy of natural food supplies resulting from wetland losses.

157. Impacts of flooding regime modifications. The lower Mississippi River Valley supports the largest wintering population of mallards in North America (Bellrose 1976). Flooded bottomland hardwoods in this region supply excellent feeding and roosting areas. However, nonflooded hardwoods receive very little, if any, mallard usage. Any significant decrease in the normal flooding of a bottomland forest will reduce the available wintering habitat for this species. The importance of these bottomlands in supplying a winter food source may increase if present agricultural food sources available to the mallard diminish.

158. Extensive deep-water flooding will decrease mallard use of acorns as water depths greater than 1 m make these acorns unavailable to mallards (Hall 1962). However, it would be difficult to say that deep-water flooding would be detrimental to wintering mallards. The water depth in a flooded bottomland hardwood forest should have no appreciable effect on the use of the area for rafting and roosting. This is true as long as the stand is not subject to strong water currents and food sources are available within a radius of approximately 64 km. It would seem that no matter what the extent of the flooding, new shallow-water food sources would be made available on a continuing basis. Thus, although extensive flooding may reduce mallard use in a local area, it

should have no appreciable effect on a regional basis.

Wild turkey (Meleagris gallopavo)

159. Habitat requirements. The eastern wild turkey requires extensive forest lands. Blocks of approximately 2000 ha are considered the minimum necessary for effective management (Holbrook 1973, Davis 1976), while areas with 3200-4000 ha of contiguous land are capable of meeting the year-round needs of a turkey population (Speake et al. 1969). According to Holbrook (1973), desirable turkey habitat is characterized by "stands of mixed hardwoods, groups of conifers, relatively open understories, scattered clearings, and well-distributed water; additional requisites are reasonable freedom from disturbance and adequate area." Speake et al. (1975) also stressed the importance of habitat diversity as they noted that turkeys generally range through more than one cover type.

160. Meanley (1956) reported the foods and forest types used by turkeys in the bottomland hardwoods of the lower Arkansas, White, and Mississippi Rivers. Meanley found that the well-drained first bottom ridges (sweetgum-sweet pecan-southern red oak) were the preferred habitat, followed by the sweetgum-water oak type which was widely used when not inundated. The overcup oak-bitter pecan forest type was considered to be relatively unimportant for turkeys, while cypress-swamp tupelo trees were not considered to be food-producing trees for turkeys. However, Bowen (as reported by Schumacher 1977) noted that the larger cypress brakes were the preferred winter habitat for turkeys on the Huntington Point Hunting Club (Bolivar and Washington Counties, Mississippi).

161. Although food supply and cover conditions on the fall-winter range are important, Hillestad and Speake (1970) noted that the spring-summer brood rearing habitat may be a controlling factor for turkey populations. These authors cited the observation that gobblers are usually at their maximum weight for the year at the beginning of the breeding season since the turkey is a highly opportunistic feeder and thus probably fares better during the winter than do most game species.

162. Speake et al. (1969) and Hillestad and Speake (1970) stressed the importance of openings and permanent pastures as a critical component of spring-summer turkey range. These authors found that openings were very important for nesting and brood habitat. Of 40 nests located, 75 percent were either in openings or within 37 m of an opening.

163. Hurst and Stringer (1975) and Hurst (1978) documented the importance of insects in the diets of young turkey poults. Hurst and Stringer (1975) found that turkey poults that fed in bottomland hardwood stands ate mainly plant foods due to the lack of insects available. The above authors noted that the herbaceous layer was very sparse and that the area was commonly flooded in winter and spring. In contrast, Williams et al. (1974) found that turkeys heavily used a cypress stand in south Florida. They believed that the cypress woods provided the same type of habitat generally found in woodland openings. The cypress canopy varied in density and permitted enough sunlight penetration to allow a heavy ground cover of grasses and forbs.

164. Impacts of flooding regime modifications. According to Davis (1962, cited bv Powell 1967), very few turkeys are lost directly as a result of winter and spring floods in the bottomlands of southwestern Alabama. These floods result in a temporary loss of food, and if the water remains high until late spring, nesting success generally shows a decline. Powell (1967) stated that high rainfall in southern Alabama and Florida can cause nests to be flooded and can kill poults directly through drowning. Stoddard (undated, cited by Shaffer and Gwynn 1967), noted that turkey poults in the downy stage will frequently die during long protracted spells of wet, cold weather. Williams et al. (1973) believed, however, that the flooding conditions brought about by a rain were more of a hazard than the falling rain itself. These authors found indirect evidence of poult loss apparently when the poults crossed flooded creeks and streams. Schumacher (1977) noted that the nesting season in the batture lands of the Mississippi Delta was delayed for 5 weeks due to flooding in April of 1975. Although Kennamer et al. (1975) noted that turkey productivity in the same general area was lowest in the same year that the highest flooding occurred (1970), they

were not able to document any definite correlation between flooding and turkey productivity.

165. Meanley (1956) suggested that dry years, which exposed many sandbars and dry oxbow lake beds during the fall, were beneficial to the turkey population in the lower White River area. He also noted that during the winter, turkeys fed heavily on selected insects found under the ground litter of the first bottom ridges.

166. The wild turkey has apparently adapted to the periodic flooding conditions found in bottomland hardwoods. According to Clawson (1962, cited by Lewis 1967), the bottomland hardwoods of the Mississippi River in Arkansas and Mississippi have produced some of the highest turkey populations in the nation. Population densities were estimated to approach one bird per 6 to 8 ha. Holbrook and Lewis (1967) cited a population estimate of one bird per 8 ha for the Shelby Wildlife Management Area in Shelby County, Tennessee.

American woodcock (*Philohela minor*)

167. Habitat requirements. Most woodcocks that breed west of the Appalachian Mountains winter primarily in Arkansas, Louisiana, Mississippi, and Alabama. Although specific habitat requirements for woodcocks wintering in the Southeast are not completely known, the birds apparently prefer alluvial floodplains with a brushy understory. Overstory species composition seems to be unimportant, but certain understory species seem to be highly preferred. Some of these are swamp privet, holly, switch cane, honeysuckle, greenbrier, and blackberry (Owens 1977).

168. During the day, woodcocks feed in brushy bottomland hardwood stands. Horton and Causey (1979) found that these diurnal activity centers averaged approximately 3800 saplings/ha, approximately 4000 seedlings/ha, and were about 9 ha in size. These sites must also have moist, fertile soils that support high earthworm populations since earthworms normally constitute 50 to 90 percent of the woodcock's diet (Owens 1977).

169. In the evenings, woodcocks leave their diurnal coverts and

move to fields, pastures, and small forest openings to roost. Roosting areas generally contain scattered clumps of grasses, sedges, or weeds that the woodcock uses as cover. Although the birds may do some feeding in fields in the early evening and early morning, the fields apparently are used primarily as roosting sites (Kletzly 1976).

170. The Southeast is generally considered winter range, but recent reports indicate that the woodcock may breed in the South more frequently than was previously thought (Owens 1977). Kletzly (1976) noted that nests are normally located near an occupied singing ground within approximately 100 m or less, and a variety of brushy habitats may be used such as abandoned fields, brushy fence rows near cover, and young second-growth timber. According to Owens (1977), most of the woodcock in the northern part of the range hatch in May, and Kletzly (1976) reported that most young woodcock are independent of their mothers by early June.

171. Impacts of flooding regime modifications. Owens (1977) stated that channelization and drainage were important causes of habitat destruction on the woodcock's winter range, and he believed that woodcock habitat was declining at a faster rate in the Gulf States than anywhere else on the breeding and wintering grounds. According to Kletzly (1976), stream channelization destroys wookcock habitat by eliminating shrub vegetation and by reducing soil moisture. In a study of invertebrate populations in a floodplain forest in southcentral Illinois, Goff (1952) found that the highest numbers of earthworms occurred in an area subjected to moderate seasonal flooding. Earthworm numbers decreased as the sites changed to wetter or drier conditions. Apparently, the moderately flooded site represented an optimum mix of drainage and periodic moisture recharge. Thus, since woodcocks depend to a large degree on earthworms and associated moist woodlands for feeding and daily activities, it is expected that a reduction of flooding and the associated lowering of the water table would be detrimental to woodcock populations.

172. Any significant increase in flooding frequency and duration also would probably be detrimental to woodcocks. High water levels would make flooded areas unavailable for feeding, and some nests might

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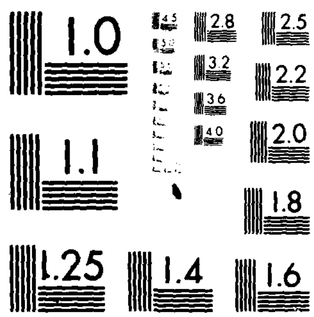

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be inundated by spring floods. Any decrease in the density of understory shrubs, saplings, and seedlings used as cover by woodcocks also would be detrimental.

Nongame birds

173. Habitat requirements. According to Dickson (1978), bird populations in a forest stand are influenced by a number of habitat factors, including: number of vertical foliage layers; total foliage volume; foliage density near the ground; overstory hardwood and conifer mixture; habitat patchiness; successional stage of the stand; and moisture content. Gauthreaux (1978) also noted the importance of community characters (spatial complexity, trophic complexity, niche breadth, standing crop, turnover, and diversity) to the structure and organization of forest avian communities.

174. MacArthur and MacArthur (1961) found that in deciduous forests, the bird species diversity generally increased with increased foliage height diversity. MacArthur et al. (1962) found that although vertical foliage layers (herbaceous layer, shrub layer, and canopy) were important, the horizontal variation in vegetation profile, or "patchiness," was probably more important in determining bird species diversity. Willson (1974) and Samson (1979) found that breeding season guilds were added in a stepwise progression as vegetative layers were added. Willson (1974) believed that this increased vegetational complexity resulted in increased environmental patchiness in three dimensions thus providing more opportunities for space utilization by different bird species. Hooper et al. (1973) also noted the importance of the clumping of understory vegetation and mixture of overstory hardwood and conifer trees to breeding bird populations. They found that numbers of breeding pairs increased as clumping and canopy diversity increased. Webb et al. (1977) found that the foliage height diversity in a mature northern hardwood stand was increased by logging and that bird species diversity increased as a result. Dickson (1978) noted that the high stand basal area and closed canopy in bottomland hardwood stands lowered light penetration, thereby reducing understory vegetation, habitat patchiness, and, indirectly, breeding bird diversity.

Shugart and James (1973) found that bird population density and bird species diversity tended to increase with the ecological age of the site. They also noted that the density of breeding territorial males in their mesic forest plot (370/40 ha) was almost twice that found in the intermediate forest plot (196/40 ha) and slightly over three times that of the xeric forest plot (115/40 ha). These authors attributed the large difference between the mesic and xeric plots to the uniformity of the vegetation in the xeric forest plot. Smith (1977) also noted the importance of a forest soil moisture gradient to the vegetation and thus to the distribution of bird species in the area.

175. Although a general trend of increased bird species diversity resulting from increased structural complexity of the vegetation appears evident, one should be cautious when dealing with bird species diversity indices. The singing male mapping method is generally acknowledged to be the most dependable technique available for censusing forest birds during the breeding season (Robbins 1978) and is often used in calculating breeding bird species diversity indices. However, Best (1975) has pointed out some significant problems associated with this technique since the population estimates derived from it are subject to observational and interpretational errors. In some species, song is not necessarily related to territory, while in other species, nonbreeding males may sing more often than breeding males (Samson 1979). Willson (1974) and Peet (1975) have questioned the biological relevance of the diversity indices used in various studies, and Peet (1975) has shown that these indices are significantly influenced by small changes in the data used to calculate them. A problem may arise in determining whether differences in diversity values reflect actual differences among study areas, or whether they reflect errors in population estimates. Samson (1979) and Willson (1974) have suggested that overwinter survival may be more important than the condition of the local breeding habitat in determining subsequent breeding bird densities and diversity.

176. Impacts of flooding regime modifications. In a study comparing seasonal bird populations in three forest stand types in the Atchafalaya River Basin of Louisiana, Kennedy (1977) found that the mean

number of individuals, the mean number of species, and the bird species diversity were consistently higher in the bottomland hardwood (sweetgum-hackberry-water oak) type than in the cottonwood-willow-sycamore type or the cypress-tupelo type. More than 60 percent of the birds observed in the cypress-tupelo stands were in the upper canopy. The author believed that the annual flooding regime reduced the foliage density and plant species composition of the midstory and understory of the cypress-tupelo type, thereby reducing potential bird usage of these layers.

177. Fredrickson (1979) noted that channelization or drainage of a bottomland hardwood forest gradually changed the plant community to one characteristic of a drier site, while the periodic impoundment of a greentree reservoir gradually changed the plant community to one characteristic of a wetter site. However, as long as the forest stands remained intact after channelization, drainage, or greentree operation, he was not able to detect any significant differences in bird numbers and bird species composition on his study area.

178. According to Dickson (1978), bottomland hardwood forests support breeding and wintering bird densities 2-4 times larger than those found in upland pine and pine-hardwood stands. It seems likely that the regime of periodic dormant-season flooding with an occasional growing-season flood may be responsible for these high relative bird densities. Some of the contributing factors are the increases in overstory species richness on infrequently flooded sites (Bedinger 1971, Bell 1980), the good understory vegetation growth on the bottomland sites (Dickson 1978), the ability of the understory vegetation to recover quickly from the effects of a flood (Noble and Murphy 1975), the within-habitat patchiness created by scattered openings caused by tree mortality associated with severe floods (Fredrickson 1980b), and the between-habitat diversity evidenced by differin[illegible] types resulting from soil and hydrologic influences (Putnam et al. 1960).

179. The impacts of flooding regime modifications should be considered in terms of the within-stand or local impacts, and the between-stand or regional impacts. Local impacts will depend on the initial overstory/understory cover conditions and the direction and rate of

vegetation change for a given forest type. Regional impacts will depend on the number and degree of interspersion of existing forest types, and the various directions and rates of vegetation change for each particular forest type affected. Bell (1980) found an increase in diversity of overstory tree species as he moved from a frequently flooded site to an infrequently flooded site, with a slight decrease in diversity from the infrequently flooded site to an adjacent nonflooded upland site. Fredrickson (1980a) stated that understory density and diversity would increase as flooding was reduced on bottomland sites. Thus, the direction of vegetation change will probably be similar for most forest types. Individual stands and grounds of stands should become more homogeneous, with a resultant loss of overall between-habitat diversity. The trend that may improve the habitat for birds in an individual stand may at the same time create less favorable conditions throughout a region.

Reptiles and Amphibians

180. Faunal status and habitat requirements. The reptile and amphibian fauna of the lower Mississippi Valley region is composed of over 100 species with some 140 morphologically distinct subspecies. Species of known or probable occurrence in the study area and general information on their occurrence in major habitats are shown in Table 12. Habitat preferences basically follow Keiser and Wilson (1969), Keiser (1971), Conant (1975), and USDI (1974, 1976). Subspecies are not listed for the sake of simplicity and because of the paucity of specific habitat data for certain races.

181. The majority of reptiles and amphibians of the study area may be found either permanently or during certain periods of their life cycles in riverine habitats, wooded bottomlands, or swamplands. Species such as the American alligator (*Alligator mississippiensis*), most turtles, the western cottonmouth (*Agkistrodon piscivorus*), natracine snakes (primarily members of the genera *Nerodia* and *Regina*), and numerous amphibians are especially adapted to aquatic and semiaquatic habitats. The dependence of certain species on wetland ecosystems was

Table 12

Reptiles and Amphibians of Actual or Probable Occurrence in the Lower Mississippi Valley Study Area, Southern Illinois to South Louisiana (Primary References were Keiser 1971, Conant 1975, and USDI 1974, 1976)

Species	Habitat Type-Occurrence						
	Marshlands	Lakes, Ponds	Rivers, Streams, Bayous	Swamps, Sloughs	Wooded Bottomland	Wooded Uplands	Grasslands, Shrublands, Open Terrain
Crocodilians							
American alligator (Alligator mississippiensis)	+	+	+	+	+ (edge)		
Turtles							
Snapping turtle (Chelydra serpentina)	+	+	+	+	+ (edge)		+ (edge)
Alligator snapping turtle (Macroclemys temmincki)		+	+	+			
Stinkpot (Sternotherus odoratus)	+	+	+	+			
Razor-backed musk turtle (Sternotherus carinatus)		+	+	+			
Loggerhead musk turtle (Sternotherus minor)				+			
Mud turtle (Kinosternon subrubrum)	+	+	+	+			+ (wet)
Eastern box turtle (Terrepene carolina)	+	+ (edge)	+ (edge)	+	+	+	+
Ornate box turtle (Terrepene ornata)						+	+
Diamondback terrapin (Malaclemys terrapin)	+		+ (coastal)				
Map turtle (Graptemys geographica)		+	+				
Alabama map turtle (Graptemys pulchra)			+				
Mississippi map turtle (Graptemys kohni)		+	+	+			
False map turtle (Graptemys pseudogeographica)		+	+				
Red-eared turtle (Chrysemys scripta)	+	+	+	+			
Cooter (Chrysemys concinna)		+	+				
Missouri slider (Chrysemys floridana)		+	+	+			
Painted turtle (Chrysemys picta)	+	+	+	+			
Chicken turtle (Deirochelys reticularia)	+	+		+			
Smooth softshell (Trionyx muticus)	+	+	+				
Spiny softshell (Trionyx spiniferus)	+	+	+	+			
Lizards							
Green anole (Anolis carolinensis)	+	+ (edge)		+	+	+	+
Fence lizard (Sceloporus undulatus)						+	
Six-lined racerunner (Cnemidophorus sexlineatus)					+ (sandy soil)	+ (sandy soil)	+
Ground skink (Leiolopisma laterale)	+			+	+	+	+
Five-lined skink (Eumeces fasciatus)	+			+	+	+	+
Broad-headed skink (Eumeces laticeps)				+	+	+	
Southeastern five-lined skink (Eumeces inexpectatus)						+	+
Coal skink (Eumeces anthracinus)						+	
Eastern glass lizard (Ophisaurus ventralis)	+						+ (wet)
Slender glass lizard (Ophisaurus attenuatus)						+	+
Snakes							
Green water snake (Nerodia cyclopian)	+	+	+	+	+		
Diamondback water snake (Nerodia rhombifera)	+	+	+	+	+		
Yellow-bellied water snake (Nerodia erythrogaster)	+	+	+	+	+		
Midland water snake (Nerodia sipedon)	+	+	+	+	+		
Broad-banded water snake (Nerodia fasciata)	+	+	+	+	+		+ (wet)
Graham's water snake (Regina grahami)	+	+	+	+	+		
Glossy water snake (Regina rigida)	+		+ (small)	+	+		

(Continued)

(Sheet 1 of 4)

Table 12 (Continued)

Species	Habitat Type-Occurrence: Marshlands	Lakes, Ponds	Rivers, Streams, Bayous	Swamps, Sloughs	Wooded Bottomland	Wooded Uplands	Grasslands, Shrublands, Open Terrain
Snakes (continued)							
Queen snake (Regina septemvittata)			+ (stony creeks and rivers)				
Midland brown snake (Storeria dekayi)	+			+	+	+	+
Red-bellied snake (Storeria occipitomaculata)	+				+	+	+
Eastern garter snake (Thamnophis sirtalis)	+	+ (edge)	+ (edge)	+	+	+	+
Eastern ribbon snake (Thamnophis sauritus)			+	+	+		
Western ribbon snake (Thamnophis proximus)	+	+	+	+	+		+
Smooth earth snake (Virginia valeriae)						+	+
Rough earth snake (Virginia striatula)				+	+	+	+
Eastern hognose snake (Heterodon platyrhinos)	+				+ (edge)	+	+
Western hognose snake (Heterodon nasicus)							+
Ringneck snake (Diadophis punctatus)				+ (edge)	+	+ (poorly drained)	+
Worm snake (Carphophis amoenus)						+ (moist)	+
Mud snake (Farancia abacura)	+	+ (edge)	+ (edge)	+	+		+
Rainbow snake (Farancia erytrogramma)			+	+			
Racer (Coluber constrictor)	+			+	+	+	+
Coachwhip (Masticophis flagellum)						+ (open)	+
Rough green snake (Opheodrys aestivus)				+ (edge)	+	+	+
Corn snake (Elaphe guttata)	+ (high ground)			+ (edge)		+	+
Gray rat snake (Elaphe obsoleta)	+	+	+	+	+	+	+
Speckled kingsnake (Lampropeltis getulus)	+		+ (edge)	+	+	+	+
Milk snake (Lampropeltis triangulum)				+	+	+	+
Prairie kingsnake (Lampropeltis calligaster)						+ (open)	+
Scarlet snake (Cemophora coccinea)						+	
Southeastern crowned snake (Tantilla coronata)				+	+	+	+
Coral snake (Micrurus fulvius)				+	+	+	+
Copperhead (Agkistrodon contortrix)	+			+ (margins)	+	+	
Western cottonmouth (Agkistrodon piscivorus)	+	+	+	+	+	+ (occasional)	
Pygmy rattlesnake (Sistrurus miliarius)	+			+	+	+	+ (wet)
Canebrake rattlesnake (Crotalus horridus)	+ (occasional)			+	+	+ (moist)	
Salamanders							
Hellbender (Cryptobranchus alleganiensis)			+ (fast-running waters; doubtful in study area)				
Mudpuppy (Necturus maculosus)		+	+				
Gulf Coast water dog (Necturus beyeri)		+	+				+
Three-toed amphiuma (Amphiuma tridactylum)	+	+	+ (bayous and ditches)	+			
Two-toed amphiuma (Amphiuma means)				+ (+ ditches)			+
Lesser siren (Siren intermedia)	+	+ (+ ditches)		+	+		
Mole salamander (Ambystoma talpoideum)		+ (breeding ponds)			+		
Marbled salamander (Ambystoma opacum)		+ (breeding ponds)			+ (lowland, deciduous)	+	

(Continued)

(Sheet 2 of 4)

Table 12 (Continued)

Species	Marshlands	Lakes, Ponds	Rivers, Streams, Bayous	Swamps, Sloughs	Wooded Bottomland	Wooded Uplands	Grasslands, Shrublands, Open Terrain
	Habitat Type-Occurrence						
Salamanders (continued)							
Small-mouthed salamander (*Ambystoma texanum*)		+ (breeding ponds)		+	+	+	+
Spotted salamander (*Ambystoma maculatum*)		+ (breeding ponds)			+	+	
Tiger salamander (*Ambystoma tigrinum*)		+ (breeding ponds)		(Habitat essentially unknown in study area)			
Central newt (*Notopthalmus viridescens*)		+	+	+	+ (moist woodlands)		+
Dusky salamander (*Desmognathus fuscus*)			+ (springs, seeps)			+ (hillside streams)	
Southern dusky salamander (*Desmognathus auriculatus*)				+	+ (pools)		
Zigzag salamander (*Plethodon dorsalis*)						+	+
Slimy salamander (*Plethodon glutinosus*)					+	+	
Red salamander (*Pseudotriton ruber*)			+ (streams)				
Two-lined salamander (*Eurycea bislineata*)			+ (edge)	+	+		+
Long-tailed salamander (*Eurycea longicauda*)			+ (edge)			+	
Dwarf salamander (*Eurycea quadridigitata*)				+	+		
Cave salamander (*Eurycea lucifuga*)			+ (cool springs)				limestone bluffs
Frogs and Toads							
Eastern spadefoot (*Scaphiopus holbrooki*)						+ (sandy)	+
American toad (*Bufo americanus*)		+ (pools)	+ (shallow streams)		+	+	+
Southern toad (*Bufo terrestris*)		+ (pools)				+	
Fowler's toad (*Bufo woodhousei*)		+ (pools)	+ (streams and ditches)	+	+	+	+
Gulf Coast toad (*Bufo valliceps*)	+	+ (rainpools, ditches)			+	+	+
Oak toad (*Bufo quercicus*)				+ (edge)		+	
Southern cricket frog (*Acris gryllus*)		+	+		+ (not generally in Delta)		
Northern cricket frog (*Acris crepitans*)	+	+	+	+	+		+
Spring peeper (*Hyla crucifer*)		+ (temporary)		+ (temporary)		+	+
Green treefrog (*Hyla cinerea*)	+	+ (borders)	+ (borders)	+	+		+
Barking treefrog (*Hyla gratiosa*)						+	
Squirrel treefrog (*Hyla squirella*)	+	+ (woodland ponds)		+	+	+	+
Gray treefrog (*Hyla versicolor*)		+ (edge)	+	+	+		+
Gray treefrog (*Hyla chrysoscelis*)		+ (edge)		+	+		
Bird-voiced treefrog (*Hyla avivoca*)			+	+	+		
Pine woods treefrog (*Hyla femoralis*)				+		+	
Upland chorus frog (*Pseudacris triseriata*)	+	+ (edge)		+	+	+ (sparse)	+

(Sheet 3 of 4)

(Continued)

Table 12 (Concluded)

Species	Habitat Type-Occurrence						
	Marshlands	Lakes, Ponds	Rivers, Streams, Bayous	Swamps, Sloughs	Wooded Bottomland	Wooded Uplands	Grasslands, Shrublands, Open Terrain
Frogs and Toads (continued)							
Streckers chorus frog (*Pseudacris streckeri*)		+ (breeding ponds)		+	+	+	+
Eastern narrow-mouthed toad (*Gastrophryne carolinensis*)	+	+ (margins)		+ (borders)	+	+ (moist)	+ (moist)
Bullfrog (*Rana catesbeiana*)	+	+	+	+	+ (edge)		+ (edge)
Pig frog (*Rana grylio*)	+	+		+			
Bronze frog (*Rana clamitans*)	+	+	+	+	+		+ (edge)
Southern leopard frog (*Rana utricularia*)	+	+	+	+	+		+
Pickerel frog (*Rana palustris*)			+	+	+		+
Crawfish frog (*Rana areolata*)			+ (+ ditches)	+	+		+

(Sheet 4 of 4)

discussed by Clark (1978), who stated that their distribution and abundance were controlled by several major factors including wetland size and location, relationship to terrestrial and aquatic systems, flooding regime, water quality, substrate, and vegetation structure.

182. Clark (1978) provided a detailed review of the role of reptiles and amphibians in freshwater wetland habitats. Portions of that study are pertinent to bottomland habitats of the lower Mississippi Valley and are summarized as follows:

a. Frogs, toads, and salamanders may be somewhat terrestrial outside the breeding season but generally depend on water or moist ground for egg laying and maturation.

b. Ponds, bogs, marshes, swamps, or other areas of still-to-slowly moving water are essential for the success of frogs and all salamanders except those entirely adapted to living in moist soil or talus.

c. Bullfrogs (Rana catesbeiana) and green or bronze frogs (R. clamitans) are found in water or shore vegetation of permanently flooded wetlands during both breeding and nonbreeding seasons, but other members of the family Ranidae (e.g. leopard frogs, R. utricularia) are terrestrial except during the breeding season and are able to survive in moist depressions during dry periods.

d. Toads and tree frogs are also terrestrial or arboreal outside the breeding season but generally remain close to their breeding ponds and, therefore, require suitable habitat near flooded wetlands.

e. Many reptiles use freshwater wetlands for food and cover but move to the wetland edge or to drier land to deposit eggs.

f. The majority of wetland snakes are viviparous and are therefore less dependent on dry land.

g. Snapping turtles, mud and musk turtles, softshells, and some pond turtles are truly aquatic, leaving the water only to lay eggs, but other species such as box turtles (Terrepene spp.) are largely terrestrial and may enter water only to hibernate in the muddy bottom.

h. Lizards are rare in freshwater wetlands.

i. Skinks (Eumeces spp.) and anoles (Anolis carolinensis) occur in southern river swamps and floodplain forests but are also found in uplands.

j. Many snakes, including king snakes (*Lampropeltis* spp.) and rat snakes (*Elaphe* spp.), frequent wetlands but are not restricted to them.

k. Although the cottonmouth is common in wetlands, water snakes of the genus *Nerodia* are most important in terms of numbers and biomass.

l. Other common natricine snakes include the ribbon and garter snakes (*Thamnophis* spp.), queen snakes (*Regina* spp.), and mud snakes (*Farancia* spp.). Many snakes depend on wetlands for food such as fish, frogs, salamanders, and crayfish, but certain species are opportunistic in their feeding habits.

Clark (1978) additionally stressed the importance of aquatic and wetland herpetofauna as food organisms for widely valued wildlife.

183. Herpetofaunal studies dealing specifically with bottomland regions of the lower Mississippi Valley include those of Viosca (1923, 1928), Tinkle (1959), Keiser and Wilson (1969), Keiser (1971), and USDI (1974, 1976). Tinkle (1959) reported results of a study on herpetofaunal use of a cypress-gum swamp near New Orleans and found that richness of the fauna appeared dependent on ridges and adjacent shallow water (Table 13). According to Tinkle, microhabitats associated with the swamp were least productive, whereas ridges and marsh areas supported larger populations although they comprised a much smaller portion of the study area. Dominant plants on ridges were willow, red maple, baccharis, and blackberry. Tinkle also found a positive correlation between abundance of snakes and the amount of surface area covered by water. During dry periods, amphibians and reptiles accumulated around remaining waterholes where prey items such as frogs and small fish were concentrated. Use of the ridge for egg deposition was significantly greater than other areas for anoles and ground skinks (*Leiolopisma laterale*) (Tinkle 1959).

184. A survey of amphibians and reptiles of the Mississippi River floodplain from extreme southern Illinois to the mouth of the Mississippi River in Louisiana was conducted by Keiser (1971). The report was derived from a detailed literature search and from personal field experience by the author at floodplain localities in Illinois, Missouri, Kentucky, Tennessee, Mississippi, and Louisiana. Although the original

Table 13

Habitat Use by Certain Reptiles and Amphibians in a Cypress-Gum Swamp in Southern Louisiana (After Tinkle 1959)

Species**	Habitat-Numbers Observed* Pure Cypress-Gum	Ridge (Dominants = Black Willow, Red Maple, Baccharis, and Blackberry)	Purely Aquatic	Marsh
Western cottonmouth	25	23	6	19
Green anole	8	96	3	104
Yellow-bellied racer	--	16	--	--
Five-lined skink	2	53	--	1
Green treefrog	--	36	--	132
Speckled kingsnake	--	15	--	--
Eastern narrow-mouthed toad	--	78	--	2
Green water snake	--	--	12	6
Broad-banded water snake	3	6	25	12
Bronze frog	15	675	7	165
Western ribbon snake	2	180	8	31
Total	55	1178	61	472

* Entries are numbers observed during field visits, November 1953 to December 1954.

** Other species encountered on the refuge: American alligator, snapping turtle, mud turtle (Mississippi), mud snake (western), glossy water snake, rough green snake, red-eared turtle, three-toed amphiuma, Gulf Coast toad, bullfrog, eastern (three-toes) box turtle, ground skink, milk snake (Louisiana), northern cricket frog, squirrel treefrog, gray treefrog (*Hyla versicolor*), pig frog, and southern leopard frog.

study area was designated as only the interlevee floodplain, the literature search revealed that ecological information on amphibians and reptiles from localities between the levees was extremely rare. The survey was therefore modified to include all floodplain regions within the general vicinity of the levee system. Keiser listed over 100 species as occurring or potentially occurring in the study area, and approximately 50 species were shown to be common throughout much of the floodplain.

185. A detailed survey of the herpetofauna of the Atchafalaya Basin, Louisiana, was sponsored by the U. S. Fish and Wildlife Service (USDI 1974, 1975, 1976). Table 14 shows the actual or probable occurrence of species within bottomlands and swamplands of the basin (USDI 1974). The following specific comments were made regarding the preference of certain species for bottomland situations (USDI 1974): the marbled salamander (*Ambystoma opacum*) and small-mouthed salamander (*A. texanum*) were reported only from woodland situations where prolonged and frequent flooding did not occur; all frogs found within the basin, with the possible exception of the pig frog (*Rana grylio*), were widespread, occurred in a variety of habitats, and were found in considerable numbers; the alligator occurred in the basin in all wetland situations except for the levee, forbs and grasses complex, and bottomland forests rarely subject to flooding, but might be found as a transient in these habitats. USDI (1976) additionally provided data on reptiles and amphibians occurring in 20 specific habitats in the Atchafalaya Basin (Table 15). Numbers of species were greatest in the following habitats: bottomland forests rarely or incompletely flooded (61), levee and other forbs and grasses complexes (61), cottonwood-willow-sycamore (57), and cypress-tupelo habitats (51). Upland forests supported only 34 species (USDI 1976).

186. Impacts of flooding regime modifications. Few studies have been conducted on the effects of flooding or reduced water levels on herpetofauna of the lower Mississippi Valley region. Clark (1978) discussed generalized impacts of flooding on aquatic invertebrates, fish, reptiles, and amphibians and commented that seasonal or longer term successions of invertebrate and associated vertebrate communities were

Table 14

Reptiles and Amphibians Found in Woodland Habitat Types in the Atchafalaya River Basin (After USDI 1974)

Species	Habitat-Species Occurrence: Bottomland Forest Rarely Subject to Flooding	Seasonally Flooded Bottomland Forest	Wooded Swamplands
Snapping turtle	--	*	√
Stinkpot	√	√	√
Razor-backed musk turtle	--	--	*
Mud turtle (Mississippi race)	√	√	√
Eastern box turtle (Gulf Coast race)	√	*	--
Mississippi map turtle	--	*	*
Red-cased turtle	*	√	√
Missouri slider	--	√	√
Painted turtle (Southern race)	*	√	√
Spiny soft shell	--	--	*
Green anole	√	√	√
Ground skink	√	√	√
Five-lined skink	√	√	√
Broad-headed skink	√	√	√
Green water snake	√	√	√
Diamondback water snake	√	√	√
Yellow-bellied water snake	√	√	--
Broad-banded water snake	√	√	√
Graham's water snake	√	√	√
Glossy water snake	√	√	√
Brown snake	√	√	*
Red-bellied snake (Northern race)	√	√	--
Eastern garter snake	√	√	*
Western ribbon snake	√	√	√
Eastern hognose snake	√	√	*
Bingneck snake (Mississippi race)	*	*	--
Mud snake	√	√	√
Racer (Black-masked race)	√	√	√
Rough earth snake	√	√	√
Corn snake	*	*	--

(Continued)

* Indicates expected occurrence.

Table 14 (Concluded)

Species	Habitat-Species Occurrence: Bottomland Forest Rarely Subject to Flooding	Seasonally Flooded Bottomland Forest	Wooded Swamplands
Rat snake (Texas race)	✓	✓	✓
Speckled king snake	✓	✓	✓
Milk snake (Louisiana race)	✓	*	—
Copperhead (Southern race)	✓	✓	*
Western cottonmouth	✓	✓	✓
Canebreak rattlesnake	✓	*	—
Three-toed amphiuma	✓	✓	✓
Lesser siren (Western race)	*	✓	✓
Marbled salamander	✓	*	—
Small-mouthed salamander	✓	*	—
Central newt	✓	✓	✓
Dusky salamander	*	*	—
Dwarf salamander	*	*	*
Fowler's toad	✓	✓	✓
Gulf Coast toad	✓	✓	*
Northern cricket frog	✓	✓	*
Spring peeper (Northern race)	✓	✓	*
Green treefrog	✓	✓	✓
Squirrel treefrog	✓	—	✓
Gray treefrog (*Hyla versicolor*)	✓	✓	✓
Upland Chorus frog	✓	✓	✓
Eastern narrow-mouthed toad	✓	✓	✓
Bullfrog	—	✓	✓
Bronze frog	✓	✓	✓
Southern leopard frog	✓	✓	✓

Table 15

Occurrence of Reptiles and Amphibians in Specific Habitats in the Atchafalaya River Basin (From USDI 1976)

Habitat	Crocodilians	Turtles	Lizards	Snakes	Salamanders	Frogs and Toads	Total
Cottonwood-willow-sycamore	1*	13	4	21	6	12	57
Cypress-tupelo	1	12	4	16	5	13	51
Bottomland forests (rarely or incompletely flooded)	1	13	4	23	8	12	61
Upland forests	1	2	4	14	1	12	34
Levee and other forbs and grasses complexes	1	12	4	24	7	13	61
Sandbars	1	13	2	11	--	9	36
Mud flats	1	13	1	10	2	9	36
Treeless ridges and spoil banks	1	13	2	15	2	9	42
Bays	1	3	--	6	--	4	14
Tidal ditches	1	4	--	8	2	8	23
Freshwater marshes	1	8	2	14	3	10	38
Atchafalaya River	1	11	--	7	1	5	25
Bayous	1	14	--	9	3	9	36
Canals	1	14	--	9	3	8	35
Shallow woodland streams	1	11	--	10	5	8	35
Shallow woodland pools	1	6	--	11	8	12	38
Shallow nonwoodland pools	1	7	--	13	5	13	39
Ponds (land-isolated)	1	8	--	10	3	13	35
Freshwater lakes	1	9	--	10	3	8	31
Floating hyacinth mats	1	11	--	11	3	11	37

* Expected number of species.

closely related to fluctuations in wetland water levels. Decreasing water levels were said to possibly initiate dormancy of some aquatic snakes and salamanders in southern river swamps (Clark 1978). Guidelines for managing water levels for reptiles and amphibians were prepared by USDI (1976) for the Atchafalaya River Basin. Information in that report is of considerable pertinence to the entire lower Mississippi Valley study area and is therefore summarized below (refer to Table 12 for scientific names of species mentioned):

a. Excessive high waters during May, June, July, and August may reduce the number of oviposition sites available to reptiles, and flooding during this period may inundate and destroy nesting sites. The influx of high waters into areas utilized for nesting should therefore be avoided from May through August.

b. Management procedures that tend to reduce the amount and extent of annual flooding may ultimately result in range extensions and population increases for the following species (providing that forestation and succession continue and the land is not converted to farming operations): marbled and small-mouthed salamanders, dusky salamanders, dwarf salamander, spring peeper, upland chorus frog, broad-headed skink, copperhead, canebrake rattlesnake, ringneck snake, corn snake, eastern hognose snake, milk snake, pygmy rattlesnake, midland brown snake, red-bellied snake, eastern garter snake, rough earth snake, and eastern box turtle.

c. Diminishing the basin's water regime can generally be expected to be detrimental to most species because it will allow human exploitation of habitats without the interference of swamps and other wetland conditions. The loss of surface water will be directly detrimental to those species dependent upon such waters for their existence. If, however, forest succession is allowed to continue as swamplands dry up, and if increased human activities and construction are not allowed, then most species listed in paragraph b. might eventually expand their ranges into the former swamplands. However, if annual flooding is still permitted, it is expected that these would expand their ranges only into areas where high ground refuges are abundant.

d. If the basin water regime is diminished and if a system of control structures is not installed, then it is expected that deleterious impacts will occur to populations of the following species: three-toed amphiuma, lesser siren, central newt, all turtles except box turtles and the diamondback terrapin, northern cricket frog, green treefrog, bullfrog, pig frog, alligator, western cottonmouth, green water snake, yellow-bellied water snake, broad-banded (Gulf salt marsh) water snake, diamond-backed water snake, Graham's water snake, and glossy water snake.

e. Unless the water levels are lowered considerably, drastic declines in populations of the above species are not expected, and detrimental impacts could be minimized with the design and operation of proper control structures. Dredging would destroy sandbars and peripheral sites where many species deposit their eggs.

187. Other appropriate management guidelines suggested in USDI (1976) included developing and maintaining a levee-base buffer zone on most basin levees; minimizing mowing operations (limited to September and October); restricting removal of logs and debris; avoiding use of iron pilings; controlling removal of timber; creating wilderness areas; restricting construction of paved roads; avoiding use of herbicides, pesticides, and other toxins; and protecting turtle nesting sites such as levees and sandbars.

188. In summary, reduction in the frequency and duration of flooding could result in range extensions and population increases for several species of salamanders, box turtles, lizards, and more terrestrial species of snakes. Reduction of extensive flooding and high waters from May through August would be especially beneficial to certain species by preventing inundation of egg deposition sites. Reduced flooding, however, would be detrimental to aquatic and semiaquatic species such as sirens, frogs and toads, most turtles, alligators, and natricine snakes. Lowered water levels during the breeding season would be especially harmful to many species of amphibians.

PART V: SUMMARY

189. Historically, the principal impact of flood reduction on lower Mississippi Valley bottomland hardwood wildlife has been elimination of forested habitat through facilitation of conversion to row crops. A related impact is the reduction of overall habitat diversity; that is, land-clearing has resulted in large-scale losses of infrequently flooded forest types such that remaining forests are primarily the regularly flooded types in batture lands and sumps.

190. Plant species composition of bottomland forests is controlled largely by flooding, and tree species tolerances to flooding are fairly well known. Flood tolerances of understory species have not been well documented. Forest structure also appears to be related to flooding regime. In general, perennial understory productivity and diversity and overstory diversity are lowest in near-permanently flooded habitats and increase in areas flooded less frequently and for shorter periods. Values of these community attributes may be somewhat lower in nonflooded areas than in infrequently flooded areas, but this relationship is not consistently reported. These patterns of variation may be overridden by the effects of other influences, particularly timber harvesting.

191. A reduction in flooding may be expected to reduce tree growth if available moisture is reduced during the growing season. Mature trees will not generally suffer mortality due to flood reduction, although this may occur where the effects of severe drought are intensified by land drainage. Flood reduction will generally result in a gradual change to a drier forest type, with its attendant compositional and structural characteristics.

192. Drastic increases in seasonal flooding may cause severe tree mortality within a decade or less, particularly in drier forests not adapted to regular inundation or prolonged saturation. Minor increases in flooding may also cause mortality, but in bottomland forests such increases will generally result in a slow shift in species composition to a wetter character. Increases in flood depth or siltation may compound community stress, particularly affecting understory plants and

tree seedlings. Individual severe flooding events will probably affect community structure, but recovery is rapid if overstory trees are not killed. If increases in flooding increase the available water supply without causing plant stress, tree growth may be enhanced.

193. Imposition of dormant-season (greentree reservoir) flooding appears to cause a gradual shift to a wetter species composition, and there is a danger of significant tree mortality or stress-related disease problems if recommended flooding schedules are not strictly adhered to. Studies suggest that production of sound, fully developed acorns is neither stimulated nor depressed by dormant-season flooding. Short-term studies indicate that tree growth is improved with increased dormant-season flooding, but results of longer term studies suggest that species respond differentially, with a significant reduction in growth evident in some cases.

194. Prediction of eventual plant community composition and structure following flooding regime alteration is complex. Changes in flooding may impact the existing plant community and influence the development of succeeding communities in predictable ways, but other factors may be of equal or overriding importance in determining eventual community characteristics. Light availability will have a great influence on understory density and diversity and is related to timber harvesting and stand management. Forest management may also be of primary importance in determining canopy structure and composition and therefore mast production. Other factors affecting rate and direction of stand development include initial stand condition, distance to seed sources, length of growing season, and soil characteristics. Thus, prediction of plant community change following flood alteration should be site-specific and incorporate considerations other than flooding effects.

195. Bottomland hardwoods of the lower Mississippi Valley are considered highly productive wildlife habitat due to high soil fertility, abundant moisture, abundance and quality of wildlife foods--especially mast, good escape cover, low incidence of fire, and general accessibility to agricultural food crops. Diversity of vegetation, especially in regard to food supply, is considered extremely important to most

species of wildlife in bottomland hardwoods. Certain species are known to make seasonal shifts into different hardwood zones to forage, to escape flooding, or to hibernate.

196. Modifications to bottomland hardwoods known to affect wildlife populations include logging, burning, grazing, flood control, ditching, construction and management of greentree reservoirs, beaver activity, and agriculture. Modifications in the magnitude, frequency, and duration of flooding will bring about a wide variety of impacts to different species depending on their ability to tolerate both direct and indirect changes in the flooding regime.

197. Approximately 70 species of mammals have been reported from the lower Mississippi Valley region, the majority of which occur in a variety of habitats. Several species, however, have a definite preference for bottomland forests and wooded swamps. Principal game and commercial mammals of bottomland hardwoods include the swamp rabbit, eastern cottontail, raccoon, mink, river otter, bobcat, and white-tailed deer. The beaver and river otter are considered the most aquatic mammals of lowland hardwood systems in the study area. Channelization is generally considered detrimental to these species because of the removal of streamside vegetation and resulting deterioration of habitat quality. The beaver, muskrat, mink, and river otter are especially affected by channelization but will apparently repopulate old channelized regions following the return of riparian vegetation and improved water quality.

198. The swamp rabbit is a resident of lowland hardwoods and marshlands and is expected to be detrimentally affected by significant reductions in water levels. Intense flooding may temporarily eliminate local populations, but the long-term effects of flooding could provide benefits by creating openings and downed timber which are highly used by the species. Reduced flooding of bottomlands could bring about invasion of swamp rabbit habitat and resultant competition for food and cover by the cottontail which uses similar resources but prefers drier sites. This shift of species should not appreciably affect total rabbit numbers but could eliminate local populations of the swamp rabbit.

199. Reduced water levels should be generally beneficial to

cottontails provided that adequate food and cover remain available. Inundation of bottomland hardwoods is considered detrimental to local populations during flood periods, but long-term production is not generally affected because of the conttontail's high reproductive potential and generally adequate brood stock in adjacent uplands.

200. Both the gray squirrel and fox squirrel occur in a variety of forested habitats with an adequate supply of mast-producing trees and den sites. Many studies, however, have shown that bottomland hardwoods provide optimum habitat, especially for the gray squirrel. Normal flooding appears to have insignificant effects on squirrel populations, but temporary shifts to upland sites are known to occur during flood periods. Reduced flooding of bottomlands followed by land clearing would be highly detrimental to both gray and fox squirrels. Where clearing does not occur with reduced flooding, squirrel populations will be most affected by changes in the abundance and diversity of mast-producing vegetation. Several studies have shown that the greatest overstory richness and diversity in bottomland hardwoods occur in infrequently flooded zones compared with frequently flooded areas. Squirrel populations are, therefore, expected to be more stable in infrequently flooded zones and could benefit from decreased flooding of frequently inundated sites. It is possible, however, that reduced flooding throughout a site could produce a more homogeneous forest cover, thus decreasing overall community diversity. An increase in herbaceous ground cover could be detrimental to fox squirrels.

201. The beaver is especially dependent upon flooded timberland and will be adversely affected by decreased flooding and conversion of bottomland hardwoods to drier plant communities. Populations of the muskrat will also be impacted by significant reductions in water levels, but the species is also adversely affected by heavy seasonal flooding.

202. The opossum occurs commonly in seasonally flooded hardwoods but is adversely affected by heavy flooding. Reduced flooding could be beneficial to the species by decreasing the incidence of flooding at terrestrial den sites and by increasing habitat for ground-dwelling insects and other food items.

203. The raccoon occurs in a variety of habitats but is apparently most abundant in swamps, marshes, and bottomland hardwoods. Drying out of bottomland hardwoods through reduced flooding is expected to have an adverse impact on raccoon populations, especially where a reduction in aquatic food items occurs.

204. Reduced flooding in bottomland hardwoods is expected to be highly detrimental to minks and river otter because of their high preference for wetland habitats. These species are critically dependent on the availability of aquatic and semiaquatic foods such as fish, crayfish, mollusks, and aquatic insects.

205. Little information appears available on the effects of flooding regime modifications to the bobcat, but it is expected that reduced flooding in itself would have little impact on local populations. Normal flooding probably brings about only temporary impacts because of the mobility of the species.

206. The white-tailed deer is common in a variety of habitats, but numerous studies have shown that bottomland hardwoods are capable of supporting higher populations per unit area than adjacent uplands. This apparent preference for wooded bottomlands indicates that deer are not detrimentally affected by normal flooding cycles. Several studies have shown that prolonged flooding during the growing season could affect deer populations by limiting the availability and diversity of forage plants. Therefore, reduced flooding in near-permanently inundated bottomlands could improve habitat for deer by bringing about an increase in the diversity and density of understory food plants (assuming mast production is not reduced).

207. Upland furbearers occasionally found in bottomland hardwoods include the coyote, red fox, gray fox, striped skunk, and eastern spotted skunk. These species, however, prefer upland sites and would be beneficially affected by reduced flooding. Flooding is known to limit areas suitable for ground dens for terrestrial species such as skunks and foxes.

208. Nongame mammals with a decided preference for wooded bottomlands are the southeastern shrew, white-footed mouse, cotton mouse,

golden mouse, and eastern woodrat. Numerous other species have been reported from bottomlands but are equally common or more abundant in upland habitats. Several studies have shown that the density and diversity of small mammals are greater on well-drained sites with abundant ground cover compared to periodically inundated bottomland forests. However, bottomland hardwoods and adjacent upland forests may support similar population densities for certain species.

209. The majority of studies dealing with effects of flooding on small mammals showed that short-term flooding (approximately 1 week) was not detrimental to most species, but severe flooding for prolonged periods was highly detrimental to both terrestrial and arboreal species. Lower elevations in bottomland hardwoods are subject to longer periods of inundation and generally support unstable populations of small mammals. Reduced flooding is expected to bring about a greater diversity of small mammals but may not increase densities. Reduced flooding will also lessen the frequency of severe flood conditions and will therefore be beneficial to populations occurring in the lowest elevations of bottomland hardwoods.

210. Approximately 100 species of birds use bottomland hardwood forests in the lower Mississippi River Valley as breeding and wintering habitat. The principal game birds occurring here are the wood duck, mallard, wild turkey, hooded merganser, and American woodcock.

211. Wood ducks and mallards seldom feed on hardwood mast in dry woods, and the elimination of fall and winter flooding would eliminate a food source for wintering populations of these species. Drainage and flood control would have a detrimental effect on wood duck production. The reduced availability of aquatic invertebrate populations in late winter and early spring would reduce the overall supply of proteins and amino acids needed by the hen for successful nesting. The direct elimination of brood habitat and wetland complexes through drainage and reduced flooding would increase brood mortality.

212. With their dependence on aquatic foods, any decrease in water coverage by drainage or reduced flooding would eliminate hooded merganser habitat. Any reduction in hooded merganser habitat in the lower

Mississippi River Valley would be likely to have a detrimental impact on the total species population.

213. Very few wild turkeys are lost directly as a result of winter and spring floods. Flooding results in a temporary loss of a food source, and if the water remains high until late spring, nesting success may decline. Turkeys are apparently adapted to the periodic flooding conditions found in bottomland hardwood forests as these forests will support high turkey populations.

214. Woodcock appear to be adapted to a moist habitat, and any changes to drier or wetter conditions may be detrimental. Woodcock depend heavily on earthworms for food, and any reduction of earthworm populations or availability caused by drier soil conditions would ultimately be detrimental. An increase in flooding may be detrimental to woodcock through the direct elimination of feeding areas and inundation of nests and through reductions in earthworm populations and brushy understory vegetation used as cover.

215. Bird populations in a forest stand are influenced by the number of vertical foliage layers, total foliage volume, foliage density near the ground, overstory hardwood/conifer mixture, habitat patchiness, successional stage of the stand, and soil moisture conditions. Generally, an increase in the structural complexity of the vegetation results in higher bird species diversity. Under conditions of prolonged flooding and with standing water in swamps, the foliage layers near the ground are virtually eliminated and the numbers of ground nesting and foraging birds are reduced. However, periodic dormant-season floods with occasional growing-season floods appear to maintain good vegetational structure, desirable habitat patchiness, and relatively high breeding and wintering bird populations. No immediate significant differences in nongame bird populations as a result of a reduction in flooding were noted. The long-term effects of reduced flooding on nongame bird populations in bottomland hardwoods stands are not known.

216. Reduced flooding could result in range extension and population increases for box turtles, lizards, and several species of snakes and salamanders, providing that the land is not cleared and converted to

farming operations. Reduction of extensive flooding and high waters from May through August would be especially beneficial to certain species by preventing the inundation of terrestrial egg deposition sites.

217. Reduced flooding would be detrimental to aquatic and semi-aquatic reptiles and amphibians such as sirens, frogs, most turtles, alligators, and water snakes. Lowered water levels during the reproductive season would be especially harmful to frogs and toads by reducing breeding ponds and backwater areas.

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APPENDIX A: SUMMARY OF FLOOD TOLERANCE RESEARCH, LOWER MISSISSIPPI VALLEY, FROM WHITLOW AND HARRIS (1979)

Table A1
Data Summary, Lower Mississippi Valley Division

		Conditions						
		Depth cm						
Species	**Experimental method**	**Over root crown or as noted**	**Over terminal bud**	**Duration: consecutive days or as noted**	**No. of plants**	**No. or % survival**	**Comments**	**Authority**
Acer negundo Box elder	Greenhouse study, current year seedlings 7.6 cm high, 3/pot flooded in July and August	50.8	43.2	2	3	3	No injury	Hosner, 1958
		50.8	43.2	4	3	3	Leaves slightly chlorotic, slow recovery	
		50.8	43.2	8	3	3	Leaves moderately chlorotic, terminal buds died on 2 plants; slow recovery	
		50.8	43.2	16	3	1	Terminal bud on survivor was dead	
		50.8	43.2	32	3	0		
	Greenhouse study, current year seedlings 16.5 cm tall, 5/pot flooded 14 Jul-21 Aug; 60 day recovery period after drainage.	61	-	5	15	15	All recovered rapidly	Hosner, 1960
		61	-	10	15	15	All recovered rapidly	
		61	-	20	15	15	Recovery moderately fast	
		61	-	30	15	14	4 survivors lost terminals; recovery moderately fast	
	Greenhouse study, current seedlings 5/pot, established as natural seed became available; only 60-day data presented.	2.5	-	60	15	15	No significant height difference between treatment and control	Hosner and Boyce, 1962

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Acer negundo Boxelder	Study of tree mortality following the creation of a reservoir behind Alton Dam in southern Illinois. Permanent transects sampled at intervals over a 4-yr period. Sample stratified according to location, land, mud, or water.	land	-	240	20	100%		Yeager 1949
		mud	-	240	0	-		
		water	-	240	0	-		
		land	-	730	20	100%		
		mud	-	730	0	-		
		water	-	730	0	-		
		land	-	1460	20	100%		
		mud	-	1460	0	-		
		water	-	1460	0	-		
	Correlated flood frequency and duration in the lower White River valley, Ark., with forest composition.	-	-	29-40% of time	0	-		Bedinger 1971
		-	-	10-21% of time	5	-		
		-	-	once every 2-8 yrs	0	-		
	Study of tree mortality during flood surcharge at Rend Lk. and Lk. Shelbyville in Illinois during 1973 growing season.	-	-	149	6	6	Ranked as tolerant by authors; able to withstand more than 150 days of flooding. Mature trees sampled.	Bell and Johnson 1974
		-	-	189	6	6		

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Acer negundo Boxelder	Sapling survival observed in a hardwood forest along the Mississippi River in La. before and after flooding during the 1973 growing season.	240-480	-	105 (116 max.)	-	-	A. negundo comprised 1.2% of understory cover before flood and 1.0% of cover after flood. Saplings generally able to recover.	Noble and Murphy 1975
Acer rubrum Red maple	Greenhouse study, 8-day-old seedlings 5/pot; soil kept saturated.	.64 below root crown	-	1-32	20	20	Growth retarded by all treatments except 4 day.	McDermott 1954
	Greenhouse study; current year seedlings 9.9 cm tall, 5/pot flooded 14 Jul-21 Aug; 60-day recovery period after drainage.	61	-	5	15	15	Recovery rapid.	Hosner 1960
		61	-	10	15	14	Moderately rapid recovery.	
		61	-	20	15	0		
	Greenhouse study; current year seedlings, 5/pot, established as natural seed because available; only 60 day data presented.	2.5 cm	-	60	15	15	No shoot mortality, many adventitious roots; non-adventitious roots went dormant but recovered rapidly; authors rank as intolerant.	Hosner and Boyce 1962

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Acer rubrum Red maple	Controlled field experiment, & natural stands in Mississippi Delta flooded Feb-Jul for 4 years to ascertain effect on growth.	90, max.	-	210	3	-	Trees of timber and pole size; 85% radial growth increase over control.	Broadfoot 1967
	Correlated flood frequency and duration in the lower White River valley, Ark., with forest composition.	-	-	29-40% of time	1	-		Bedinger 1971
		-	-	10-21% of time	10	-		
		-	-	once every 2-8 yrs	7	-		
Acer rubrum var. drummondii Red maple	Ecological study of a bald cypress-water tupelo swamp site flooded each spring, with soil remaining saturated for duration of year.	15-30	-	90	-	-	Importance value of 3.09, where IV = relative frequency and relative density and relative dominance. Species increases IV after bald cypress are logged.	Connor and Day 1976

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Acer saccharinum Silver maple	Greenhouse study, current year seedlings 7.6 cm high, 3/pot flooded in July and August.	50.8	43.2	2	3	3	Lower wilted; slow recovery.	Hosner 1958
		50.8	43.2	4	3	0	Seedlings had low initial vigor possibly accounting for low survival.	
		50.8	43.2	8	3	0		
		50.8	43.2	16	3	0		
		50.8	43.2	32	3	0		
	Greenhouse study; current year seedlings 3.15 cm tall, 5/pot flooded 14 Jul-21 Aug; 60-day recovery period after drainage.	61	58	5	15	15	Rapid recovery.	Hosner 1960
		61	58	10	15	15	Rapid recovery.	
		61	58	20	15	15	Rapid recovery.	
		61	58	30	15	15	2 lost terminals; rapid recovery.	
	Greenhouse study; current year seedlings, 5/pot established as natural seed became available; only 60 day data presented here.	2.5 cm	-	60	15	15	No shoot mortality; many adventitious roots; non-adventitious roots dormant and alive; ranked as intolerant by authors.	Hosner and Boyce 1962

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Acer saccharinum Silver maple	Study of tree mortality following the creation of a reservoir behind Alton Dam in southern Illinois. Permanent transects sampled at intervals over a 4-yr period. Sample grouped according to location: land, mud, or water.	land	-	240	216	98%		Yeager 1949
		mud	-	240	55	100%		
		water	-	240	177	66%		
		land	-	730	216	96%		
		mud	-	730	55	80%		
		water	-	730	177	1%		
		land	-	1460	216	95%	Water depth and dbh* had no effect on 920 day survival (*diameter breast height).	
		mud	-	1460	55	64%		
		water	-	1460	177	0%		
	Study of tree mortality during flood surcharge at Rend Lk. and Lk. Shelbyville in Illinois during 1973.	-	-	149	39	39	Data not provided for other durations of flooding. Ranked as tolerant by authors.	Bell and Johnson 1974
Alnus rugosa Hazel Alder	Greenhouse study, 8-day seedlings, 5/pot, soil kept saturated.	.64	-	1-32	20/trt	20	60% mortality in 8 day treatment. NSD among other treatments.	McDermott 1954

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Betula nigra River birch	Study of tree mortality following the creation of a reservoir behind Alton Dam in S. Illinois. Permanent transects sampled at intervals over a 4-yr period. Samples grouped according to location: land, mud, water.	land	-	240	4	100%		Yeager 1949
		mud	-	240	2	100%		
		water	-	240	17	77%		
		land	-	730	4	100%		
		mud	-	730	2	100%		
		water	-	730	17	0%		
		land	-	1460	4	100%		
		mud	-	1460	2	100%		
		water	-	1460	17	0%		
	Greenhouse study, 8-day-old seedlings 5/pot, soil kept saturated.	.64	-	1-32	20	20	All treatments except 1 day caused stunting.	McDermott 1954
Carpinus caroliniana Ironwood	Correlated flood frequency and duration in the lower White River valley, Ark., with forest composition.	-	-	29-40%	1	-		Bedinger 1971
		-	-	10-21%	19	-		
		-	-	once every 2-8 yrs	3	-		

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Carya aquatica Water hickory	Controlled field experiment, 8 natural stands in Miss. Delta flooded Feb-Jul for 4 years to ascertain effect on growth.	90, max	-	210	15		Trees of timber & pole size, 45% radial growth increase over control.	Broadfoot 1967
	Correlated flood frequency and duration in the lower White River valley, Ark., with forest composition.			29-40% of time	120	-		Bedinger 1971
				10-21% of time	70	-		
				once every 2-8 yrs	0	-		
Carya cordiformis Bitternut hickory	Correlated flood frequency and duration in the lower White River valley, Ark., with forest composition.			29-40%	0	-		Bedinger 1971
				10-21% of time	0	-		
				once every 2-8 yrs	9	-		
Carya illinoensis Pecan	Study of tree mortality following the creation of a reservoir behind Alton Dam in S. Illinois. Permanent transects sampled at intervals over a 4-yr pd. Samples grouped according to location: land, mud, water.	land	-	240	46	100%		Yeager 1949
		mud	-	"	2	100%		
		water	-	"	26	77%		

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Carya illinoensis Pecan		land	-	730	46	100%		
		mud	-	730	2	100%		
		water	-	730	26	11%		
		land	-	1460	46	100%		
		mud	-	1460	2	0%		
		water	-	1460	26	0%		
	Report of impacts of 1973 flood during spring & early summer on 1-yr-old plantation in Mississippi.	198 max.	-	60	-	-	Trees had not leafed out when first flooded; maximum water depth occurred on 15 May. Plantation survived flood.	Kennedy and Krinard 1974
	Sapling survival observed in a hardwood forest along the Mississippi River in La. before and after flooding during 1973 growing season.	243-488	-	105	-	-	Saplings were either killed or growth severely retarded.	Noble and Murphy 1975

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Carya laciniosa								
Shellbark hickory	Correlated flood frequency and duration in the lower White River valley, Ark., with forest composition.	-	-	29-40% of time	0	-		Bedinger 1971
				10-21%	0	-		
				once every 2-8 yrs	9			
Carya ovata	Same as above	-	-	29-40%	0	-		Bedinger 1971
Shagbark hickory				10-21% of time	0	-		
				once every 2-8 yrs	38			
	Study of tree mortality during flood surcharge at Rend Lk. and Lk. Shelbyville in Illinois during 1973 growing season.	-	-	50	114	100%	Same trees observed throughout study. Authors described as somewhat tolerant.	Bell and Johnson 1974
				109	114	57%		
				149	114	56%		
				189	114	38%		
Carya tomentosa	Correlated flood frequency and duration in the lower White River valley, Ark., with forest composition.	-	-	29-40% of time	0	-		Bedinger 1971
Mockernut hickory				10-21% of time	0	-		
				once every 2-8 yrs	53	-		

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Carya tomentosa Mockernut hickory	Study of tree mortality during flood surcharge at Rend Lk. & Lk. Shelbyville in Illinois during 1973 growing season.	-	-	50	47	100%	Ranked as slightly tolerant by authors, able to survive 50-100 days of flooding.	Bell and Johnson 1974
				109	47	35%		
				149	47	0%		
				189	47	0%		
Celtis laevigata Sugarberry	Greenhouse study; current yr seedlings, 15/pot, established as natural seed became available; only 60 day data presented here.	2.5	-	60	15	-	7% shoot mortality, no adventitious roots, all other roots dead except primary.	Hosner and Boyce 1962
	Correlated flood frequency and duration in the lower White River valley, Ark., with forest composition.	-	-	29-40% of time	84	-		Bedinger 1971
				10-21% of time	181	-		
				once every 2-8 yrs	19	-		
Celtis occidentalis Hackberry	Greenhouse study; current year seedlings, 5/pot.	.64	-	38	5	0%	All plants dead in in three wks; no sprouting or signs of recovery.	Hosner 1959

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Celtis occidentalis Hackberry	Greenhouse study; current year seedlings 22 cm tall, 5/pot flooded 14 July-Aug 21; 60-day recovery period after drainage.	61	58	5	15	14	4 lost terminals recovered slowly.	Hosner 1960
		61	58	10	15	1	survivor developed a weak sprout.	
		61	58	20	15	0		
		61	58	30	15	0		
	Greenhouse study; current year seedlings, 5/pot. established as natural seed became available; only 60 day data presented here.	2.5	-	60	15	-	20% shoot dieback after removal from flood tank; sparse adventitious rooting some secondary roots killed.	Hosner and Boyce 1962
	Study of tree mortality following the creation of a reservoir behind Alton Dam in S. Illinois. Permanent transects sampled at intervals over a 4-yr period. Samples grouped according to location: land, mud, water.	land	-	240	45	100%		Yeager 1949
		mud	-	240	3	100%		
		water	-	240	3	66%		
		land	-	730	45	96%		
		mud	-	730	3	66%		
		water	-	730	3	0%		

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Celtis occidentalis		land	-	1460	45	96%		Yeager 1949
Hackberry		mud	-	1460	3	32%		
		water	-	1460	3	0%		
	Controlled field experiment; 8 natural stands in Miss. Delta flooded Feb-Jul for 4 yrs to assess effect on growth.	90, max	-	210	21	-	Trees of timber and pole size; 45% increase in radial growth over controls.	Broadfoot 1967
	Study of tree mortality during flood surcharge at Rend Lk. and Lk. Shelbyville in Ill. during 1973 growing season.	-	-	49	37	100%	Note increased mortality as flooding extends into growing season.	Bell and Johnson 1974
				109	37	100%		
				149	37	55%		
				189	37	0%		
Cephalanthus occidentalis	Greenhouse study, current year seedlings, 12.7 cm tall, 5/pot. Flooded 14 Jul-21 Aug. 60-day recovery period after drainage.	61	48	5	15	15	Rapid recovery.	Hosner 1960
Buttonbush		61	48	10	15	15	Rapid recovery.	
		61	48	20	15	15	Rapid recovery.	
		61	48	30	15	15	2 lost terminals; Rapid recovery.	

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Cephalanthus occidentalis Buttonbush	Study of tree mortality following the creation of a reservoir behind Alton Dam in S. Ill. Permanent transects sampled at intervals over a 4-yr period. Samples grouped by location: land, *mud*, water.	land	-	240	0	-		Yeager 1949
		mud	-	240	0	-		
		water	-	240	15	80%		
		land	-	730	0	-		
		mud	-	730	0	-		
		water	-	730	15	47%		
		land	-	1460	0	-		
		mud	-	1460	0	-		
		water	-	1460	15	40%		
	Ecological study of a baldcypress - water tupelo swamp; site flooded each spring, with soil remaining saturated for duration of year.	15 - 30		90			Importance value= 1.71 where IV = relative frequency + relative density + relative dominance. Ranked above *Salix nigra* at IV= .88.	Conner and Day 1976

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Cercis canadensis Redbud	Study of tree mortality following the creation of a reservoir behind Alton Dam in S. Ill. Permanent transects sampled at intervals over a 4-yr period. Samples grouped by location: land, mud, water.	land	-	240	1	100%		Yeager 1949
		mud	-	240	0	0		
		water	-	240	0	0		
		land	-	730	1	100%		
		mud	-	730	0	0		
		water	-	730	0	0		
		land	-	1460	1	100%		
		mud	-	1460	0	0		
		water	-	1460	0	0		
	Correlated flood frequency and duration in the lower White River valley, Ark., with forest composition.			29-40% of time	0			Bedinger 1971
				10-21% of time	0			
				once every 2-8 yrs	5			

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Cornus florida Flowering dogwood	Study of tree mortality behind Alton Dam in S. Ill. Permanent transects sampled at intervals over a 4-yr period. Samples grouped by location: land, mud, water.	land	-	240	2	100%		Yeager 1949
		mud	-	240	0	-		
		water	-	240	0	-		
		land	-	730	2	100%		
		mud	-	730	0	-		
		water	-	730	0	-		
		land	-	1460	2	100%		
		mud	-	1460	0	-		
		water	-	1460	0	-		
	Correlated flood frequency and duration in the lower White River valley, Ark., with forest composition.	-	-	29-40% of time	0	-		Bedinger 1971
		-	-	10-21% of time	0	-		
		-	-	once every 2-8	8	-		

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Crataegus mollis Hawthorn	Study of tree mortality during flood surcharge at Rend Lk. and Lk. Shelbyville in Ill. during 1973 growing season.	-	-	149	6	6		Bell and Johnson 1974
Crataegus spp. Hawthorn	Study of tree mortality upstream from Alton Dam in S. Ill. Permanent transects sampled at intervals over a 4-yr period. Samples grouped by location: land, mud, water.	land	-	240	17	88%	A taxonomically complex genus which undoubtedly displays a range of flood tolerance.	Yeager 1949
		mud	-	240	4	100%		
		water	-	240	16	44%		
		land	-	730	17	88%		
		mud	-	730	4	25%		
		water	-	730	16	19%		
		land	-	1460	17	88%		
		mud	-	1460	4	25%		
		water	-	1460	16	0%		
	Correlated flood frequency and duration in the lower White River valley, Ark., with forest composition.	-	-	29-40% of time	1	-		Bedinger, 1971

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Crataegus spp.		-	-	10-21% of time	17	-		Bedinger 1971
Hawthorn		-	-	once every 2-8 yrs	2	-		
Diospyros virginiana	Study of tree mortality upstream from *Alton Dam* in S. Ill. Permanent transects sampled at intervals over a 4-yr period. Samples grouped by location: land, mud, water.	land	-	240	27	96%		Yeager 1949
		mud	-	240	5	100%		
Persimmon		water	-	240	35	67%		
		land	-	730	27	96%		
		mud	-	730	5	100%		
		water	-	730	35	0%		
		land	-	1460	27	96%		
		mud	-	1460	5	20%		
		water	-	1460	35	0%		

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Diospyros virginiana Persimmon	Controlled field experiment, 8 natural stands in Miss. Delta flooded Feb-Jul for 4 yrs to assess effect on growth.	90, max.	-	210	/	-	10% radial growth increase over control; timber and pole size trees.	Broadfoot 1967
	Observations of tree mortality in Miss. stand flooded for 4 yrs.	<30	-	1460	-	0	All trees died by end of second growing season.	Broadfoot and Williston 1973
	Correlated flood frequency and duration in the lower White River valley, Ark., with forest composition.	-	-	29-40% of time	7	-		Bedinger 1971
		-	-	10-21% of time	44	-		
		-	-	once every 2-8 yrs	5	-		
	Study of tree mortality during flood surcharge at Rend Lk. and Lk. Shelbyville in Ill. during 1973 growing season.	-	-	100	5	5		Bell and Johnson 1974

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Forestiera acuminata Water privet	Study of tree mortality upstream from Alton Dam in S. Ill. Permanent transects sampled at intervals over a 4-year period. Samples grouped by location: land, mud, water.	land	-	240	18	100%		Yeager 1949
		mud	-	240	5	100%		
		water	-	240	47	68%		
		land	-	730	18	100%		
		mud	-	730	5	100%		
		water	-	730	47	30%		
		land	-	1460	18	100%	Survivors all found in < 102 cm water; 15% survival after 2555 days.	
		mud	-	1460	5	100%		
		water	-	1460	47	17%		
Fraxinus americana White ash	Study of the mortality upstream from Alton Dam in S. Ill. Permanent transects sampled at intervals over a 4-yr period. Samples grouped by location: land, mud, water.	land	-	240	59	100%		Yeager 1949
		mud	-	240	18	100%		
		water	-	240	31	97%		
		land	-	730	59	100%		
		mud	-	730	18	100%		
		water	-	730	31	61%		
		land	-	1460	59	100%	Survivors in 51 cm water; 7% survival after 2555 days.	
		mud	-	1460	18	73%		
		water	-	1460	31	29%		

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Fraxinus pennsylvanica Green ash	Greenhouse study; current year seedlings, 7.6 cm tall, 3/pot flooded in July and August.	51	43	2	3	3	No effect.	Hosner 1958
		51	43	4	3	3	No effect.	
		51	43	8	3	3	No chlorosis, some loss of lower leaves.	
		51	43	16	3	3	Some wilting after removal from flood.	
		51	43	32	3	0	All died.	
	Greenhouse study; current year seedlings, 5/pot flooded in July and August.	.64	-	38	5	5	Height growth reduced to 21% of controls; secondary roots died and were replaced by a new root system in addition to adventitious rooting; chlorosis observed; plants recovered in 60 days after removal from flood.	Hosner 1959
	Greenhouse study; current year seedlings, 19 cm tall, 5/pot flooded 14 Jul-21 Aug; 60-day recovery period after drainage.	61	-	5	15	15	No effect.	Hosner 1960
		61	-	10	15	14	Rapid recovery.	
		61	-	20	15	14	3 survivors lost terminals; recovered rapidly.	
		61	-	20	15	14	2 survivors lost terminals; recovered slowly.	

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Fraxinus pennsylvanica Green ash	Greenhouse study; current year seedlings, 5/pot established as material seed became available.	2.5	-	60	15	15	No shoot mortality; many adventitious roots, some dead secondary roots but many new tips.	Hosner and Boyce 1962
	Greenhouse study with current year seedlings to determine effects of different moisture regimes on growth.	Soil saturated	-	84	12	12	Out of 4 moisture treatments, plants in saturated soil (the wettest treatment) did best.	Dickson, Hosner, and Hosley 1965
	Controlled field experiment, natural stands in Miss. Delta flooded.	90, max	-	210	9	9	Saplings: 17% growth increase over control.	Broadfoot 1967
					14	14	Poles: 80% growth increase over control.	
					24	24	Timber: 90% growth increase over control.	
	Observations of tree mortality in Miss. stand flooded continuously for 4 yrs.	< 30	-	1460	-	-	Among few species able to survive into fourth growing season	Broadfoot and Williston 1973

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Fraxinus pennsylvanica Green ash	Study of tree mortality during flood surcharge at Rend Lk. and Lk. Shelbyville in Ill. during 1973 growing season.	-	-	109	8	8		Bell and Johnson 1974
		-	-	149	68	68		
		-	-	189	82	82		
	Report of impacts of 1973 flood during spring and early summer on 1-, 10-, and 11-yr-old plantations.	76-198	-	60	-	-	1-yr-old plantation not *yet leafed out* when flooded; emerging leaves were killed but were replaced when flood receeded. Older plantations not affected.	Kennedy and Krinnard 1974
	Sapling survival observed in a hardwood forest along the Miss. River in La. before and after flood during 1973 growing season.	240-480	-	105	-	-	Trees generally able to survive	Noble and Murphy 1975
Gleditsia aquatica Water locust	*Study of tree mortality upstream from Alton* Dam in S. Ill. Permanent transects sampled at intervals over 4-yr period. Samples grouped by location: land, mud, water.	land	-	240	24	100%		Yeager 1949
		mud	-	240	2	100%		
		water	-	240	25	64%		

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Gleditsia aquatica		land	-	730	24	96%		Yeager 1949
		mud	-	730	2	100%		
Water locust		water	-	730	25	8%		
		land	-	1460	24	96%		
		mud	-	1460	2	0%		
		water	-	1460	25	4%	Survivors in < 25 cm water, 28-38 cm dbh. (dbh=diameter breast height)	
	Correlated flood frequency and duration in the lower White River valley, Ark., with forest composition.	-	-	29-40% of time	83	-		Bedinger 1971
		-	-	10-21% of time	0	-		
		-	-	once every 2-8 yrs	0	-		
Gleditsia triacanthos Honey locust	Controlled field study; 50-yr-old natural stands in Miss. flooded Feb-Jul every year for 4 yrs.	90, max	-	150	5	-	Timber and pole size 53% increase in radial growth over control.	Broadfoot 1967
	Correlated flood frequency and duration in the lower White R. valley, Ark., with forest composition.	-	-	29-40% of time	0	-		Bedinger 1971
		-	-	10-21% of time	4	-		
		-	-	once every 2-8 yrs	0	-		

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Gleditsia triacanthos Honey locust	Study of tree mortality during flood surcharge around Rend Lk. and Lk. Shelbyville in Illinois during 1973 growing season.			109	26	100%		Bell and Johnson 1974
				149	26	100%		
				189	26	100%		
	Study of sapling mortality resulting from March-July flood of Miss. River.	244-488		105			Saplings either killed or growth severely retarded.	Noble and Murphy 1975
Gymnocladus dioicus Kentucky coffee tree	Study of tree mortality upstream from Alton Dam in S. Ill. Permanent transects sampled at intervals over 4-yr period. Samples grouped by location: land, mud, water.	land		240	1	100%		Yeager 1949
		mud		240	0	100%		
		water		240	0	100%		
		land		730	1	100%		
		mud		730	0	100%		
		water		730	0	100%		
		land		1460	1	100%		
		mud		1460	0	100%		
		water		1460	0	100%		

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Ilex decidua Deciduous holly	Correlated flood frequency and duration in the lower White River valley with forest composition.			29-40% of time	0	-		Bedinger 1971
				10-21% of time	3	-		
				and every 2-8 yrs	1	-		
	Study of sapling mortality resulting from March-July flood of Miss. River.	244-488		105	-	-	Saplings generally able to recover.	Noble and Murphy 1975
Ilex opaca American holly	Study of tree mortality upstream from Alton Dam in S. Ill. Permanent transects sampled at intervals over 4-yr period. Samples grouped by location: land, mud, water.	land		240	6	100%		Yeager 1949
		mud		240	1	100%		
		water		240	8	75%		
		land		730	6	100%		
		mud		730	1	100%		
		water		730	8	0		
		land		1460	6	100		
		mud		1460	1	100		
		water		1460	8	0		

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Juglans nigra Black walnut	Study of tree mortality during flood surcharge at Rend Lk. and Lk. Shelbyville in Ill. during 1973 growing season.	-	-	50	4	100%	Ranked as somewhat tolerant by authors, able to survive 90-150 days of flooding. (This is unusually tolerant for *J. nigra*.	Bell and Johnson 1974
				109	4	100%		
				149	4	0		
				189	4	0		
	Report of mortality in 10- and 11-yr-old plantations resulting from flood during 1973 growing season (Apr-Sept).	-	-	180	-	0%	All trees dead.	Kennedy and Krinnard 1974
Liquidambar styraciflua Sweetgum	Greenhouse study, current year seedlings, 7.6 cm tall, 3/pot flooded in July and August.	50.8	43.2	2	3	3	Necrotic leaf margins, rapid recovery.	Hosner 1958
		50.8	43.2	4	3	3	Necrotic leaves, mostly lower; slow recovery.	
		50.8	43.2	8	3	3	Leaf chlorosis, slow recovery.	
		50.8	43.2	16	3	2	Survivors had small dead areas on leaves.	
		50.8	43.2	32	3	0	All dead.	

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Liquidambar styraciflua Sweetgum	Greenhouse study; current year seedlings, 5/pot under conditions similar to other Hosner 1960 trials; no height recorded. 60-day recovery period after drainage.	61	-	5	15	14	4 lost terminals, recovered rapidly.	Hosner 1960
		61	-	10	15	10	Medium recovery.	
		61	-	20	15	0		
		61	-	30	15	0		
	Greenhouse study; current year seedlings, 5/pot, 30 cm tall established as natural seed became available; flooded 27 Jul-27 Sep., Only 60 day data presented here.	2.5	-	60	15	15	No shoot mortality or adventitious roots; secondary roots died while upper laterals grew to surface.	Hosner and Boyce 1962
	Controlled field experiment; natural stands in Miss. Delta flooded Feb-Jul for 4 yrs to assess effect on growth.	90, max	-	210	6	6	Sapling: 82% growth increase over control.	Broadfoot 1967
					37	37	Pole: 77% growth increase over control.	
					25	25	Timber: 86% growth increase over control.	

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Liquidambar styraciflua Sweetgum	Correlated flood frequency and duration in the lower White R. valley, Ark., with forest composition.	-	-	29-40% of time	0	-		Bedinger 1971
				10-21% of time	85	-		
				once every 2-8 yrs	76	-		
	Observations of tree mortality in Miss. stand flooded continuously for 4 yrs.	<30	-	1460	-	-	Dead after third year.	Broadfoot and Williston 1973
	Report of impacts of 1973 flood during spring and early summer on 1-, 10-, and 11-yr-old plantations.	198, max	-	58	-	∿ 100%	1-yr-old plantation leafing out when flooded.	Kennedy and Krinnard 1974
		-	-	88	-	0	1-yr-old plantation.	
		-	-	-	-	∿ 100%	10- and 11-yr-old plantations.	
	Sapling survival observed in a hardwood forest along Mississippi River in La. after flood during 1973 growing season.	240-480	-	105 (116 max)	-	-	Many small seedlings and saplings killed.	Noble and Murphy 1975

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Liriodendron tulipifera Tulip tree	Report of impacts of 1973 flood during spring and early summer on plantations of various ages.	198,max	-	30	-	0%	1-yr-old plantation; leaves wilted	Kennedy Krinard 1974
		198,max	-	45	-	0%	1-yr-old plantation; trees killed.	
		213	-	60	-	0%	11-yr-old plantation killed; trees averaged 17 cm diameter breast height (dbh)	
		91	-	60	-	0%	15-yr-old plantation killed; trees averaged 20 cm dbh and 22 m tall.	
Morus rubra Red mulberry	Study of tree mortality upstream from Alton Dam in Ill. over a period of 4 yrs. Samples grouped by location: land, mud, water.	land		240	15	100%	Typically not a swamp species but apparently able to survive some rise in the water table.	Yeager 1949
		mud		240	0	-		
		water		240	0	-		
		land		730	15	100%		
		mud		730	0	-		
		water		730	0	-		
		land		1460	15	100%		
		mud		1460	0	-		
		water		1460	0	-		

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Nyssa aquatica Water tupelo	Controlled field experiment using 10-month-old seedlings averaging 46 cm tall.	8		120	30	100%	52 cm height increase.	Kennedy 1970
				150	30	98%	29 cm height increase.	
				180	30	100%	39 cm height increase.	
		15-25		120	30	92%	27 cm height increase.	
				150	30	100%	30 cm height increase.	
				180	30	95%	17 cm height increase.	
			10-15	120	30	93%	17 cm height increase.	
				150	30	87%	-6 cm height decrease.	
				180	30	32%	-24 cm height decrease.	
		0				95%	Control: 61 cm height increase.	
							Siltation decreased survival to 87% in 15-25 cm flood. Reflooding for 14 days in August reduced survival and caused dieback on survivors.	
	Greenhouse study; current year seedlings grown under 4 different moisture regimes to determine effects on growth.	Soil kept saturated	-	84	12	12	Growth was significantly better under continuous saturation. Growth restricted under moisture equivalent regime.	Dickson, Hosner, and Hosley 1965

(Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Nyssa aquatica Water tupelo	Ecological study of a baldcypress-tupelo swamp in La. Swamp flooded for 90 days every spring with soil remaining saturated for rest of year.	15-30	-	90	-	-	Importance value of 37.58 where IV = relative frequence + relative dominance + relative density. Second only to baldcypress, with IV = 39.20.	Connor and Day 1976
Nyssa sylvatica Black gum	Correlated flood frequency and duration with forest composition in White River valley, Ark.	-	-	29-40% of time	0	-	The genus and species both exhibit a range of flooding tolerances. Provenience is important when selecting planting stock.	Bedinger 1971

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Pinus echinata Shortleaf pine	Observation of planting in a permanent pool and detention pond in Northern Miss. for 3 consecutive growing seasons.	46		105	-	0%	1st winter flood; no survivors in this area.	Williston 1962
		Sat. soil		60	-	-	2nd winter flood didn't lessen survival (sic.).	
		Sat. soil	-	-	-	-	Height growth reduced by 25-50% when roots flooded for winters of 3 consecutive years.	
Pinus taeda Loblolly pine	Same as above.	-	Flooded over terminal to unspecified depth.	180	-	0%		Williston 1962
		Sat. soil	Flooded over terminal to unspecified depth.	120	-	79%	30 days of complete submergence followed by 90 days of root submergence.	
			Flooded over terminal to unspecified deptn.	180	-	0%		

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Pinus taeda	2-yr-old potted plants flooded	-	-	0	9	9		Burton 1972
Loblolly pine	outside for varying periods of time beginning 3 Jan; stem, foliage, and root parameters	soil sat.	-	49	9	9	49-day treatment gave best performance on all parameters.	
	measured as well as nutrient	soil sat.	-	98	9	9		
	level in foliage.	soil sat.	-	147	9	9	147-day treatment gave poorest performance. Seedling size class had no apparent effect on performance.	
	Report of impact of 1973 Miss. flood on 15-yr-old plantation; flooded during growing season.	-	-	60	-	100%	Two months of flooding during growing season had no injurious effects.	Kennedy and Krinard 1974
Planera aquatica	Correlated flood duration and frequency with	-	-	29-40% of time	37	-		Bedinger 1971
Water elm	forest composition in the lower White River valley, Ark.	-	-	10-21% of time	0	-		
		-	-	once every 2-8 yrs	0	-		

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Platanus occidentalis Sycamore	Greenhouse study; current year seedlings, 11.7 cm tall, 5/pot, flooded 14 Jul-21 Aug 60-day recovery period after drainage.	.64	-	38	5	5	Developed adventitious roots and leaf chlorosis followed by reddening, height growth 13% of controls.	Hosner 1959
	Greenhouse study; current year seedlings, 5/pot, 11.7 cm tall, flooded 2 July - 1 Aug.	61	49	5	15	15	Rapid recovery.	Hosner 1960
		61	49	10	15	15	Medium recovery.	
		61	49	20	15	0	All dead.	
		61	49	30	15	0	All dead.	
	Greenhouse study; current year seedlings, 31 cm tall, 5/pot established as natural seed became available. Flooded 27 Jul-27 Sep. Only 60-day data presented here.	2.5	-	60	15	73%	Many adventitious roots, all secondary and lower primary roots died. Classed as intermediate tolerance by authors.	Hosner and Boyce 1962

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Platanus occidentalis Sycamore	Greenhouse study; current year seedlings grown under 4 different moisture regimes to determine effects on growth.	soil kept saturated	-	84	12	12	Best growth achieved in treatment which involved watering to moisture equivalent.	Dickson, Hosner, and Hosley 1965
	17-day-old seedlings kept in pots in saturated soil in early June.	-2.5	-	0-32	20	95%	32-day treatment resulted in slight stunting; rapid recovery.	McDermott 1954
	Study of tree mortality upstream from Alton Dam in S. Ill. Permanent transects sampled at intervals over a 4-yr period Samples grouped by location: land, mud, water.	land		240	6	100%		Yeager 1949
		mud		240	0	-		
		water		240	0	-		
		land		730	6	100%		
		mud		730	0	-		
		water		730	0	-		

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Platanus occidentalis		land		1460	6	100%		Yeager 1949
Sycamore		mud		1460	0	-		
		water		1460	0	-		
	Correlated flood duration and frequency with forest composition in the lower White River valley, Ark.	-	-	29-40% of time	3	-		Bedinger 1971
		-	-	10-21% of time	1	-		
		-	-	once every 2-8 yrs	0	-		Bedinger 1971
	Study of tree mortality during flood surcharge at Rend Lk. and Lk. Shelbyville in Ill. during 1973 growing season.	-	-	129	4	100%		Bell and Johnson 1974
		-	-	169	4	100%		

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Platanus occidentalis Sycamore (continued)	Report of mortality in plantations of various ages after 1973 flood.	-	tops emergent	-	-	~ 100%	1 yr old: infected with Anthracnose but recovered when water receded.	Kennedy and Krinard 1974
		-	-	-	-	100%	11-yr-old plantation survived in good condition.	
		-	-	180	-	100%	10- to 11-yr-old plantation flooded March-August; healthy in September.	
		-	-	-	-	100%	Coppice, cut in Jan 73 sprouted when water receded.	
		-	tops covered	-	-	0%	Seedlings planted in January 73 all died.	
Populus deltoides Cottonwood	Greenhouse study; current year seedlings, 7.6 cm tall, 3/pot, flooded July and August.	50.8	43.2	2	3	3	Some leaf necrosis; rapid recovery.	Hosner 1958
		50.8	43.2	4	3	3	Leaf necrosis; rapid recovery.	
		50.8	43.2	8	3	3	Leaf abscission; slow recovery.	
		50.8	43.2	16	3	0	All died.	
		50.8	43.2	32	3	0	All died.	

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Populus deltoides Cottonwood	Greenhouse study; current year seedlings, 5/pot, flooded July 14-21 Aug, 60-day recovery period after drainage.	.64	-	38	5	5	Original roots died and were replaced by extensive adventitious system. Slight chlorosis; height growth 77% of controls.	Hosner 1959
	Greenhouse study; current year seedlings, 7.11 cm tall, 5/pot, flooded 2 Jul-1 Aug.	61	54	5	15	15	No effect.	Hosner 1960
		61	54	10	15	14	Rapid recovery.	
		61	54	20	15	11	2 survivors lost terminals; slow recovery.	
		61	54	30	15	7	2 lost terminals; slow recovery.	
	Greenhouse study; current year seedlings, 18.4 cm tall, 5/pot, established as natural seed became available. Flooded 27 Jul-27 Sep. Only 60 day data presented here.	2.5	-	60	15	93%	Many adventitious roots; all roots except primary died. Ranked as intermediate tolerance by authors.	Hosner and Boyce 1962

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Populus deltoides Cottonwood	Study of tree mortality upstream from Alton Dam in S. Ill. Permanent transects sampled at intervals over a 4-yr period. Samples grouped by location: land, mud, water.	land	-	240	5	100%		Yeager 1949
		mud	-	240	1	100%		
		water	-	240	9	89%		
		land	-	730	5	100%		
		mud	-	730	1	100%		
		water	-	730	9	0%		
		land	-	1460	5	100%		
		mud	-	1460	1	100%		
		water	-	1460	9	0%		
	Comparison of survival of first year cuttings and seedlings on a low site in a wet year.						Seedlings survive inundation better than cuttings.	Bull and Putnam 1941
	Controlled field experiment; natural strands in Miss. Delta, flooded Feb-Jul for 4 yrs to assess affect on growth.	90 max.		210	8	8	Timber size; 90% growth increase over controls.	Broadfoot 1967

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Populus deltoides Cottonwood	Comparison of survival of seedlings and cuttings on a Miss. site flooded during spring; post-flood cuttings planted for comparison.			±75; 1st season	-	90%	1-0 seedlings, planted in Jan.	Maisenhelder and McKnight 1968
					-	16%	102-cm cuttings, planted in Jan.	
					-	19%	51-cm cuttings, planted in Dec.	
					-	41%	51-cm cuttings, planted in June	
				±75, 2nd season	-	87%	1-0 seedlings, planted in Jan.	
					-	16%	102-cm cuttings, planted in Jan.	
					-	15%	51-cm cuttings, planted in Dec.	
					-	24%	51-cm cuttings, planted in June.	
	Correlated flood duration and frequency with forest composition in the lower White River valley, Ark.	-	-	29-40% of time	1	-		Bedinger 1971
		-	-	10-21% of time	0	-		
		-	-	once every 2-8	0	-		
	Report mortality in various plantations resulting from flood in spring, 1973.	61-183	-	90	- - -	24% 18% 50%	Current year's cuttings.	Kennedy and Krinard 1974
		61-183	-	90	-	100%	1-yr-old cuttings in leaf, with emergent tips.	

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Populus deltoides Cottonwood		61-183	-	90	-	70%	Stump sprouts on 2-to 3-yr-old rootstock stump 25.4 cm tall.	Kennedy and Krinnard 1974
		61-183	-	90	-	20%	Stump sprouts on 2-to 3-yr-old rootstock, stump level with ground.	
	Study of tree mortality during flood surcharge at Rend Lk. and Lk. Shelbyville in Ill. during 1973 growing season.	-	-	149	7	100%	Ranked by authors as tolerant; able to survive more than 150 days of flooding.	Bell and Johnson 1974
		-	-	189	7	100%		
Prunus americana Wild plum	Study of tree mortality upstream from Alton Dam in S. Ill. Permanent transects sampled at intervals over a 4-yr period. Samples grouped by location: land, mud, water.	land	-	240	1	100%	Tolerance to a rise in the water table is impossible to infer from this study, since depth to water table was not studied.	Yeager 1949
		mud	-	240	0	-		
		water	-	240	0	-		
		land	-	730	1	100%		
		mud	-	730	0	-		
		water	-	730	0	-		
		land	-	1460	1	100%		
		mud	-	1460	0	-		
		water	-	1460	0	-		

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Prunus serotina: Black cherry	Correlated flood frequency and duration with forest composition in the lower White River valley, Ark.	-	-	29-40% of time	0	-		Bedinger 1971
		-	-	10-21% of time	0	-		
		-	-	every 2-8 yrs	2	-		
	Study of tree mortality during flood surcharge at Rend Lk. and Lk. Shelbyville in Ill. during 1973 growing season.	-	-	149	3	0	Ranked as intolerant by authors; severely injured by under 50 days of flooding.	Bell and Johnson 1974
		-	-	189	3	0		
Quercus alba White oak	Correlated flood frequency and duration with forest composition in the lower White River valley, Ark.	-	-	29-40% of time	0	-		Bedinger 1971
		-	-	10-21% of time	0	-		
		-	-	once every 2-8 yrs	27	-		
	Study of tree mortality during flood surcharge at Rend Lk. and Lk. Shelbyville in Illinois during 1973 growing season.	-	-	50	58	100%	Ranked as slightly tolerant by authors; surviving 50-100 days of flooding.	Bell and Johnson 1974
		-	-	109	58	54%		
		-	-	149	58	0%		
		-	-	189	58	0%		

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Quercus bicolor Swamp white oak	Study of tree mortality during flood surcharge at Rend Lk. and Lk. Shelbyville in Ill. during 1973 growing season.	-	-	49	4	100%	Ranked as tolerant by authors; surviving more than 150 days of inundation.	Bell and Johnson 1974
		-	-	149	4	100%		
	Report of condition of 15-yr-old plantation in Miss. after 2 months flood during 1973 growing season.	-	-	60	-	100%	No apparent damage.	Kennedy and Krinard 1974
Quercus falcata Spanish oak	Greenhouse study; current year seedlings, 5/pot, flooded 14 Jul-21 Aug, 60-day period after drainage.	.64	-	38	5	4	Severe chlorosis; secondary roots died; no adventitious roots. No new leaf or top growth during recovery period. var. *pagodaefolia* used in this study.	Hosner 1959
	Greenhouse study; current year seedlings, 5/pot, 14 cm tall, flooded 2 Jul-1 Aug.	61	49	5	15	13	Survivors recovered moderately fast.	Hosner 1960
		61	49	10	15	1	Recovery very slow.	
		61	49	20	15	0	All dead.	
		61	49	30	15	0	All dead. var. *pagodaefolia* used in this study.	

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Quercus falcata Spanish oak	Greenhouse study; current year seedlings, 71 cm tall, established as natural seed became available. Flooded 27 Jul-27 Sep. Only 60 day data presented here.	2.5	-	60	15	-	87% shoot dieback. All roots died, no adventitious roots produced.	Hosner and Boyce 1962
	Correlated flood frequency and duration with forest composition in the lower White River valley, Ark.	-	-	29-40% of time	0	-		Bedinger 1971
		-	-	10-21% of time	0	-		
		-	-	once every 2-8 yrs	131	-		
	Report on condition of 1-yr-old plantation in Miss. flooded during 1973 growing season.	-	-	60	-	100%	No apparent damage.	Kennedy and Krinnard 1974
Quercus imbricaria Shingle oak	Study of tree mortality during flood surcharge of Rend Lk. and Lk. Shelbyville in Ill. during 1973 growing season.	-	-	50	14	100%	Ranked as somewhat tolerant by authors, surviving 90-150 days of flooding.	Bell and Johnson 1974
		-	-	109	14	100%		
		-	-	149	14	0%		
		-	-	189	14	0%		

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Quercus lyrata Overcup oak	Controlled field experiment, natural stands in Miss. Delta flooded Feb-Jul for 4 yrs to determine effects on growth.	90 max.	-	210	7	-	Timber sized; 20% radial growth increase over control. Genus as a whole benefited very little from flood treatment.	Broadfoot 1967
	Correlated flood frequency and duration with forest composition in the lower White River valley, Ark.	-	-	29-40% of time	209	-		Bedinger 1971
		-	-	10-21% of time	125	-		
		-	-	once every 2-8 yrs	2	-		
Quercus macrocarpa Bur oak	Study of tree mortality upstream from Alton Dam in S. Ill. Permanent transects sampled at intervals over a 4-yr period. Samples grouped by land, mud, water.	land	-	240	3	100%		Yeager 1949
		mud	-	240	0	-		
		water	-	240	5	-		
		land	-	730	3	100%		
		mud	-	730	0	-		
		water	-	730	5	0%		
		land	-	1460	3	100%		
		mud	-	1460	0	-		
		water	-	1460	5	0%		

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Quercus macrocarpa Bur oak	Observations of tree mortality in Miss. stand flooded continuously for 4 yrs.	< 30	-	1460	-	-	Dead after 4th season.	Broadfoot and Williston 1973
	Study of tree mortality during flood surcharge at Rend Lk.& Lk. Shelbyville in Ill. during 1973 growing season.	-	-	189	13	100%	Ranked as tolerant by authors; survived more than 150 days of flooding.	Bell and Johnson 1974
Quercus marilandica Blackjack oak	Correlated flood frequency and duration with forest composition River valley, Ark.	-	-	29-40% of time	0	-	2 individuals found on a site never flooded.	Bedinger 1971
		-	-	10-21% of time	0	-		
		-	-	once every 2-8 yrs	0	-		
Quercus nigra Water oak	Correlated flood frequency and duration with forest composition in the lower White River valley, Ark.	-	-	29-40% of time	0	-		Bedinger 1971
		-	-	10-21% of time	29	-		
		-	-	once every 2-8 yrs	15	-		

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Quercus nigra Water oak	Observations of tree mortality in Miss. stand flooded continuously for 4 yrs.	< 30	-	1460	-	-	Dead after 3rd season.	Broadfoot and Williston 1973
	Report on condition of 1-yr-old plantation in Miss. flooded during 1973 growing season.	-	-	60	-	100%	No apparent injury.	Kennedy and Krinard 1974
Quercus nuttallii Nuttall's oak	Correlated flood frequency and duration with forest composition in the lower White River valley, Ark.	-	-	29-40% of time	16	-		Bedinger 1971
		-	-	10-21% of time	128	-		
		-	-	once every 2-8 yrs	2	-		
	See above: Kennedy and Krinard 1974.	-	-	60	-	100%	No apparent damage.	Kennedy and Krinard 1974

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Quercus palustris Pin oak	Greenhouse study; current year seedlings, 5/pot, flooded 14 July-21 Aug. 60-day recovery period after drainage.	.64	-	38	5	5	Severe chlorosis, no height growth, secondary roots died, no adventitious roots.	Hosner 1959
	Greenhouse study; current year seedlings, 14.7 cm tall, 5/pot, flooded 2 Jul-1 Aug.	61	46.3	5	15	15	Rapid recovery.	Hosner 1960
		61	46.3	10	15	14	Slow recovery.	
		61	46.3	20	15	4	Very slow recovery.	
		61	46.3	30	15	0	All dead.	
	Greenhouse study; current year seedlings, 20.8 cm tall, 5/pot, established as natural seed became available. Flooded 27 Jul-27 Sep. Only 60 day data presented here.	2.5	-	60	15	15	Sparse adventitious rooting, some mortality of secondary roots. Ranked as intermediate tolerance by authors.	Hosner and Boyce 1962

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Quercus palustris Pin oak	Greenhouse study; current year seedlings grown under 4 different moisture regimes to determine effects on growth.	soil kept saturated	-	84	12	12	Best growth under moisture equivalent watering regime; saturated soil killed the root system and adventitious roots were virtually non-existent.	Dickson, Hosner and Hosley 1965
	Study of tree mortality upstream from Alton Dam in S. Illinois. Permanent transects sampled at intervals over a 4-yr period. Samples grouped by location: land, mud, water.	land	-	240	46	96%	Trees in < 76.2 cm water, maximum.	Yeager 1949
		mud	-	240	5	100%		
		water	-	240	28	71%		
		land	-	730	46	80%		
		mud	-	730	5	0%		
		water	-	730	28	0%		
		land	-	1460	46	72%		
		mud	-	1460	5	0%		
		water	-	1460	28	0%		

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AD-A113 296 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG--ETC F/G 6/6
IMPACTS OF FLOODING REGIME MODIFICATION ON WILDLIFE HABITATS OF--ETC(U)
OCT 81 C V KLIMAS, C O MARTIN, J W TEAFORD

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Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
<u>Quercus palustris</u> Pin oak	Correlated flood frequency and duration with forest composition in the lower White River valley, Ark.	-	-	29-40% of time	0	-		Bedinger 1971
		-	-	10-21% of time	0	-		
		-	-	once every 2-8 yrs	4	-		
	Study of tree mortality during flood surcharge at Rend Lk. and Lk. Shelbyville in Ill. during 1973 growing season.	-	-	109	4	100%	Ranked as tolerant by authors.	Bell and Johnson 1974
<u>Quercus phellos</u> Willow oak	Greenhouse study; current year seedlings, 24.8 cm tall, 5/pot, established as natural seed became available. Flooded 27 Jul-27 Sep. Only 60 day data presented here.	2.5	-	60	15	15	No shoot mortality No adventitious roots.	Hosner and Boyce 1962

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Quercus phellos Willow oak	Controlled field experiment, natural stands in Miss. Delta flooded Feb-Jul for 4 yrs to determine effects on growth.	90, max	-	210	20	-	Timber size; 10% radial growth increase over control.	Broadfoot 1967
	Correlated flood frequency and duration with forest composition in the lower White River valley, Ark.	-	-	29-40% of time	0	-		Bedinger 1971
		-	-	10-21% of time	80	-		
		-	-	once every 2-8 yrs	73	-		
	Observations of tree mortality in Miss. stand flooded for 4 yrs.	< 30	-	1460	-	-	Most trees died during 3rd year.	Broadfoot and Williston 1973

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Quercus rubra Red oak	Study of tree mortality during flood surcharge at Rend Lk. and Lk. Shelbyville in Ill. during 1973 growing season.	-	-	50	16	100%	Ranked as slightly tolerant by authors; survive 50-100 days of flooding.	Bell and Johnson 1974
Quercus shumardii Shumard oak	Greenhouse study; current year seedlings, 13 cm tall, 5/pot, flooded 2 Jul-1 Aug.	61	48	5	15	15	Only 2 plants grew after flooding.	Hosner 1960
		61	48	10	15	15	Slow recovery.	
		61	48	20	15	0	All dead.	
		61	48	30	15	0	All dead.	
	Greenhouse study; current year seedlings, 21.3 cm tall, 5/pot, established as natural seed became avai[illegible]. Flooded 27 [illegible] 27 Sep. Or[illegible] day data [illegible]ed here.	2.5	-	60	15	15	33.3% shoot mortality no adventitious roots, some dead secondary roots.	Hosner and Boyce 1962

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
<u>Quercus shumardii</u>	Correlated flood frequency and duration with	-	-	29-40% of time	-	-		Bedinger 1971
Shumard oak	forest composition in the lower White River valley, Ark.	-	-	10-21% of time	0	-		
		-	-	once every 2-8 yrs	9	-		
	Report on condition of several Miss. plantations flooded	76-198	-	75	-	10%	January planting of seedlings.	Kennedy and Krinard 1974
	during 1973 growing season.	-	-	75	-	100%		
<u>Quercus stellata</u>	Correlated flood frequency and duration with	-	-	29-40% of time	0	-	10 individuals found on sites never flooded.	Bedinger 1971
Post oak	forest composition in the lower White River valley, Ark.	-	-	10-21% of time	0	-		
		-	-	once every 2-8 yrs	32	-		

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Quercus velutina Black oak	Study of tree mortality during flood surcharge at Rend Lk. and Lk. Shelbyville in Ill. during 1973 growing season.	-	-	50	13	66%	Ranked as intolerant by authors; severe injury from under 50 days of flooding.	Bell and Johnson 1974
		-	-	109	13	0%		
		-	-	149	13	0%		
		-	-	189	13	0%		
Salix nigra Black willow	Greenhouse study; current year seedlings, 7.6 cm tall, 3/pot, flooded in July and August.	50.8	43.2	2	3	3	No effect.	Hosner 1958
		50.8	43.2	4	3	3	Lower leaves abscissed, rapid recovery.	
		50.8	43.2	8	3	3	Lower leaves abscissed, slight chlorosis, rapid recovery.	
		50.8	43.2	16	3	3	Lower leaves abscissed, slight chlorosis, rapid recovery.	
		50.8	43.2	32	3	3	Severe chlorosis, rapid recovery.	
	Greenhouse study; current year seedlings, 8 cm tall, 5/pot, flooded 2 Jul-1 Aug.	61	53	5	15	15	No effect.	Hosner 1960
		61	53	10	15	15	No effect.	
		61	53	20	15	15	Rapid recovery.	
		61	53	30	15	13	3 lost terminals, recovered rapidly.	

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Salix nigra Black willow	Study of tree mortality upstream from Alton Dam in Ill. Permanent transects sampled at intervals over 4-yr period. Samples grouped by location: land, mud, water	land	-	240	0	-		Yeager 1949
		mud	-	240	0	-		
		water	-	240	23	87%		
		land	-	730	0	-		
		mud	-	730	0	-		
		water	-	730	23	61%		
		land	-	1460	0	-		
		mud	-	1460	0	-		
		water	-	1460	23	56%	39% survival in 1946. More than half of the mortality occurred in > 104 cm of water.	
	Study of tree mortality resulting from flood surcharge at Rend Lk. and Lk. Shelbyville, Ill., during 1973 growing season.	-	-	189	1	1		Bell and Johnson 1974

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Salix nigra Black willow	Ecological study of a baldcypress - water tupelo swamp in La.	-	-	-	-	-	Importance value of .88 where IV= relative frequency + relative dominance + relative density.	Connor and Day 1976
Sassafras albidum Sassafras	Study of tree mortality resulting from flood surcharge at Rend Lk. and Lk. Shelbyville, Ill., during 1973 growing season.	-	-	49	5	100%	Ranked as intolerant by authors.	Bell and Johnson 1974
				109	5	100%		
				149	5	0%		
				189	5	0%		
Taxodium distichum Baldcypress	1- to 4-yr-old seedlings 20-30 cm high were submerged in the St. Francis River, Ark., from 26 June-6-Jul.	200		11	30	0		Demaree 1932
		300		11	80	1		
		100		11	80	0		
		2-3		11	80	0		
		2-3		11	80	2		
	Correlated flood frequency and duration with forest composition in the lower White River valley, Ark.	-	-	29-40% of time	117	-		Bedinger 1971
		-	-	10-21% of time	0	-		

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Taxodium distichum Baldcypress		-	-	once every 2-8 yrs	1	-		
	Ecological study of baldcypress - water tupelo swamp in La.	-	-	-	-	-	Importance value= 39.2, where IV= relative frequency + relative density + relative dominance.	Conner and Day 1976
Ulmus alata Winged elm	17-day-old seedlings placed in saturated soil in June.	-2.5		0-32	20	100%	Growth stunted in all treatments except 1 day.	McDermott 1954
	Correlated flood frequency and duration with forest composition in the lower White River valley, Ark.	-	-	29-40% of time	0	-		Bedinger 1971
		-	-	10-21% of time	13	-		
		-	-	once every 2-8 yrs	79	-		

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Over terminal bud	Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Ulmus americana	Greenhouse study; current year seedlings, 23 cm tall, 5/pot, flooded 2 Jul-1 Aug.	61	38	5	15	15	14 developed "side branches."	Hosner. 1960
American elm		61	38	10	15	15	7 lost terminals; recovered rapidly.	
		61	38	20	15	4	Survivors lost terminals; sprouted weakly.	
		61	38	30	15	0	All dead.	
	Greenhouse study; current year seedlings, 37 cm tall, 5/pot established as natural seed became available. Flooded 27 Jul-27 Sep. Only 60 day data presented here.	2.5	-	60	15	15	6.7% shoot.	Hosner and Boyce 1962
	Study of tree mortality upstream from Alton Dam, Ill. Permanent transects sampled at intervals over 4-yr period. Samples grouped by location: land, mud, water.	land	-	240	98	99%		Yeager 1949
		mud	-	240	37	100%		
		water	-	240	104	78%		

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Ulmus americana		land	-	730	98	95%		
American elm		mud	-	730	37	86%		
		water	-	730	104	3%		
		land	-	1460	98	94%		
		mud	-	1460	37	49%		
		water	-	1460	104	0%		
	Correlated flood frequency and duration with forest composition in lower White River valley, Ark.	-	-	29-40% of time	4	-		Bedinger 1971
		-	-	10-21% of time	47	-		
		-	-	once every 2-8 yrs	29	-		
	Observations of tree mortality in Miss. in stand flooded for 4 consecutive years.	< 30	-	1460	-	-	Trees died during second year.	Broadfoot and Williston 1973

(Continued)

Table A1 (Continued)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Ulmus americana American elm	Study of tree mortality during flood surcharge at Rend Lk. and Lk. Shelbyville, Ill., during 1973 growing season.	-	-	49	102	100	Ranked as somewhat tolerant by authors; generally killed by 90-150 days of flooding.	Bell and Johnson 1974
		-	-	109	102	98		
		-	-	149	102	77		
		-	-	189	102	91		
	Mortality observed in understory as result of 1973 flood during growing season.	243-488	-	105	-	-	Species was killed or severely retarded by flood.	Noble & Murphy 1975
Ulmus rubra Slippery elm	Study of tree mortality upstream from Alton Dam, Ill. Permanent transects sampled at intervals over 4-yr. period. Samples grouped by location: land, mud, water.	land		240	1	100%		Yeager 1949
		mud			0	-		
		water			0	-		
		land		730	1	100%		
		mud			0	-		
		water			0	-		

(Continued)

Table A1 (Concluded)

Species	Experimental method	Conditions: Depth, cm: Over root crown or as noted	Conditions: Depth, cm: Over terminal bud	Conditions: Duration: consecutive days or as noted	No. of plants	No. or % survival	Comments	Authority
Ulmus rubra		land		1460	1	100%		
Slippery elm		mud			0	-		
		water			0	-		

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Klimas, Charles V.
Impacts of flooding regime modification on wildlife habitats of bottomland hardwood forests in the Lower Mississippi Valley / by Charles V. Klimas, Chester O. Martin, James W. Teaford (Environmental Laboratory, U.S. Army Engineer Waterways Experiment Station). -- Vicksburg, Miss. : The Station ; Springfield, Va. : available from NTIS, 1981.
137, 63 p. : ill. ; 27 cm. -- (Technical report ; EL-81-13)
Cover title.
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Final report.
"Prepared for U.S. Army Engineer Division, Lower Mississippi Valley."
Bibliography: p. 118-137.

1. Floods. 2. Forests and forestry. 3. Hardwoods. 4. Mississippi River. 5. Wildlife management. I. Martin,

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Impacts of flooding regime modification : ... 1981.
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