# GREENTREE RESERVOIR MANAGEMENT HANDBOOK

**Gaylord Memorial Laboratory**
**Wetland Management Series**

**Number 1**

Leigh H. Fredrickson
Donald L. Batema

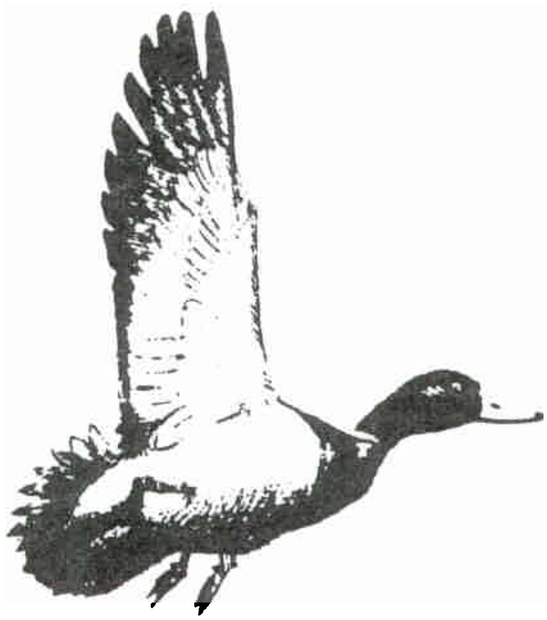
Gaylord Memorial Laboratory
The School of Natural Resources
University of Missouri-Columbia
Puxico, MO 63960

**This publication was produced by**

**the University of Missouri-Columbia**
**The School of Natural Resources**
**Gaylord Memorial Laboratory**

Copies can be ordered through Gaylord Memorial Laboratory, Route 1, Box 185, Puxico, MO, 63960. The cost (including shipping and handling) is $10.00 per copy.

# TABLE OF CONTENTS



# CHAPTER 1. INTRODUCTION

Lowland hardwood wetlands occupy the floodplains of many rivers of the southeastern United States and are prevalent throughout the Mississippi Alluvial Valley (MAV). These forested wetlands are characterized by variable precipitation, fluctuating water regimes, low water velocity and extensive lateral flooding. Lowland hardwood wetlands, in general, are productive ecosystems that have a variety of habitats for wildlife and are particularly important as breeding and wintering sites for 8 species of waterfowl.

Despite awareness that forested wetlands have great wildlife value, lowland hardwood forests have been, and continue to be, drained and cleared. The original 25 million acres of lowland forest in the MAV were reduced to about 5.0 million acres by 1978. An estimated 100,000 acres have been cleared annually since 1978, leaving about 4.5 million acres of lowland hardwood forest in 1992. Extensive losses of forested habitat have important implications for waterfowl and other wetland wildlife because the MAV is a prime wintering area for mallards, encompasses the major breeding and wintering area for wood ducks and provides a multitude of habitats for herps and mammals as well as many birds other than waterfowl.

Forested areas throughout the MAV have been leveed and then flooded to make foods such as acorns and other seeds available to waterfowl. Forested sites within these levees are called greentree reservoirs (GTRs) because flooding normally occurs during the dormant season. Thus, trees survive the period of dormant flooding and when floodwaters are withdrawn they continue to develop foliage and survive the growing season. GTR management was originally developed to create more dependable habitats for waterfowl in the fall. The majority of sites were developed for hunting by attracting early migrating ducks before natural flooding occurred. This management scenario compensated for variable fall precipitation and provided more flooded forest habitat early in the season for ducks. Where extensive drainage has occurred in lowland hardwood forests, GTRs often provide the only habitat consistently available to migrating and wintering waterfowl.

GTR flooding differs from natural flooding regimes because the manipulations by design do not duplicate natural flooding (Fig. 1). Typically, these forested habitats are flooded earlier and at depths greater than would normally occur under natural flooding from fall or winter rainfall. These alterations in hydrology impact ecological structure and function of lowland hardwood wetlands. Characteristically, leveed sites remain flooded for longer periods and often at greater depths than unleveed sites. These modifications in hydrology cause changes in the diverse flora and fauna that are adapted to normal seasonal and long-term fluctuating water regimes.

Long-term productivity in GTRs has been compromised as a result of modifications in the natural flooding regime. Early and prolonged flooding to greater depths during the dormant season and flooding into the growing season are associated with vegetation changes, lack of regeneration, decreased mast production, tree mortality and disease.

Maintaining productivity in GTRs and providing quality hunting opportunities require information to mimic natural water regimes. This need is particularly important as lowlands continue to be cleared, drained and subjected to an ever increasing number of perturbations. The body of knowledge on lowland hardwood wetlands has increased rather rapidly in recent years, and covers subject areas such as nutrient cycling, decomposition, invertebrate ecology,

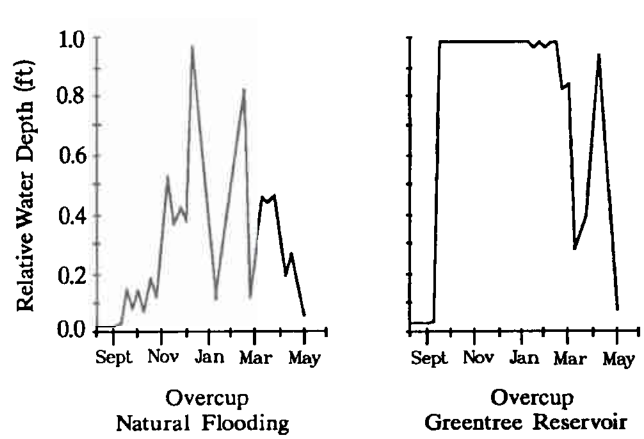
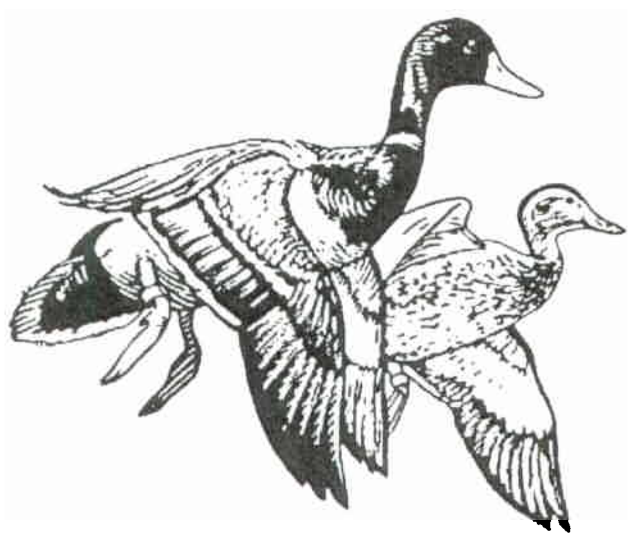



Fig. 1. Comparison by month of relative water depth (ft) between a naturally flooded southern forest and a greentree reservoir in southeastern Missouri (after Heitmeyer et al. 1989).

productivity and wildlife use. However, this new information is scattered among many outlets or in a form not readily available to or usable by managers. The primary objective of this handbook is to provide a synopsis of current information to managers as well as a conceptual approach to management of GTRs. The focus is on manipulations to enhance wildlife benefits via hydrological approaches and not on forest management. A future handbook is planned to address the complex issue of forest restoration and regeneration.



# CHAPTER 2. HISTORY AND RATIONALE FOR GREENTREE RESERVOIR MANAGEMENT

Historically, 8 species of migrating and wintering waterfowl were attracted to lowland hardwood wetlands primarily when shallow flooding made food and cover available. Seasonal and long-term natural flooding in lowland hardwood forests normally occurred between late fall and spring depending on variations in precipitation cycles. Because of variability in timing, depth and duration of flooding, waterfowl use also was variable within and among seasons.

In the late 1930s, development and management of forested sites were initiated on an area known as Grand Prairie near Stuttgart, Arkansas. These forested sites were leveed and flooded to provide waterfowl hunting opportunities during fall and winter. Because flooding was normally restricted to the dormant season, most trees survived among years, thus the name GTRs. GTRs were unique to Arkansas for a few years, but the success of this management technique in providing excellent hunting led to construction of GTRs throughout the South. By 1963 most states in the MAV, as well as states in the Northeast and Southeast, had established GTRs.

Development of a GTR requires levee construction or some modification to the natural drainage of a forested wetland in order to hold and manipulate water. Typically, GTRs are flooded in relation to a specific date based on timing of the waterfowl hunting season. They are usually filled rapidly and in most cases, if water is readily available, they are flooded to full pool as soon as possible (Fig. 1). The early thinking was that GTRs also should be drained immediately following waterfowl hunting season to protect trees from flooding stress and mortality. Early management trials in Arkansas determined that consistent flooding beyond the dormant season resulted in "dead tree reservoirs" or "stick reservoirs" because most trees were intolerant of extended annual flooding into the growing season.

## CONDITIONS AND BENEFITS IMMEDIATELY FOLLOWING DEVELOPMENT

Effects of modified flooding on survival and vigor of trees, mast production and regeneration of mast producing species have been of concern since the first GTRs were developed in Arkansas. Evaluation of effects of modified flooding within the first 10 years of reservoir development suggested that managed flooding did not have detrimental effects on tree growth, provided water was removed before the growing season. In some cases modified flooding associated with GTRs produced benefits, such as increased waterfowl use, greater acorn production, increased radial growth in trees and fire protection (Table 1).

One of the greatest benefits of GTR management was the increase in waterfowl use during fall resulting from the provision of a consistent

Table 1. Benefits and problems associated with greentree reservoir management and operation.

| Benefits | Problems |
|---|---|
| Initial increase in use by waterfowl | Decline in waterfowl use over time |
| Increase in viable acorn production | Decline in acorn production for some oak species |
| Initial increase in radial growth for some tree species | Decrease in radial growth for some tree species |
| Increase in fire protection | Lack of regeneration of desirable mast species |
| Control of timing and duration of flooding | Burrowing animals compromise levees; beavers alter flooding regimes |
| Consistent supply of food and cover in fall | Flooding stress, disease, morphological changes and tree mortality |
| Acorns available sooner and longer; invertebrates larger in size, available sooner and longer | Lower plant species diversity and plant community changes to more water tolerant forms; possibly lower invertebrate species diveristy |

food supply. Following development of GTRs at Noxubee National Wildlife Refuge, foods, primarily acorns and invertebrates, were available to support waterfowl populations. Soon after development, ducks were attracted to managed sites in greater numbers than to unmanaged sites lacking the potential for shallow flooding.

Another benefit soon after development was an apparent increase in acorn production. For example, acorn production improved in a Missouri GTR after 4 years of flooding compared to an adjacent site that was flooded naturally. The Missouri GTR, subjected to earlier and deeper flooding, had greater numbers of sound acorns with lower rates of insect infection. Apparently, continuous fall and winter flooding adversely affected survival of nut weevil larvae. Thus, acorn damage from the nut weevil was reduced on sites with GTR management.

Managed flooding also benefitted timber resources. A 50% increase in radial growth over a 5-year period has been documented after impounding a lowland hardwood forest in Mississippi. Increased radial growth resulted from raised water tables and more favorable moisture conditions during the growing season. Increased moisture in fall also provided fire protection. Typically, fire hazard is high in fall and early winter and the presence of water reduces the fire potential of these forested areas.

GTR management provides food and cover and has the potential to enhance habitat for ducks, as long as flooding is restricted primarily to the dormant season. GTRs have attracted waterfowl and provided hunting opportunities without apparent adverse effects on the forest during the first 8-10 years of managed flooding.

## LONG-TERM CHANGES AND APPARENT PROBLEMS

After 10 or more years of annual flooding, benefits associated with initial development of GTRs decrease and long-term problems become more evident (Table 1). One of the first problems associated with GTRs is the decline in waterfowl use. As waterfowl use declines, long-term effects of modified flooding on tree growth, acorn production and regeneration of desirable plant species for wildlife become more obvious.

Although GTRs continue to attract ducks after many years of flooding, managers consistently agree that waterfowl use declines. Acorn production is one possible factor related to declining duck use because acorn production is less consistent among years after a GTR has been in operation for several years. Furthermore a shift in species composition to trees that do not produce mast or species that produce large acorns (i.e., overcup oak) also reduces the potential for providing small acorns for ducks.

Recent studies have shown that after long periods of flooding some tree species have modified or reduced growth rates in GTRs. Nuttall oak, for example, had reduced bole growth in a Mississippi GTR that was flooded annually for 15 years.

Regeneration of desirable mast producing over-story species is a very important component of GTR management, but the modified flooding regimes characteristic of most GTRs complicate regeneration processes. For example, in Missouri GTRs numerous pin oak acorns germinate, but few seedlings survive longer than 1–3 years because of a combination of effects including shading, flooding that overtops new seedlings during the dormant season and sedimentation. Thus, water management becomes a key feature in the regeneration process because suitable conditions must be created for regeneration and long-term productivity of soils. These factors include adequate light and water regimes conducive to regeneration.

Oak wilt stress of certain red oak species has been identified in GTRs, but the extent of this disease is poorly documented. Additional stress, resulting from sedimentation, abnormal morphological growth (basal swellings) and altered physiology, contribute to insect and disease problems associated with mortality or reduced vigor of trees commonly found in GTRs. Although dormant season flooding did not have apparent impacts on the physiology of pin oaks in Missouri, continuous flooding decreased reproductive fitness and resulted in premature leaf abscission in fall. Furthermore, the herbaceous community of the forest floor typically shifts from a diverse community mixed with annuals and perennials to a perennial dominated flora. Important moist-soil seed producers may be reduced in older GTRs and monocultures of poison ivy are common.

Beaver are an increasingly important problem in GTRs because they can have rapid and drastic effects on flooding regimes. The construction of levees and annual fall flooding has provided key habitat requirements for beaver. Beaver activity is particularly detrimental when their dams impede water movement in late winter and early spring. Water that remains on GTRs after leaf expansion and well into the growing season often results in tree mortality, flooding stress and gradual change in tree composition from oak dominated forests to scrub/shrub swamps.

The benefits of GTR management diminish as impacts that modify the structure and function of lowland hardwood wetlands become apparent after 10 or more years of annual, modified flooding. In recent years, understanding the processes that influence long-term productivity of GTRs is becoming increasingly important to mediate adverse impacts of intensive management.

## CURRENT VALUES

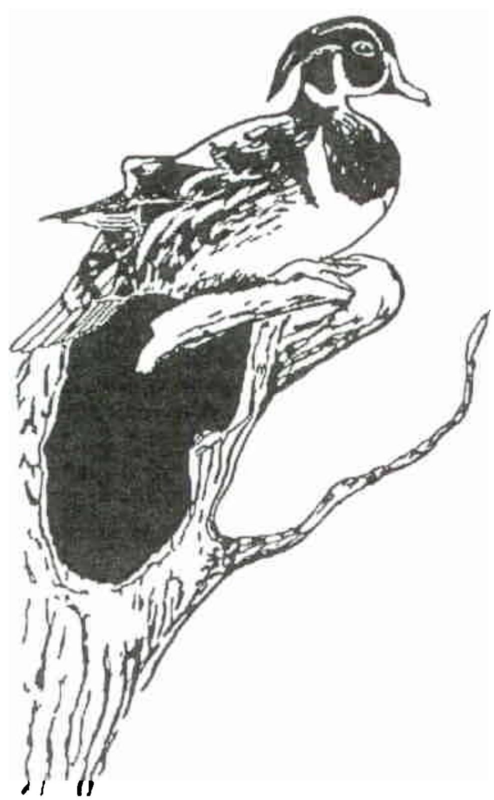
Only about 17% of the original forested acreage remains in the MAV today because extensive areas of lowland hardwood forests have been converted to agriculture. In addition to losses in area, lowland hardwoods have been impacted further by perturbations including: grazing, overcutting, sedimentation, agricultural chemicals and modified hydrology. GTRs have been used in recent years to mitigate the loss of waterfowl habitat through construction of flood control projects.

The original purpose to provide a reliable supply of food and cover for migratory and wintering waterfowl continues to have great value today. Despite declining waterfowl use of GTRs that were developed 10 or more years ago, these intensively managed habitats continue to provide important resources for waterfowl because these reservoirs are often the only forested habitat with suitable water at the time ducks arrive in fall.

Furthermore, the recently recognized value of forest macroinvertebrates as proteinaceous foods for mallards and wood ducks also contribute significantly to the value of GTRs. The numbers and biomass of macroinvertebrates that occur regularly in GTRs in fall are greater than on naturally flooded sites. Water control in GTRs allows managers to select timing and availability of macroinvertebrates, as well as plant foods.

GTRs continue to supply critical habitat and food requirements for many waterfowl and other wildlife adapted to lowland hardwood wetlands. The need to mediate negative impacts of long-term problems of GTR management and loss of bottomland hardwoods was a primary impetus for this handbook. In succeeding chapters we address specific topics to assist managers in maintaining the values of GTRs.

Nevertheless, certain sites that continue to be flooded naturally should be protected from development. Their functions and values for multiple benefits including waterfowl habitat are best achieved without developments. If nature is working, our recommendation is to protect the habitat from changes that would compromise its natural functions.



# CHAPTER 3. FORESTED WETLAND ECOLOGY

Forested wetlands are most beneficial to waterfowl when adequate water, food resources and cover are available. Optimizing the value and use of forested wetlands for waterfowl requires knowledge of hydroperiod, wetland structure and function. A successfully managed GTR must have conditions that meet the social, nutritional and physiological needs of migratory and wintering waterfowl. The type, quality and distribution of food and cover in GTRs should be guided by the same resources that are present in naturally-flooded forested habitats.

## WETLAND MODEL

Lowland hardwood wetlands occupy floodplains that border many of the major rivers in the MAV. These wetlands are transitional habitats between truly aquatic and terrestrial communities. The river systems, surrounding uplands and the lowland hardwood wetlands are integrally linked by hydrology and because of this linkage, lowland hardwood wetlands provide valuable resources for wildlife .

A conceptual model of lowland hardwood wetlands depicts four components that are related to waterfowl values (Fig. 2). These components are surrounded by a dashed line to suggest the transitional nature of forested wetlands and to account for water and nutrient movements into and from the system. Dynamic changes in the amount of organic material, nutrients and energy among seasons and years are characteristic of lowland hardwood wetlands.

Biological, physical and chemical factors have important influences on lowland hardwood wetland dynamics and productivity (Fig. 2). Biological factors such as parasites, pathogens, predators and plant composition influence waterfowl directly, or indirectly by affecting wetland communities. Wetland community structure is influenced by abiotic (physical and chemical) factors including hydrologic regime, water quality, climate, fire, soil nutrients and ground water table. Hydrologic regime, ground water table and climate determine the extent and timing of waterfowl use in lowlands because of the dynamics of flooding, length of growing season and growing conditions. These factors directly influence the amount and type of food and cover available during the annual cycle. Hydrologic and climatic factors affect soil and water chemistry, which in turn influence decom-

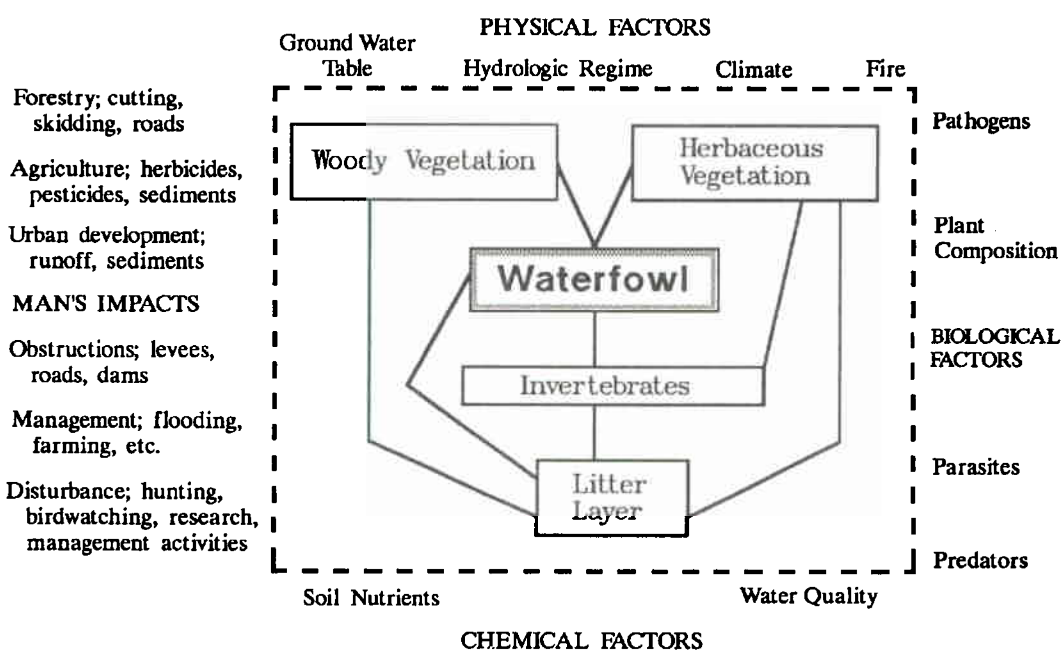



Fig. 2. Wetland model for lowland hardwood wetlands depicting the influence of physical, chemical, biological, and man-impacted factors on wetland function.

position, nutrient cycling and productivity of lowland hardwood wetlands.

Other factors strongly influencing wetland dynamics are related to mans' activities and include: agricultural practices resulting in sedimentation; accumulations of herbicides and pesticides; construction of roads, levees and canals; and management practices such as flooding, drawdowns, farming and timber harvest.

### Waterfowl

Lowland hardwood wetlands are regularly used by migrating and wintering waterfowl because of abundant and diverse food, cover and water resources. Waterfowl represent important vertebrate consumers that exploit wetland areas, and therefore are central to our model of lowland hardwoods. Species commonly encountered in the MAV include: wood duck, mallard, hooded merganser, northern pintail, green-winged teal, gadwall, ring-necked duck and Canada goose. These species of waterfowl (and other wildlife) are closely associated with and influenced by 4 components of lowland hardwood wetlands depicted in the wetland model (Fig. 2): herbaceous vegetation, woody vegetation, forest litter and wetland macroinvertebrates. The interaction of waterfowl and these 4 biological components with the physical, other biological and chemical factors as well as man's activities provide a basis for understanding waterfowl use of lowland hardwood wetlands and for enhancing management opportunities.

### Herbaceous Vegetation

Herbaceous vegetation (e.g., moist-soil plants and aquatic macrophytes) provides cover, energy and nutrient requirements for waterfowl as well as an important substrate for macroinvertebrates. Plant foods that attract waterfowl are produced on exposed mudflats when surface water disappears during natural drawdowns in spring or summer or after a managed drawdown. Different types of moist-soil plants grow in relation to the timing of water removal. Hydroperiod, weather, plant succession, plant competition, seed banks and/or propagule availability are factors influencing establishment of herbaceous plants in forest openings.

### Woody Vegetation

Woody vegetation is composed primarily of trees, but also includes shrubs and woody vines. This vegetation provides food for waterfowl in the form of acorns and soft mast (e.g., samaras, drupes). Trees of significance as acorn producers are members of the red oak group: pin, Nuttall, willow, water and cherrybark oak. Red maple, elms, ashes and tupelo are important for producing soft mast.

Woody vegetation also provides cover for broods, and trees serve as roosting and nesting sites for waterfowl. Scrub/shrub habitat is ideal cover for wood duck broods, as well as cover for migratory species. The larger cavity nesting species, such as wood ducks and hooded mergansers, require oak trees with a dbh of at least 26 inches for cavity formation in the bole of the tree. Some species, such as sycamore and willow, form cavities when diameter at breast height (dbh) is only 14-16 inches. Woody species with a dbh as small as 3 inches provide suitable cavities for other cavity nesters such as tufted titmice, Carolina wrens, Carolina chickadees and prothonotary warblers.

### Forest Litter

The forest litter layer constitutes the organic material that is present on the forest floor and is formed by deposition of dead wood, tree leaves and herbaceous vegetation. This layer is important for several reasons and represents a key factor in productivity of lowland hardwood wetlands. The fungi and bacteria associated with the litter layer are key components resulting in the release of energy and nuturients. Thus, accumulated litter from woody and leafy components is an important source of energy and nutrients for lowland hardwood wetlands. The litter layer also provides a substrate for a community of specialized macroinvertebrates. These macroinvertebrates aid in the decomposition and nutrient cycling process by feeding on the litter that has the bacteria and fungi. Waterfowl not only consume plant foods from woody and herbaceous vegetation, but macroinvertebrates associated with the litter layer are important in their diets.

### Macroinvertebrates

Macroinvertebrates occur in a variety of lowland habitats including: seasonally-flooded impoundments with moist-soil plants, small and large tree openings in forested areas, marshes, drainage ditches, canals, barrow ditches, tree cavities (e.g., mosquitoes) and most prominantly

Table 2. Classification of major bottomland macroinvertebrate species based on tolerance or avoidance of drought[a].

| Overwintering residents | Overwintering spring recruits | Overwintering summer recruits | Nonwintering spring migrants |
|---|---|---|---|
| Aquatic worms | Dytiscids | Damselflies | Hemipterans |
| Leeches | Hydrophilids | Dragonflies | Some dipterans |
| Amphipods | Midge larvae | Midge larvae | Midge larvae |
| Isopods | Marshflies | Shore flies | Some odonates |
| Crayfish | Horseflies | | |

[a] Tolerance or avoidance of drought is defined as follows (after Wiggens et al. 1981):
Overwintering residents. These animals are capable of passive dispersal only and overwinter as drought-resistent cysts and eggs or as juveniles or adults.
Overwintering spring recruits. These animals must reproduce in the spring before surface water disappears. They aestivate and overwinter as eggs or larvae, but as adults in some beetle species.
Overwintering summer recruits. These animals can enter basin after surface water disappears. They overwinter as eggs or larva within the egg matrix.
Nonwintering spring migrants. These animals enter surface water in spring. Adults of subsequent generations leave basin before drydown and overwintering is in permanent water.

in the litter layers associated with the continuum of forest zones of lowland hardwood wetlands.

Macroinvertebrates associated with the litter layer are dominated by isopods, amphipods, freshwater worms (oligochaetes), midge larvae (chironomids) and fingernail clams (Appendix 3). Long-term hydrologic regimes in lowland hardwood wetlands (every 4-6 years) have shaped adaptive life history strategies of these macroinvertebrates. These strategies are related to seasonal flooding, dynamic water fluctuations within and among years, and are based on adaptations of macroinvertebrates to tolerate or avoid drought (Table 2). Macroinvertebrate adaptations require one or more of the following characteristics: 1) withstand drought in the egg, pupal, larval, or adult stage; 2) exhibit rapid growth; 3) produce numerous offspring; 4) complete their life cycle within 1 year (wet season); and 5) posses high mobility.

The ability to withstand drought is a characteristic shared by several lowland hardwood macroinvertebrate species and is of importance to managers. Several invertebrates, including marsh flies and mosquitoes, produce drought resistant eggs. Freshwater worms use mucosal secretions to survive drought, while midge larvae aestivate in cocoons. Fingernail clams resist dessication because of their shell, but also burrow into the litter layer to avoid predation, disease and drought. Isopods and amphipods have no morphological adaptations to resist drought, but will aestivate as adults or juveniles, and appear to find adequate moisture during the dry season within the deeper litter layers.

Because of the dynamic nature of the flooding regime in lowland hardwood wetlands, macroinvertebrates that grow rapidly while water and nutrients are available have an advantage. Furthermore, producing a large number of offspring and completing the life cycle within the water year allows for greater success. When water levels decline, species that are not adapted to survival during drought must avoid dry conditions. Successful strategies used by these species include high mobility; either moving to deeper water within the basin or emigrating from the basin (Table 2). Beetles and true bugs, in particular, survive drawdowns by having an aerial dispersal to more permanent waters.

## TYPES OF FLOODING AND IMPORTANCE OF HYDROPERIOD

The timing, extent and duration of flooding in lowland hardwood wetlands is quite variable not only within a season (short term) but also over longer periods (cycles of approx. 4-6 yrs.). Typical flooding usually occurs from late fall to late spring as precipitation increases; while little or no flooding occurs from late summer to early fall.

Lowland hardwoods characteristically are subjected to fluctuating water levels that occur as puddling, backwater and flash flooding. Puddling is the most frequent form of flooding and occurs as local rainfall fills small depressions in the forest floor (Fig. 3). Some puddles form during the growing season but high rates of evapotranspiration usually remove shallow surface accumulations rapidly. During the dormant

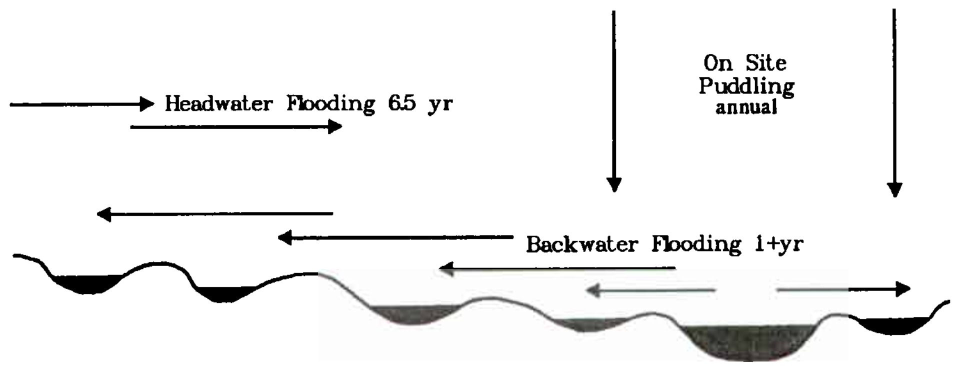



Fig. 3. Three common types of natural flooding in lowland hardwood wetlands puddling occurs annually, backwater flooding about once each year and headwater flooding every 6.5 years.

season when evapotranspiration is low and when rainfall is greater, puddles usually increase in size as the season progresses. Small puddles join to form larger puddles, and larger puddles gradually increase in size until entire drainage basins are flooded. This filling of entire watersheds is backwater flooding and normally occurs at some time during the annual precipitation cycle. Flash flooding or headwater flooding occurs when 8 or more inches of rain falls within 24 hours. This flooding is less frequent but is important because large amounts of nutrients are imported or exported and drainage patterns may be modified. Furthermore headwater floods in unmodified systems create or destroy individual wetlands and rejuvenate systems for long-term productivity.

Annual variation in precipitation influences timing, extent and duration of flooding, and provides the proximate cues that determine the timing of biological events. Long-term precipitation cycles (4-6 years) also influence characteristics of flooding, but in contrast to annual precipitation variations, long-term cycles provide the ultimate cues that are associated with adaptive strategies of flora and fauna in lowland hardwood wetlands. Thus, hydrology is the major driving force that impacts structure (e.g., vegetation and soils) and function (e.g., processes such as decomposition, nutrient cycling) in lowland hardwood wetlands.

## WETLAND STRUCTURE

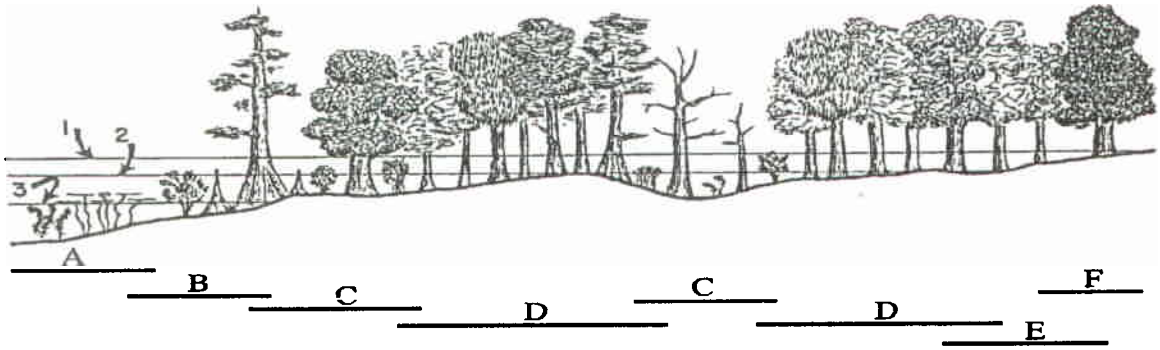
### Vegetation Profile

Tree dominated plant communities that occur where soils are either saturated or inundated with water seasonally or temporarily are referred to as lowland hardwoods. The interaction of slight elevational changes and flooding produces a mosaic of vegetation zones or forest types. Patterns of woody vegetation occur in response to a flooding regime because differences in timing, depth and duration of flooding have an important influence on the germination, establishment, growth and survival of plants.

Changes in plant composition occur in a definite pattern from the lowest to highest elevations (Fig. 4). The lowest sites that are flooded longest, most frequently and to the greatest depths are dominated by species such as baldcypress and water tupelo. Permanent flooding, however, may reduce vigor and prevent regeneration. With a small elevation increase and a slight decrease in flooding depth, overcup oak, red maple and water locust are dominant. Less water-tolerant species such as pin oak, willow oak and sweetgum are distributed where flooding generally is restricted to the dormant season. At higher elevations where flooding is shallow and infrequent, cherrybark oak, sugarberry and hickories are present. Woody species have a range of tolerances for flooding (Table 3). Some species can tolerate dormant season flooding but are intolerant of very short periods of flooding during the growing season, whereas others can tolerate flooding of their root crowns for more than 6 months. Structure and composition of lowland forests are also influenced by shade tolerance of woody species (Table 4). Understanding these characteristics is critical to developing forest management strategies.

### Canopy Gaps

Lowland hardwood communities are dominated by woody vegetation, but openings of various sizes within the forest provide an abun-




| Duration of Flooding | Herbaceous Plants | Woody Plants |
|---|---|---|
| (A) Permanent | Water Milfoil<br>Watershield<br>American Lotus | Common Baldcypress |
| (B) Semi–permanent Water | American Lotus<br>Duckweed<br>Swamp smartweed | Common Baldcypress<br>Water Tupelo<br>Water Elm<br>Buttonbush |
| (C) 3 to 8 Months | Swamp smartweed<br>Lizard's Tail<br>Sticktights<br>Arrowarum | Common Baldcypress<br>Overcup Oak<br>Red Maple<br>Waterlocust<br>Possumhaw Holly |
| (D) 1 to 6 Months | Lizard's Tail<br>Sticktights<br>Sedge | Overcup Oak<br>Willow Oak<br>Pin Oak<br>Cherrybark Oak<br>Sweetgum<br>Blackgum Tupelo |
| (E) 0 to 2 Months | Spotted Snapweed<br>Nettle<br>Giant Cane<br>Nightshade | Sweetgum<br>Blackgum Tupelo<br>Sugar Hackberry<br>Shagbark Hickory<br>American Elm<br>Swamp Chestnut Oak |
| (F) Once in 10 Years | Spotted Snapweed<br>Nettle<br>Giant Cane<br>Wildrye<br>Pokeberry | Sweetgum<br>Sugar Hackberry<br>Shagbark Hickory<br>White Oak<br>Flowering Dogwood |

Fig. 4. Typical lowland hardwood vegetation profile showing 1) maximum flooding depth, 2) mean annual dormant season flooding depth and 3) mean annual low water depth during the growing season.

dance of other vegetation that also has value for waterfowl. Openings range in size from single trees to those of considerable area. Such openings often are created by natural processes such as severe wind, lightning, disease, stress or beaver activity or are related to man's activities including agriculture or development of roads, levees or ditches. Waterfowl foods associated with forest openings include moist-soil seeds, tubers and macroinvertebrates. Plant communities associated with these openings provide food for a variety of wildlife.

Table 3. Flood tolerance scale[a] for major tree species occurring in bottomland hardwood wetlands. (After McKnight, et al. 1980).

| Intolerant | Weakly tolerant | Moderately tolerant | Tolerant |
|---|---|---|---|
| Red Elm | Cherrybark oak | Green Ash | Carolina Ash |
| American beech | Water oak | Swamp Cottonwood | Pumpkin Ash |
| Black cherry | Willow oak | Sweetgum | Buttonbush |
| Flowering dogwood | White ash | Sugarberry | Bald cypress |
| Eastern hophornbean | Eastern cottonwood | Red maple | Pond cypress |
| Paw Paw | Winged elm | Nuttall oak | Water elm |
| Sassafrass | Black tupelo | Overcup oak | Water tupelo |
| | Shellbark hickory | Pin oak | Swamp privet |
| | Pecan | River birch | Black willow |
| | Black walnut | American elm | |
| | Live oak | Hawthorne | |
| | American holly | Water hickory | |
| | American hornbeam | Laural oak | |
| | Southern magnolia | Water locust | |
| | Red mulberry | Loblolly pine | |
| | | Persimmon | |
| | | Honey locust | |
| | | Sycamore | |
| | | Slash pine | |
| | | Pond pine | |
| | | Sweetbay | |
| | | Possumhaw | |

Tree species underlined are selected species in Appendix 1.
[a] Flood tolerance scale defined as follows:
Intolerant. Cannot survive even short periods of flooding into the growing season and have no adaptations for low oxygen levels.
Weakly tolerant. Survive flooding into growing season for a few days or weeks, but trees do not develop adaptations for low oxygen levels. Not tolerant of any flooding above the root crowns during the growing season but flooding for 1 month annually may occur regularly during the dormant season.
Moderately tolerant. Survive and grow in saturated conditions for several months of the growing season, but mortality exists if flooding persists. Some adaptations for living in low oxygen. Many tolerate flooding for 1 to 3 months, part of which occurs during the growing season.
Tolerant. Survive and grow in saturated soil conditions for long periods of time and have adaptations for living in low oxygen environments. Some species can survive continuous flooding but they regularly tolerate 6 months of inundation annually including parts of the growing season.

Table 4. Shade tolerance scale[a] for major tree species occurring in bottomland hardwood wetlands. (After McKnight, et al. 1980).

| Very intolerant | Intolerant | Moderately tolerant | Tolerant | Very tolerant |
|---|---|---|---|---|
| E. cottonwood | Sweetgum | Green Ash | Red elm | Sugarberry |
| Black willow | Nuttal oak | S. cottonwood | Red maple | Am. beech |
| Sandbar willow | Pin oak | Overcup oak | Buttonbush | Am. holly |
| | Water oak | Caronlina ash | Am. elm | Possumhaw |
| | Willow oak | Pumpkin ash | Winged elm | Hornbeam |
| | Cherrybark oak | White ash | Water elm | Mulberry |
| | River birch | Bald cypress | Persimmon | Paw Paw |
| | Honey locust | Pond cypress | Swamp privet | |
| | Water locust | Black tupelo | | |
| | Live oak | Silver maple | | |
| | Pond pine | Water hickory | | |
| | Slash pine | Sweet bay | | |
| | Sassafras | Swamp chestnut oak | | |
| | Black walnut | Laural oak | | |
| | | Loblolly pine | | |
| | | Sycamore | | |

Tree species underlined are selected species in Appendix 1.
[a] Shade tolerance scale is defined as follows:.
Very intolerant. Cannot survive under full shade. No adaptations for low light conditions
Intolerant. Decreased growth under full shade; will not survive if shaded conditions persist. Few adaptations for low light conditions.
Moderately intolerant. Survives under full shade, but does best with partial shade. Some adaptations to low light conditions.
Tolerant. Survive and grow under full shade. Adapted to low light conditions.
Very tolerant. Optimal growth under full shade. Fully adapted to low light conditions.

Undoubtedly these openings played an important role in waterfowl ecology before European immigrants disrupted the forest. On Mingo National Wildlife Refuge, 5% of the forest area is in single-tree openings. These small openings are largely associated with the loss of large trees from the canopy. Extrapolation of these figures to the MAV suggest that as much as 1.25 million acres might have been in natural small openings before agricultural development.

## Wetland Complexes

The variety of wetland habitats, along with the mosaic of forest types, provides a unique complex of wetland types along the flooding gradient (Fig. 4, Table 5) available for wildlife. Benefits to wildlife are high when good wetland conditions exist on adjacent habitat types. No one wetland type provides all the required resources for waterfowl or other wildlife; thus, the presence of several habitat types within a 10 mile radius ensures conditions that potentially influence survival and reproduction of waterfowl.

## Soil Characteristics

Compared to adjacent upland forest soils, lowland hardwood soils generally have more organic matter, higher percentages of clay particles, poor drainage and greater water holding capacity, poor aeration and greater redox potentials and are more fertile. Not all lowland soils possess all the above attributes, and some lowland soils may, for example, have lower percentages of clay or be less fertile than upland soils. But it is important to point out that lowland soils are distinctly different from upland forest soils and this difference is largely related to flooding.

Flooding causes marked changes in the chemical, physical and biological nature of soils and produces a unique soil environment where sediments, nutrients and organic matter are transported or deposited, and where anaerobic conditions (absence of oxygen) can occur.

Deposition of inorganic sediments and nutrients occurs with flooding. Sediments, particularly in areas having minimal flows are comprised chiefly of clay particles. Clay particles influence soil properties, such as drainage, water holding capacity and nutrient exchange. Nutrients, metal ions and pesticides may be attached to clay particles and thus are transported and deposited with sediments. This becomes important to managers when GTRs are in close proximity to agricultural fields, a potential sediment source containing pesticides.

Table 5. Timing and duration of flooding in lowland hardwood habitat types in southeastern Missouri.

| Habitat type | Length of flooding | Flooding depth[a] Oct | Dec | Mar |
|---|---|---|---|---|
| Scrub/Shrub | | | | |
| Dry year | Oct-Jun | M | D | D |
| Wet year | Continuous | M | D | D |
| Overcup/Red Maple | | | | |
| Dry year | Oct-May | S | M | D |
| Wet year | Sept-July | M | M | D |
| Pin Oak/Overcup | | | | |
| Dry year | Dec-May | Dry | S | M |
| Wet year | Nov-Jun | Dry | M | M |
| Pin Oak/Sweetgum | | | | |
| Dry year | Jan-May | Dry | Dry | M |
| Wet year | Nov-Jun | Dry | S | M |
| Pin Oak/Shagbark Hickory | | | | |
| Dry year | Jan-Apr | Dry | Dry | S |
| Wet year | Nov-May | Dry | S | M |

[a]S = Shallow < 4 inches
M = Moderate 4–18 inches
D = Deep > 18 inches

Deposition of organic matter also occurs. Organic matter may be from litterfall or transported from other sites in flood waters. Regardless of the source, a portion of this organic matter is incorporated into the soil. Soil organic matter holds nutrients in a form unavailable for plants until released by decomposition.

Lowland soils can be anaerobic or aerobic depending on the extent and duration of flooding. Soils permanently or extensively flooded may develop anaerobic conditions. When oxygen is depleted, soil properties change and result in slower decomposition rates, nutrient limitation to plants and altered pH. Soils that are flooded occasionally may alternate between anaerobic and aerobic conditions.

## Soil Types

Like plant communities, soil types can be distinguished based on the interaction of slight elevational gradients and flooding characteristics. Permanently flooded soils are anaerobic, are poorly to very poorly drained, have high percentages of clay particles and have strongly reducing environments (evidenced by gleying). At slightly higher elevations flooding is

Table 6. Differences in pH, exchangeable bases and nutrient concentrations between overcup oak/red maple and pin oak/ sweetgum forest types in Southeastern Missouri.

| Forest type | pH | Ca | Mg | K | N | P |
|---|---|---|---|---|---|---|
| | | cmol(+)/kg | | | mg/kg | |
| Overcup oak/ red maple | 4.35 | 7.65 | 5.06 | 0.23 | 2685 | 750 |
| Pin oak/ sweetgum | 4.00 | 1.92 | 1.24 | 0.17 | 1905 | 555 |

semipermanent and soils are anaerobic more than they are aerobic, poorly drained and composed mostly of clay and silts. At seasonally flooded sites where flooding depth and duration decrease, soils still alternate between anaerobic and aerobic conditions, but aerobic conditions persist. High redox conditions are evident, clays and silts predominate and soils are poorly to somewhat poorly drained. For those soils that are rarely or temporarily flooded, aerobic conditions prevail, drainage is good, more silts than clays are deposited and reducing conditions are not evident.

Lowland soil types form a mosaic (like plant communities) and it is important to note that soils, even in close proximity, can have different characteristics. In Missouri lowland hardwoods, for example, soils associated with overcup oak/red maple types (semipermanent flooding) were less acidic and had significantly higher concentrations of nutrients compared to soils associated with pin oak/sweetgum forest types (seasonal flooding) (Table 6).

## WETLAND FUNCTION

### Decomposition

Decomposition is the breakdown of plant and animal litter that accumulates on the forest floor. The ultimate products of this breakdown process are nutrients and carbon dioxide. These products are reused and result in ecosystem productivity. The rate of litter decomposition is determined by factors such as moisture, oxygen, temperature, pH and litter quality.

Moisture, in the form of flooding, has a major impact on decomposition rates in lowland wetlands where conditions range from continuously flooded to rarely flooded. Several studies on lowland sites have suggested a relation between flooding frequency and decomposition rate. Litter decomposition rates in the Great Dismal Swamp of Virginia are more rapid on extensivley flooded and frequently flooded sites (e.g., cypress, maple-gum) than on occasionally and rarely flooded sites (e.g., cedar, mixed hardwood) (Table 7). This should not imply that increased flooding frequency or duration always leads to increased decomposition rates because factors other than flooding are important.

Table 7. Annual decay constants (-k)[a] for seasonally-flooded sites in the Great Dismal Swamp. The sites are listed in order of decreasing extent of flooding (after Day 1982).

| Litter type | Site | Annual decay constant |
|---|---|---|
| Mixed | Cypress | 0.587 |
| | Maple/gum | 0.509 |
| | Cedar | 0.348 |
| | Mixed hardwood | 0.341 |

[a] $-k = \ln(X/Xo)/t$ The larger the k value, the greater the rate of decomposition.

The amount of oxygen in soil (and overlying water) also influences decomposition of litter. Litter on continuously aerated soils tends to have more rapid decomposition rates than on soils that are partly or continuously anaerobic. Litter breakdown also proceeds at a faster rate in spring and summer than winter, indicating that warm temperatures promote decomposition. Many potential decomposer organisms are inactive or at least less active when soil pH is less than 5.0. Thus, as pH levels drop, decomposition rates also are lowered.

Decomposition is also influenced by the type or quality of the litter. In Missouri, decomposition of various litter types (e.g., tree leaf species) on the same site and under similar environmental conditions (e.g., moisture, oxygen, temperature, pH) was markedly different (Fig. 5). Red maple leaves decompose (k = 0.956) more than twice as quickly as overcup oak leaves (k = 0.456). This difference is largely related to the greater amounts of materials (e.g., tannins, lignins) in oak leaves that are resistent to decay or inhibit detritivore activity. Oak leaves on these sites have greater amounts of tannin (10% vs 5% in red maple) that produces a leaf that "tastes bad" and therefore is not readily consumed by invertebrate detritivores.

Under ideal conditions, more rapid rates of decomposition occur when litter, composed of easily digested and decomposable material, is exposed to a warm, neutral (pH) environment that alters between wet/dry flooding cycles with soils that are continuously aerated. Although

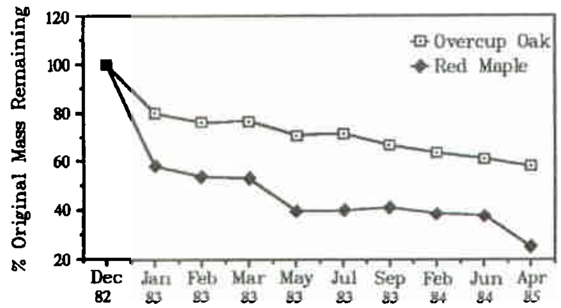



Fig. 5 Decomposition of overcup oak and red maple on naturally flooded sites in southeast Missouri.

ideal conditions are seldom met, conditions that decrease decomposition rates should be avoided when possible.

Decomposition involves 3 main processes that occur more or less simultaneously: leaching of soluble substances (e.g., organic matter, nutrients), physical fragmentation by flooding or feeding activites of detritivores; and mineralization of organic matter and nutrients by microbes (fungi, bacteria). The pattern of decomposition in lowland wetlands can be described by an initial, rapid loss of weight, followed by a more gradual weight loss over time (Fig. 5). The initial weight loss is attributed primarily to contact of litter with floodwaters and subsequent leaching of soluble organic material and physical fragmentation of litter by flooding. Not only is organic material leached, but nutrients may also be lost when floodwaters contact litter (e.g., as much as 90% of k). Nutrients and organic matter lost during this time are available for immediate plant or microbial uptake. The gradual weight loss is primarily the result of fragmentation by detritivores and microbial activity. Nutrients and organic matter are gradually released over time.

## Nutrient Cycling

The cycle of nutrients within the forest (intrasystem cycle, Fig. 6) and between the forest and surrounding areas (input and output, Fig. 6) is an important process affecting productivity. Nutrients are found in 4 major compartments: 1) atmosphere (rain, dust), 2) soil and rock minerals, 3) organic matter (living organisms, dead remains) and 4) available soil nutrients.

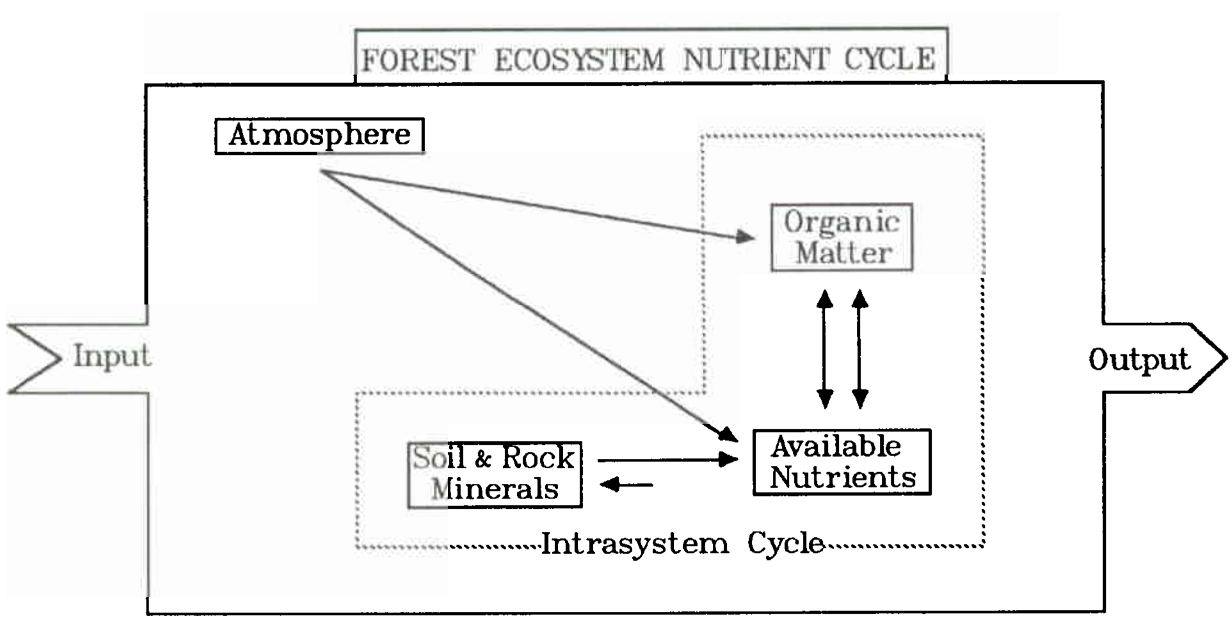



Fig. 6. Forest ecosystem nutrient cycle showing major nutrient pathways, inputs and outputs composed of geologic and biologic components. Intrasystem cycle depicts exchanges between organic, available nutrient and soil and mineral pool.

This last compartment or nutrient pool contains fewer total nutrients than other compartments, but it is the one that directly supplies nutrients required for growth and production in forests.

An important part of forest nutrient cycles is the movement of nutrients within the intrasystem cycle (Fig. 6). The cycle represents exchange of nutrients among compartments linked to the litter and soil surface. Nutrient movement within the intrasystem cycle is the result of uptake of nutrients by plants, release of nutrients from plants by leaching, release of nutrients from organic matter by decomposition and chemical and physical reactions that convert insoluble nutrient forms of rocks and soils to soluble (and usable) forms in the available nutrient pool.

Nutrient cycles, in general, are self regulating in that an increase in movement of nutrients along one pathway is compensated for by adjustments in other pathways. This regulation results in a more or less perfect cycle, where inputs balance outputs. Disruption of the cycle occurs when nutrient losses (output) are accelerated, thereby impacting productivity.

Forested wetland nutrient cycling differs from upland forest nutrient cycling in one important way. In uplands, land and water have definite boundaries and nutrient cycles in mature forests lose only small amounts of available nutrients in drainage waters (i.e., conservative or 'tight' nutrient cycles). However, land and water are not readily separable in forested wetlands and consequently nutrient cycles tend to be "leaky," or large amounts of readily available nutrients can be lost. Such losses are compensated by greater nutrient inputs and nutrient subsidies via floodwaters.

Not all forested wetland nutrient cycles are similar, because hydrologic regime influences nutrient dynamics. Forested wetlands associated with flowing water release greater amounts of nutrients than do some seasonally-flooded or still-water wetlands (Table 8). Sites with flowing water have greater nutrient inputs from fluvial sources which tend to compensate for nutrient losses from litter export, denitrification and other losses. In forested wetlands with less water flow and more dependence on atmospheric nutrient input, nutrient conservation and retention mechanisms prevent large losses of nutrients.

Table 8. Influence of hydrologic regime on nitrogen return to the forest floor in forested wetlands.

| Hydrologic regime | Site | Nitrogen return kg/ha/yr |
|---|---|---|
| Flowing water | Alluvial swamp, North Carolina | 73 |
| Seasonal flooding | Lowland hardwood, Missouri | 62 |
| Stillwater | Cypress stand, Georgia | 26 |

A couple of nutrient conservation and retention mechanisms have been suggested for lowland hardwood wetlands. Some nutrients, particularly nitrogen and phosphorus, may be immobilized by microbes in leaf litter in the fall. These nutrients, tied up in microbial biomass, may be held for several months and then mineralized and absorbed by filamentous algae or duckweed in winter or early spring. These nutrients are released by dying plants and taken up by trees and shrubs at leafout in early to late spring (i.e., nutrients move from organic matter pool, to available pool and back to organic matter pool, Fig. 6). This mechanism retains nutrients on site with little net loss. Timing and duration of flooding controls these nutrient processing mechanisms. Thus, the timing and types of drawdown influence nutrient movement from the system.

Many lowland tree species have shallowly rooting depths and thus produce very dense mats of rootlets near the soil surface. These dense mats may extract nutrients from overlying waters following leaching of litter in the fall or when microbes mineralize litter. These dense root mats may also exchange nutrients with the soil organic matter or silt and clay particles. In either case, these root mats help to retain nutrients on site.

## Trophic Dynamics

Primary producers are the link between consumers (e.g., waterfowl) and the energy and nutrient resources for any ecosystem. There are 2 pathways whereby resources from primary producers are passed on to consumers. Direct consumption of herbivores by consumers results in the grazer food chain. Use of dead plant litter by detritivores constitutes the decomposer or detrital food chain. The detrital food chain appears to be the most important pathway in lowland hardwood wetlands.

Litterfall production in lowland wetlands is comprised of leaves, twigs, fruits, flowers, etc., with the leaf component accounting for 70-80% of all material reaching the forest floor. Litterfall reaches a peak in autumn. This autumn "pulse" of litter often coincides with flood events. As leaves come in contact with water or moist-soil, organic matter and nutrients leach from the leaves (Fig. 7). At this stage of decomposition leaf material is referred to as coarse particulate organic matter (CPOM > 1mm) and is readily colonized by microbes. This colonization by microbes increases the nutritive quality of CPOM for detritivore consumers such as macroinvertebrates. The litter layer in lowland wetlands is dominated by a detritivore based community. Macroinvertebrate members of this community can be classified according to the feeding mechanisms they employ (Table 9). Shredders, including isopods and amphipods, commonly feed on the CPOM colonized or "conditioned" by microbes (Fig. 7). Shredders, by their feeding activities, fragment CPOM and reduce its size, producing fine particulate matter (FPOM, .5u - 1mm) in the process. Feces from all detritivores also become FPOM (Fig. 7).

The FPOM produced is now available to 2 distinct groups of collectors (Table 9). Collector-filterers, such as fingernail clams, have feeding mechnisms that allow them to filter FPOM suspended in the water column. Collector-gatherers (e.g., midge larvae) feed primarily by gathering FPOM from sediment or substrate surfaces. Collector feeding activities further reduce particle size and produce additional FPOM or smaller dissolved organic matter (DOM, <0.5 u) or particles resistant to further decay that become incorporated into wetland soils. Macroinvertebrates, such as predaceous diving beetles, are important predators on both collector groups and shredders (Fig. 7).

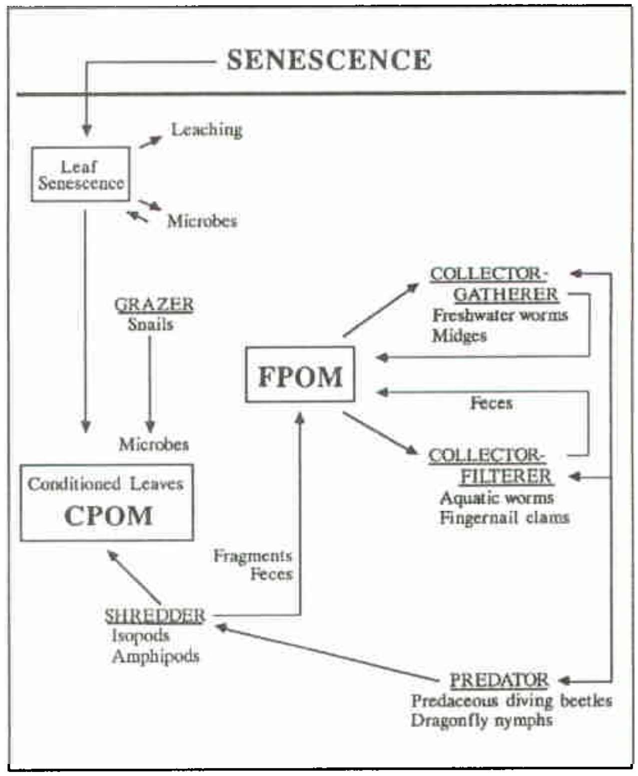



Fig. 7. Invertebrate functional groups of detritus based system.

Dissolved organic matter is also produced when organic molecules (e.g., tannic acids, sugars) are leached from leaf litter at the time the material is inundated with floodwaters. DOM and leached nutrients are resources used directly by microbes, algae and protozoa that

Table 9. Classification of major bottomland macroinvertebrate species based on feeding mechanisms[a].

| Shredder | Collector-gatherer | Collector-filterer | Predator | Scraper (grazer) |
|---|---|---|---|---|
| Amphipod | Midge larvae | Fingernail clam | Damselfly | Snail |
| Isopod | Hydrophilid | Midge larvae | Dragonfly | Midge |
| Cranefly | Midge | Horsefly | Dytiscid larvae | |
| Moth larvae | | Water boatman | Gyrinid adult | |
| | | Oligocheate | | |

[a] Feeding mechanism defined as follows (after Merritt and Cummins 1978):
Shredders. Herbivores living on plant tissue or detritivores decomposing plant tissue (CPOM) primarily by chewing.
Collector-filterer. Herbivore-detritivore living on algal cells or decomposing organic matter (FPOM) primarily by filter or suspension feeding.
Collector-gatherer. Detritivores living on decomposing organic matter (FPOM) primarily by sediment or deposit feeding.
Scrapers (or Grazers). Herbivores living on algae and associated material on plants, primarily by scraping plant surfaces.
Predators. Carnivores living on whole animals or parts, and cell and tissue fluids primarily by swallowing prey or by piercing tissues and sucking contents.

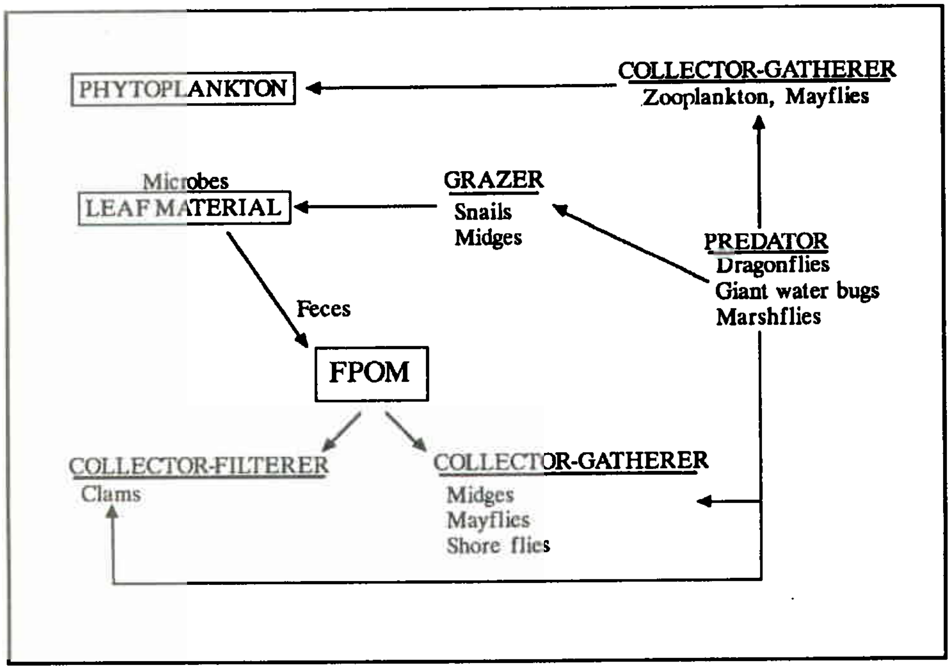



Fig. 8. Invertebrate functional groups associated with moist-soil habitats in forested wetland complexes.

colonize CPOM. These lower trophic organisms serve as a nutrient link to macroinvertebrates that consume the microbially-rich detritus. In turn, macroinvertebrates are an important nutrient link to vertebrate consumers like waterfowl that forage in the litter layer for protein-rich food.

In contrast to the detritivore based macroinvertebrate community associated with forest litter, the moist-soil and aquatic plant communities found in lowland areas are represented primarily by a grazer food chain (Fig. 8). Grazing organisms such as snails and midge larvae feed on microbes associated with plant litter, and a collector-gatherer group (e.g., zooplankton, mayflies) feeds directly on algae, an important primary producer. Grazing communities are dominated by insects and snails rather than crustaceans associated with detrital communities (Fig. 9).

## Productivity

Primary productivity is the process by which plants convert the sun's energy into chemical energy and is measured as a rate (i.e., so much organic matter is produced per given area per unit of time, such as lb/acre/yr). Most estimates of primary productivity are given as net biomass production which is the production of all vegetative parts of a plant during a time interval.

Net biomass production in lowland hardwood wetlands is strongly influenced by flooding

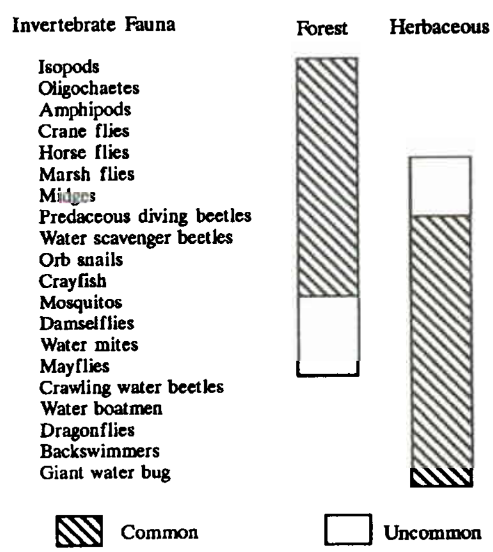



Fig. 9. Comparison of macroinvertebrate fauna in forested and herbaceous wetlands within a forested wetland complex.

regime. Slow water movement and seasonal flooding result in higher net biomass production relative to still water habitats or those that have been drained (Fig. 10). Litterfall production (material falling to forest floor only) appears to follow the same trend, increasing flood frequency yields higher litterfall rates.

Differences in this pattern occur when environmental factors (e.g., climate, temperature), nutrient availability (e.g., phosphorus), species composition (monocultures vs mixed stands) or management (flooding vs drawdown) become more important than the natural hydrologic regimes in controlling net biomass or litterfall production. For example, management alterations that result in changes in frequency, timing or depth (too much or too little) of flooding may reduce litter production in lowland hardwood wetlands. A dynamic water regime is essential in the maintenance of high productivity.

## WETLAND DYNAMICS AND PULSES

Clearly, hydrology is an important factor influencing lowland hardwood structure and function. Plant communities and soil properties of lowland hardwood wetlands depend on the hydrologic regime. Productivity, decomposition, trophic dynamics and nutrient cycling are strongly affected by naturally fluctuating waters. Seasonal, annual and long-term water cycles are dynamic or pulsed, and these irregular pulses represent selection pressure that shape community structure, soil characteristics and rates of various ecosystem functional processes.

Water pulses may be regarded as a regenerative process not unlike the cycle that occurs in prairie marshes. In prairie marshes, a water cycle (approximately 7-10 years) results in the Type IV marsh progressing from dry-dense-hemi-open marsh to open water. The continually flooded condition of open water leads to a decline in productivity. Thus a regeneration is needed, and occurs during droughts or seasonal drying when nutrients are released from the marsh litter and made available. In a similar manner, lowland hardwoods are regenerated by water and nutrient pulses which result in fast growth and consumption of available energy and nutrients. Unlike prairie marshes, if a flooding

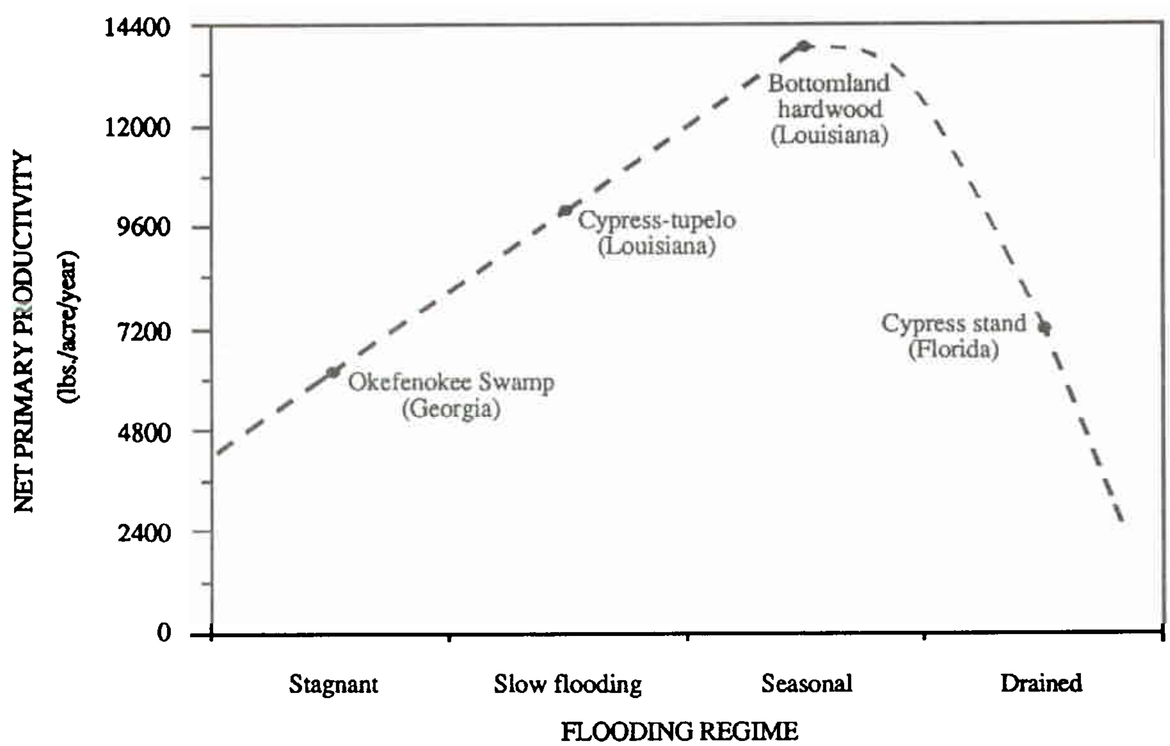
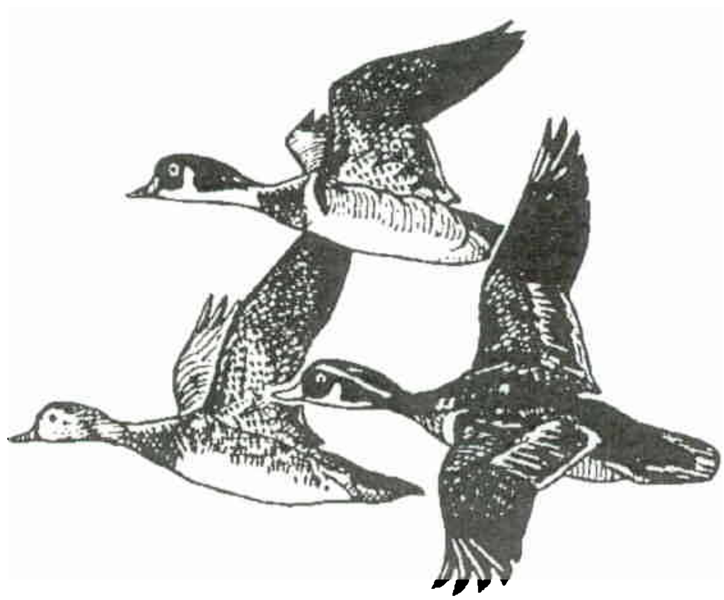



Fig. 10. Relation of net primary productivity to flooding regime.

regime is altered by man in a bottomland forest (either through management or perturbation) damage to trees and soil may be severe and regeneration may take many years.

To maintain high productivity in lowlands, fluctuating water regimes are essential. Herein lies a problem with the goals of GTR management because the normal flood management is usually 1) on a specific calendar date, 2) to a predetermined depth and 3) for a specified time. The challenge to management is to emulate a natural flooding regime while continuing to provide forested habitat for waterfowl and other wildlife, as well as conditions suitable for hunting.



# CHAPTER 4. WETLAND WILDLIFE

Many mammals, birds, amphibians and reptiles use lowland hardwood wetlands because of high productivity, diversity of habitats and moderate climate. These wetlands provide food, cover, nesting sites, winter hibernacula, and refuge as well as migration and dispersal routes. Old levee ridges, for example, are essential for egg-laying activities of many amphibians, snakes and turtles. Seasonally inundated forests provide valuable food resources and space for spawning fish. Mammals typical of uplands can find food and escape from predators in lowland hardwood forests. Wintering birds are attracted to abundant food supplies, such as mast, other seeds and fruits.

Many wildlife species that use resources in lowland hardwood wetlands are adapted to this diverse habitat and the dynamic flooding regimes associated with these wetlands. Fluctuating water levels among different zones of vegetation that are characteristic of lowland hardwoods provide numerous habitats and ecological niches that maintain high species diversity. GTR management is particularly important to waterfowl because lowland hardwood forests are traditionally used by ducks during fall migration, winter and spring migration. Eight waterfowl species regularly use lowland hardwood wetlands for varying periods each year including hooded merganser, gadwall, Canada goose, northern pintail, green-winged teal, ring-necked duck, mallard and wood duck.

## WATERFOWL

### Annual Events

Ongoing events in the annual cycle necessitate that waterfowl acquire energy and nutrients above a maintenance level. Waterfowl that regularly use lowland hardwoods experience some or all of the following biological events: fall-winter molt, pairing, winter-spring molt, fat reserve deposition, egg laying, incubation, brood rearing, summer molt, postbreeding dispersal, staging and spring and fall migration (Table 10). Many of these biological processes require different levels of energy and compositions of nutrients obtained from foods in many different habitats. Resident species, such as the wood duck, that spend their entire annual cycle in lowland habitats can satisfy all requirements for their biology from within the lowland hardwood system.

Most migratory waterfowl undergo at least portions of 4 or 5 of these major biological phenomena during the 5–8 months on the wintering area. Timing of these events and the geographic location where they are undertaken varies within and among species. Species differences reflect tribal (e.g., divers vs dabblers) associations and body size adaptations; whereas differences within species are related to age, sex, social status, physiologic condition, habitat and weather.

### Breeding Waterfowl

Habitat Segregation

Hooded mergansers and wood ducks are present in lowland hardwoods of the MAV throughout the year, although neither species is common in the upper portion of the Valley during winter. Both species regularly occur in the same geographic locale, but the 2 are segregated by differences in specific habitat use and feeding ecology.

Hooded mergansers use deeper, more permanently flooded sloughs, backwaters and rivers, dead tree habitats, beaver ponds, scrub/shrub and overcup oak sites in flooded forests. Much use of these different wetland types by hooded mergansers appears to coincide with seasonal dynamics of crayfish abundance and availability.

Wood ducks use similar deep water habitats in lowland hardwoods upon arrival at the breed-

Table 10. Life history events in the annual cycle of migratory waterfowl.

| |
|---|
| Spring migration |
| Reproduction |
| Prelaying-endogenous lipid reserves |
| Laying-endogenous or exogenous proteins |
| Incubation |
| Brood rearing |
| Summer molt |
| Postbreeding dispersal |
| Staging |
| Fall migration |
| Pairing |
| Molt |
| Endogenous reserve deposition (migration and reproduction) |

ing areas; however, during prelaying and laying, wood ducks forage extensively in shallowly flooded live forests where macroinvertebrates occur in abundance (Fig. 11). Females with their newly hatched broods use shallowly flooded forests for several weeks while these habitats are flooded in wet seasons before concentrating their use in deeper scrub/shrub habitats with dense cover.

Wood Duck Breeding Strategy

Regardless of the specific habitat, wood ducks are usually associated with dense overhead cover. Wood ducks arrive on breeding grounds at southern latitudes without the reserves necessary for egg laying. They must consume enough high energy foods to accumulate an adequate endogenous reserve of visceral fat that provides the lipids necessary for a clutch of eggs during the prelaying period (Table 10). Lipids come from sources such as the fruits of elm, ash and maple; acorns; and seeds of buttonbush, water shield and other aquatic plants. As follicle development begins, female wood ducks shift their diets to acquire greater proportions of animal foods that provide protein. Major protein sources are aquatic and semiaquatic macroinvertebrates such as amphipods, isopods, gastropods, insects and spiders (Table 11).

## Nonbreeding Waterfowl

Migratory Waterfowl

Five species of waterfowl primarily use forested wetlands during spring and fall migration. Canada geese concentrate in the upper portions of the MAV consuming moist-soil seed, browse and tubers along oxbows, river bars and larger open areas within forested wetlands. Gadwalls spend fall, early winter and late spring in scrub/shrub, dead tree and slough habitats in the upper MAV, while spending midwinter in lower portions of the valley in freshwater marshes. Pintails use marshes and single-tree openings and green-winged teals use open marshes, riparian zones, backwater areas and dead-tree habitat during fall and spring stopovers. Ring-necked ducks use the deeper, open marshes and sloughs in fall and spring.

An array of wetland types and food resources within lowland hardwood forests appears to support the needs of some important biological processes of these migratory waterfowl. Maintenance of family bonds, pairing and a partial molt are activities of Canada geese in winter. Some species, like gadwall and green-winged teal, may increase macroinvertebrate consumption during late winter and spring. The increase in invertebrate consumption may be related to energetically demanding events such as molt. Gadwalls, pintail, green-winged teal and ring-necked ducks undergo a fall/winter molt. Other important activities that take place in forested wetlands include courtship and pairing.

Wintering Waterfowl

The major wintering species in lowland hardwoods, mallards and wood ducks, are separated spatially during winter. Wood ducks are uncommon in the upper portions of the MAV during winter. Mallards use upper portions of the Valley throughout winter, with smaller numbers in the lower portions unless temperatures drop to below freezing for long enough to form ice in the north. Furthermore, mallards exploit grain in agricultural fields; whereas wood ducks make limited use of row crops provided that an adequate area of forested wetlands is available. Mallards concentrate on recently flooded openings with shallow depths in forests

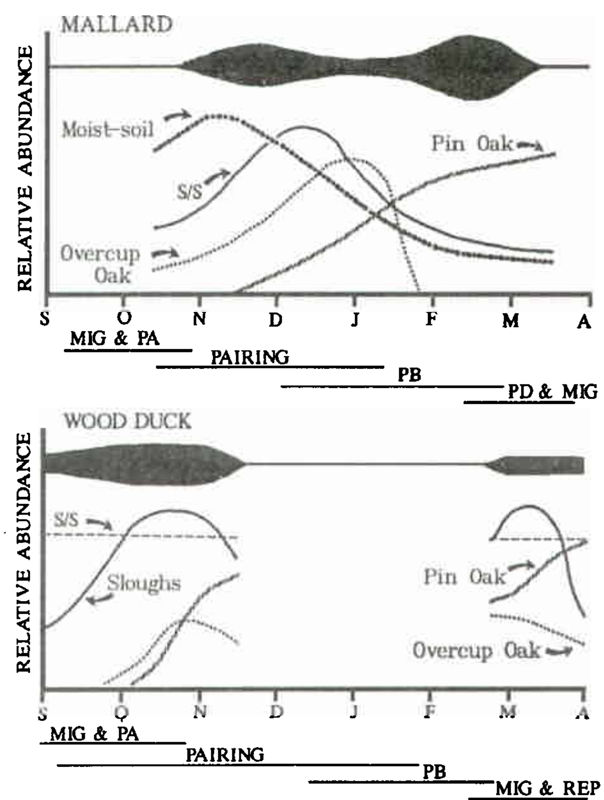



Fig. 11. Habitat use by wood ducks and mallards in southern forested wetlands (after Fredrickson and Heitmeyer 1988).

Table 11. Types, relative abundance and relative biomass of foods associated with lowland hardwood habitats.

| | Cypress/tupelo | Oak dominated live forests | Dead tree | Scrub/shrub | Slough/ open water | Moist-soil |
|---|---|---|---|---|---|---|
| Plant Foods | | | | | | |
| Energy | | | | | | |
| Acorns | | + + +[a] | | | | |
| Samaras (ash, elm, maple) | | + + + | | | | |
| Buttonbush | | | + | + + | + | |
| Watershield | | | + | + | + + + | |
| Millet | | | | | | + + + |
| Sticktights | | | + | + | | + + + |
| Protein | | | | | | |
| Samaras | | + + + | | | | |
| Sticktights | | | + | + | | + + + |
| Animal Foods | | | | | | |
| Protein | | | | | | |
| Annelids | | | | | | |
| Freshwater worms | + | + + + | + | + | + | + |
| Crustacea | | | | | | |
| Sowbugs | + | + + + | + | + | | + |
| Sideswimmers | + | + + + | + | + | | + |
| Insecta | | | | | | |
| Bugs | + | + | + | + | + | + + + |
| Beetles | + | + | + | + | + | + + + |
| Flies | + | + | + | + | + | + + + |
| Gastropoda | | | | | | |
| Pond snails | + | | + | + | + | + + + |
| Orb snails | + | + | + | + | + | + + + |
| Bivalvia | | | | | | |
| Fingernail clams | | + | | | | |

[a]Relative abundance: + + + large number and biomass, + + moderate number and biomass, + small number and biomass.

or in marsh habitats in early fall (Fig. 12). Shortly after arrival, mallards complete prealternate (breeding plumage) molt and consume aquatic insects and moist-soil seeds (Table 10). Following molt, mallards begin courtship and by early January 90% of the birds are paired (Fig. 12). During pairing mallards forage intensively in flooded forests or agricultural fields where they consume acorns and cereal grains (Fig. 12, Table 11). After pairing, mallards readily use shallowly flooded forests in the upper MAV and continue to consume acorns, but increase consumption of macroinvertebrates (Figs. 12 and 13, Table 11). Mallards in the lower MAV are well known for their use of flooded agricultural fields. Once molt begins the shallowly flooded live forests are used heavily.

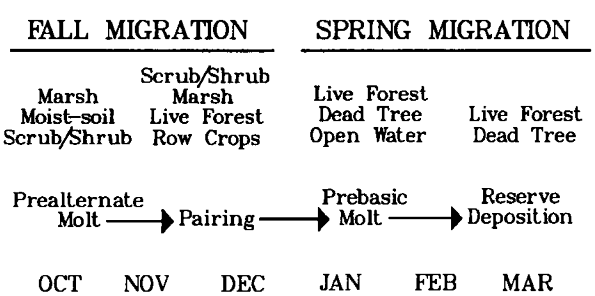



Fig. 12. Biological events and habitats used by wintering mallards between October and March.

Wood ducks use overcup oak, cypress/tupelo forest types and scrub/shrub habitats during fall courtship and pairing (Fig. 11). After pairing, wintering habitat includes the deeper areas of lowland hardwoods; cypress/tupelo, overcup oak and scrub/shrub habitats (Fig. 11).

## Foraging Strategies of Mallards and Wood Ducks

Even though mallards and wood ducks consume some of the same foods in shallowly flooded forests, their morphological adaptations for foraging, their foraging strategies and their feeding modes reduce competition. Wood ducks feed at or slightly below the surface (<1 inch) as well as at the water's edge with pecking-type foraging that is effective for aquatic, semiaquatic and terrestrial invertebrates. Mallards feed by subsurface dabbling to exploit macroinvertebrates associated with the forest litter or those macroinvertebrates that are present deeper in the water (2-8 inches).

### Other Waterfowl Adaptations

Most waterfowl are adapted to the changing food and habitat resources associated with fluctuating water regimes. Energy and nutrient requirements must be met throughout the annual cycle. Waterfowl that use forested wetlands also must cope with the dynamic nature of resource availability and habitat structural features as follows: 1) high mobility which allows them to exploit resources wherever they become available (food resources are generally present somewhere in the MAV, but food availability generally is not predictable at each location), 2) vocalizations (important because visual signals are of limited value in the dense cover that is typical of forested areas; vocalizations tend to concentrate, orient and synchronize birds for courtship and breeding), 3) bright plumage (male wood ducks provide visual signals to conspecifics at close range, but at greater distances the pattern has camouflage features in dense forest cover) and 4) precise homing to nesting areas (wood ducks return and nest in cavities where nesting was successful in previous years).

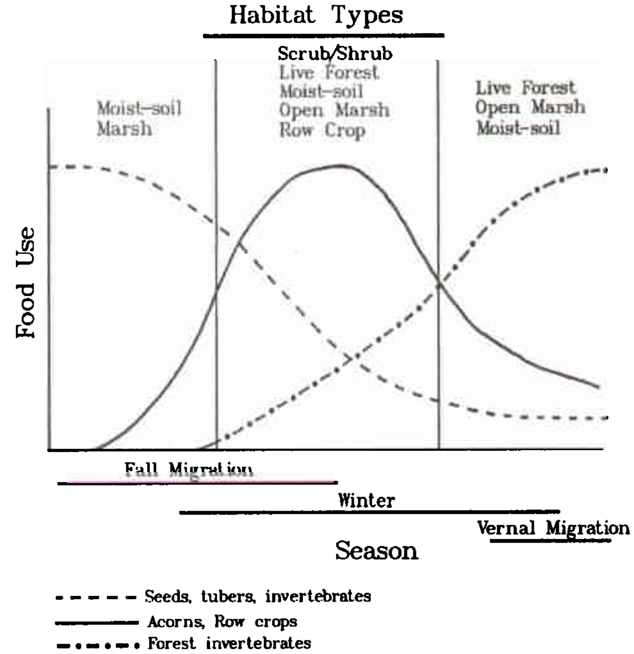



Fig. 13. Mallard food use and habitat preferences during winter in upper portions of the Mississippi Alluvial Valley.

## OTHER WETLAND WILDLIFE

Use of lowland hardwood wetlands is not limited to waterfowl. Other wetland wildlife also exploit resources and are adapted to these wetlands. Lowland hardwoods support a great variety of wildlife because of their dynamic hydrology, habitat diversity, high productivity and favorable climate. Hydrology is a major driving force in the use and adaptation to lowland hardwoods by wildlife. Varying flooding regimes and slight elevational changes provide a habitat continuum supporting a range of aquatic to terrestrial species including canopy dwellers. Although each habitat zone may have characteristic fauna, some habitat zones share several species because many wildlife common to lowland hardwoods are generalists. Opportunistic organisms have great mobility and respond rapidly to changing environmental conditions.

### Fish

Many fish species use the flooded zones of lowland hardwoods during inundation for feeding, spawning and as nursery areas. Catfish, sunfish, gar, perch and sucker families are well represented. Many fish are dependent on annual water level fluctuations inundating the lowlands. Floods provide an expanded area of habitat that reduces competition for food, space and spawning grounds. Floods also influence productivity because of nutrient pulses from floodwater and decomposition of leaf litter. Increased productivity results in a greater biomass of food for fish in the form of invertebrates such as copepods, ostracods, amphipods, isopods, midge larvae, oligochaetes and planaria.

Typical fish fauna in the more permanently flooded zones include redfin and chain pickerel, bowfin, topminnow, killifish, yellow bullhead, warmouth, swamp darter and mosquitofish species (Table 12). Semipermanently flooded areas are often characterized by some of the same species, but also by largemouth bass, brown bullhead, grass pickerel, sunfish and bluegill. In the seasonally and temporarily flooded areas, generalizations are difficult because fish distribution is often determined by duration and timing of flooding. In Missouri, the numerically dominant fish fauna using seasonally-flooded forests include mosquitofish, banded pygmy sunfish, flier and starhead topminnow. However, fish community structure in a year with a wet spring was markedly different from a dry year. A wet spring was dominated by early spawners (sunfishes), while late spring and summer spawners (mosquitofish and topminnow) were dominant in a dry year.

### Amphibians and Reptiles

Several amphibians and reptiles exploit a variety of flood conditions in lowland hardwoods because of diverse life histories (Table 12). The lesser siren, *Amphiuma* (Congo eel), water snakes and cottonmouth, anole and eastern mud turtle are representative of the more permanently flooded forest zones. Several salamanders and frogs also occur in or near permanently flooded areas, including the southern dusky, many-lined and dwarf salamanders and the river, cricket and southern leopard frogs. Depression pools and sloughs in semipermanently flooded areas support breeding sites for spotted and marbled salamanders. The mole salamander is characteristic of seasonally flooded zones. Also dominant in the seasonally flooded zone are leopard and green frogs, box turtles and rat snakes. The copperhead, canebrake rattlesnake, garter snake and spadefoot toad usually are found in temporarily flooded areas, often migrating from drier upland sites. Gray and green tree frogs are aboreal and commonly occur through several of the flooded zones.

### Birds

Avifauna exploit a diversity of habitats within lowland hardwood wetlands (Table 12). Bird distribution is dependent not only on flooding regime, but also successional stage, vegetation height and vegetation layering. The highest diversity and density of birds occur on those sites with advanced succession and greater vertical layering of plants. Because of these factors and the birds' mobility, nesting, summer foraging and winter foraging time periods must also be considered to account for distribution within lowland hardwood wetlands.

Birds representative of permanently flooded zones include the prothonotary warbler, parula warbler, tufted titmouse, red-shouldered hawk, red-winged blackbird, great blue heron, green-backed heron and yellow-crowned night-heron. Herons and egrets breed in permanently-flooded zones and several species have rookeries on these sites. Prothonotary warblers commonly nest in cavities over water, and red-winged blackbirds use buttonbush for nesting.

Many bird species are found in the higher wetland zones within lowland hardwood forests. Seasonally-flooded zones often have barred owls, downy and red-bellied woodpeckers and cardinals; whereas yellowthroats, Kentucky warblers, pine warblers, Carolina wrens, wood thrushes and wood pewees prefer temporarily flooded sites. Likewise, wintering robins are often abundant in temporarily flooded areas consuming the great variety of fruits that are available. Carolina wrens nest in cavities in understory trees, while summer tanagers nest higher in the canopy. Barred owls select nest sites high in large trees with broken tops. Turkeys do well in lowland hardwood wetlands and readily wade through shallow water to reach foraging sites or to escape predators. Wintering grackles and red-winged blackbirds occur in great numbers and feed on oak mast and other foods where surface water is not present.

### Mammals

Beaver, muskrat, mink and river otter are the most aquatic mammals in lowland hardwood wetlands, and all occur in and near permanently flooded areas (Table 12). Raccoon also are found near permanent water, but their activity also extends through the other flooded zones and into the uplands. Small mammals are largely absent from permanently flooded zones. Swamp rabbits, white-tailed deer, cougar, bobcats and gray fox use seasonally and temporarily flooded zones, but tend to concentrate their use on these sites when flooding is not in progress. Swamp rabbits are well adapted to lowland hardwood wetlands and their distribution depends on forested areas of at least 500 acres where small, natural openings are present. These openings provide essential food and cover for swamp rabbit reproduction.

Several small mammals use seasonally-flooded areas including deer, cotton and golden mice and short-tailed and southeastern shrews. Squirrels, because of their arboreal habits, occur throughout the flooded zones, but are especially common in seasonally-flooded areas where oaks are abundant.

## THE ROLE OF WETLAND COMPLEXES

Waterfowl that exploit lowland hardwood forests have diverse requirements for survival and reproduction, and these forested systems provide many of their life cycle requirements. Waterfowl are well adapted to respond to fluctuating waters where they consume foods that are constantly changing in abundance and availability. No single food source or wetland

Table 12. Representative amphibian, reptilian, fish, mammalian and bird faunas in different forest communities of lowland hardwood wetlands.

| Flooding regime[a] | Characteristic forest community types | Flood duration | Fish | Amphibians and reptiles | Birds[b] | Mammals |
|---|---|---|---|---|---|---|
| Permanently flooded (II) | Bald cypress/water tupelo | Usually 12 months except for extreme drought | Topminnow<br>Killifish<br>Swamp darter<br>Bowfin<br>Redfin & chain pickerels | Lesser siren<br>Congo eel<br>Water snakes<br>Cottonmouth<br>Many-lined & southern dusky salamanders | Prothonotary & parula warblers<br>Tufted titmouse<br>Green-backed heron<br>Great blue heron<br>Yellow-crowned night-heron<br>Red-shouldered hawk | Mink<br>Beaver<br>River otter |
| Semipermanently flooded (III) | Overcup oak/water hickory<br>Overcup oak/red maple | 6–8 months, winter, spring & well into growing season | Mosquitofish<br>Topminnow | Spotted, Marbled & two-lined salamanders | Grackle<br>Swainsons warbler | Mink<br>Raccoon |
| Seasonally flooded (IV) | Pin oak/sweetgum<br>Diamond-leaf oak/willow oak | 4–6 months, winter, spring & up to 1–2 months of the growing season | Banded pygmy sunfish<br>Flyer sunfish<br>Mosquitofish<br>Topminnow | Box turtle<br>Rat snakes<br>Leopard frog<br>Mud salamander | Red-bellied & downy woodpeckers<br>Barred owl<br>Cardinal<br>Carolina wren | Swamp rabbit<br>White-tailed deer<br>Golden and cotton mouse<br>Short-tailed shrew |
| Temporarily flooded (V) | Willow oak/cherrybark oak<br>Water oak | 1–4 months, up to 1 month of the growing season | | Copperhead<br>Canebrake rattlesnake<br>Spadefoot toad<br>Mole salamander | Yellowthroat<br>Pine warbler<br>Wood thrush<br>Wood pewee<br>Wild turkey | Cougar<br>Bobcat<br>Gray fox<br>White-tailed deer |

[a] Corresponds to zones II-IV developed by National Wetlands Technical Countil (Larson, et al. 1981).
[b] Exclusive of waterfowl.

type within the lowland hardwood ecosystem provides all the resources required by waterfowl as they progress through the continuum of biological events in the annual cycle. Rather a wetland complex that includes diverse food resources and a mix of wetland types in close juxtaposition provides the greatest benefits to waterfowl. Although waterfowl are central to our wetland model (Fig. 2), the idea of a wetland complex is also important in meeting the needs of all wetland wildlife.

# CHAPTER 5. FOOD PRODUCTION IN GREENTREE RESERVOIRS

Food abundance and availability in lowland hardwood wetlands of the MAV are 2 factors that determine the importance of lowland sites as wintering habitat for waterfowl. A major goal of GTR management is to maximize food production and provide waterfowl the diverse resources required to meet physiologic demands primarily during the winter portion of the annual cycle. Acorns are a primary food associated with southern forested wetlands. Several species of oaks produce small acorns that are a primary component in the fall and winter diets of mallards and wood ducks. Ring-necked ducks, black ducks, pintails and others consume a few acorns. Other waterfowl foods provided by lowland hardwood forests include macroinvertebrates, moist-soil seeds, browse and soft mast such as samaras, berries or drupes. Macroinvertebrates associated with the litter in forested wetlands have recently been identified as an important source of animal protein for egg laying in wood ducks and for molt in mallards. These proteinaceous foods occur more consistently than acorns; thus, macroinvertebrates serve as a reliable food source that attract waterfowl to GTRs, provided shallow foraging sites are available.

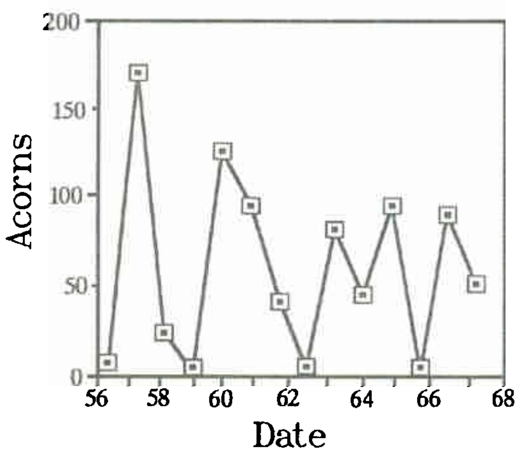



Fig. 14. Annual variation in production of sound acorns (thousands/acre) on naturally flooded sites in southeast Missouri.

## ACORN PRODUCTION

### Variability and Condition

Acorns from the red oak group, including pin, willow, cherrybark, water and Nuttall oaks, are used extensively by waterfowl and other wildlife. Acorn production in lowland oaks naturally exhibits great variation among years. In southeastern Missouri, production of pin oak acorns reaches a low (< 5,000 sound acorns/acre) every 3-4 years (Fig. 14). Acorn production over a 14-year period (1956-1969) ranged from about 2,000 sound acorns/acre (sound acorn = fully developed and usable for wildlife) to 170,000 sound acorns/acre. This variability accounts for a range in acorn biomass from 150 – 7,500 lbs/acre (mean of 2,500 lbs/acre). Similar variability in production occurs in other lowland oak species at other sites in the MAV.

Tree vigor and age are known to influence acorn production. Most red oak species begin to produce acorns at 20-25 years and production tends to fall off during the latter stages of a tree's life. However, the specific cause of the variability in oak acorn production is not known. Factors that might be associated with this variability among years are suggested to be weather related and include: amount of summer precipitation, low spring temperatures, heavy rainfall during flowering or pollination and flooding stress.

Acorns are utilized by waterfowl and other wildlife when they are in good condition (i.e., acorns are fully developed with only minor insect damage). Acorns that are heavily infested with insects or otherwise damaged, deformed or aborted are not readily consumed by wildlife. The primary insect responsible for acorn damage is the nut weevil (*Curculis* spp.)

Nut weevils may also account for some of the variability in acorn production. Weevil infestations of acorns varied from year to year in Missouri pin oak stands, but highest infestations occurred in the poorest production years. Furthermore, production of sound acorns on GTR sites was about equal to naturally flooded sites.

Although overall acorn production is greater on naturally flooded sites, the percentage of insect infested acorns was twice as high (33 or 16%). The reason for fewer insect infested acorns within GTRs is not known, but nut weevil larvae overwinter in the soil, and annual dormant season flooding undoubtedly kills some larvae.

### Stand Density and Structure

Thinning oak stands to produce different stocking rates or tree densities influences acorn production, but results have been varied. After 2–3 years of thinning pin oak stands in Missouri, high density plots (73–86 $ft^2$/acre basal area) had higher production than lower density plots (39 $ft^2$/acre basal area), but after 5–7 years low density plots had higher production. Five years after thinning, tree crowns in low density plots had expanded rapidly because of better lighting and less root competition resulting in trees that became better producers. However, after 12 years no differences existed in acorn production among thinning treatments on naturally flooded areas (Table 13) because the advantage of additional growth on low density plots diminished with time.

Thinning had a negative effect on mast production in Mississippi GTRs. Acorn production of Nuttall oak was half as great as in control areas. Although thinning improved diameter growth on greentree areas, mast production was lower, increased at a slower rate and greater tree mortality occurred. Reduced production and tree vigor may be related to in-

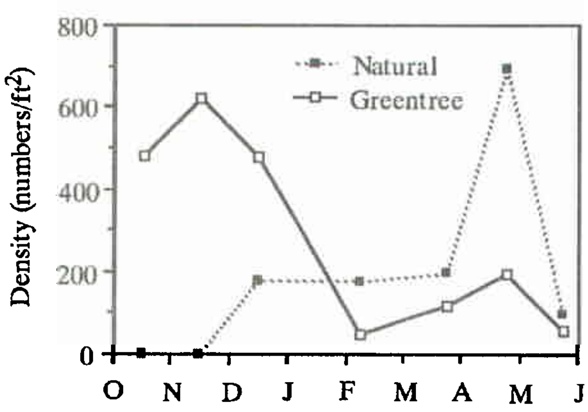



Fig. 15. An example of wetland macroinvertebrate abundance on pin oak-sweetgum forest types with natural and Greentree Reservoir flooding in southeastern Missouri (after Batema et al. 1985).

Table 13. Average annual production of sound acorns per acre by stocking and tree size[a] for natural and greentree areas over 14 growing seasons, 1956–1969 (from McQuilken and Musbach 1977).

| Stocking density | Small-tree plots | Large-tree plots | Mean |
|---|---|---|---|
| Greentree area | | | |
| Low | 314,558 | 396,348 | 355,577 |
| Medium | 296,767 | 366,944 | 331,855 |
| High | 419,823 | 446,016 | 432,919 |
| Mean | 343,716 | 403,020 | 373,368 |
| Natural area | | | |
| Low | 303,933 | 564,871 | 434,402 |
| Medium | 270,080 | 489,011 | 379,546 |
| High | 275,269 | 479,868 | 377,569 |
| Mean | 283,177 | 511,250 | 397,090 |

[a] For greentree plots, stocking density and tree size were both significant ($p = 0.05$). For natural plots, only tree size was significant.

adequately aerated soils as a result of water retention on greentree sites after drawdown.

Structure or size of trees also influences acorn production. Larger (>11 inches dbh) pin oak trees in a Missouri GTR produced more acorns than smaller (5–10 inches dbh) trees. Similarly larger Nuttall oaks in Mississippi produced more mast than smaller trees.

Studies on stand density and site structure in red oaks suggest that alterations in GTR forest stands help maximize acorn production when flooding regimes do not decrease soil aeration. For certain species (pin oak) a high stand basal area can be maintained with frequent thinnings. Thinning treatments have the potential to stimulate rapidly growing trees that develop large crowns. Maintaining oaks at appropriate densities and in age classes (40-75 years) with high acorn production is a good management strategy.

## MACROINVERTEBRATE PRODUCTION

Where long-term hydrologic cycles influence adaptive strategies of macroinvertebrates, their occurrence, growth and production at any given time is determined by short-term water regimes and physical, chemical and biological factors. The presence of macroinvertebrates in lowland hardwood wetlands is apparent soon after inundation by floodwaters, usually within 2 weeks. Peaks in abundance (Fig. 15) and biomass are often dramatic and short-lived as macroinvertebrates respond to fluctuating water levels and release of nutrients from flooded leaf litter.

This general response or "pulsing" of macroinvertebrate populations, although variable among years, may be typical of invertebrates that exploit fluctuating waters and nutrient-rich detrital resources. Nutrients and organic matter are rapidly leached from leaf litter upon initial contact with floodwaters. Limnological studies in Missouri have documented rapid increases in nutrient concentrations in the water column shortly after forest floor litter is flooded, followed by a decrease during the winter months, and then another increase in nutrient concentrations in spring. Macroinvertebrate numbers and biomass (also plankton and fish) quickly follow the same trends noted for nutrients within the water column. For waterfowl species that exploit macroinvertebrates as a food source, these invertebrate responses also seem to coincide with waterfowl use of lowland habitats (Figs. 11 and 13, pages 22 & 24).

Macroinvertebrates are adapted to naturally fluctuating water regimes, but these regimes are altered by GTR management. Modified flooding usually results in rapid flooding at an earlier date, more stable water levels and rapid dewatering. Limited information is available on the influence of prolonged flooding on invertebrate populations; however, GTR management has both positive and negative effects (Table 14).

As a result of early annual flooding in GTRs, macroinvertebrate populations appear earlier, more consistently and in greater numbers in fall relative to naturally flooded sites. Thus, a macroinvertebrate food base is available for waterfowl in GTRs before other sites are flooded naturally. Furthermore, studies have indicated that individual invertebrates tend to be larger on GTRs than naturally flooded sites. A potential disadvantage of GTR flooding is the possibility of long-term changes in the macroinvertebrate community. GTRs have a lower species diversity, and the invertebrate community structure is less complex compared to naturally flooded sites. Greater numbers of invertebrates are not always desirable because some invertebrates are indicators of degraded habitats (i.e, a high number of oligochaetes may be present), but the diversity of prey and available prey biomass may be low. Furthermore, certain indicators of poor water quality such as the rat-tailed maggot appear on some greentree sites. These organisms are indicators of low oxygen levels in water, and commonly occur in GTRs in the Mingo basin of southeastern Missouri. Low oxygen levels are most likely to occur when GTRs are flooded early in the season or at a rapid rate at anytime. Thus, gradual flooding is recommended to optimize the invertebrate response.

Table 14. Advantages and disadvantages of greentree reservoir management on wetland invertebrate response to flooding.

| Advantages | Disadvantages |
|---|---|
| Stability of food resource | Lower species diversity |
| Greater fall macroinvertebrate density | Shift in community structure |
| Ability to manipulate population levels | Presence of poor water quality organisms |
| Greater biomass for individual species | Lower spring macroinvertebrate density |
| | Potentially lower density of terrestrial invertebrates |

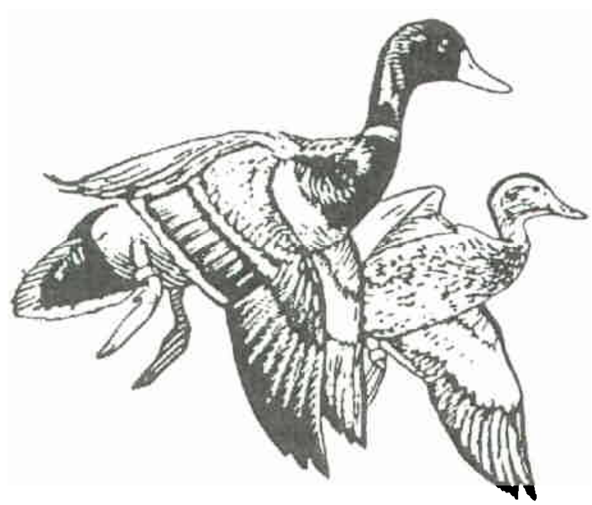
## PRODUCTION OF OTHER FOODS

Acorns are a primary food source for waterfowl in lowland wetlands, but production is highly variable among years. Macroinvertebrates are an important source of protein for wood ducks during reproduction and for mallards in preparation for molt. Although macroinvertebrate production may be more consistent than acorn production, macroinvertebrate availability is short-lived. Other foods associated with lowland hardwood wetlands become more important as waterfowl food resources during years of low acorn production and when invertebrates are unavailable.

Moist-soil plants and some aquatic plants produce an abundance of seeds that are readily consumed by waterfowl. Management strategies, using water manipulations and agricultural techniques (e.g., discing), have been successfully employed to promote germination of moist-soil species that are attractive to waterfowl and other wildlife. Seeds, tubers and browse from moist-soil plants provide important energy and protein requirements for waterfowl.

Fruits and seeds from other tree species represent an additional food resource. Tupelo drupes, samaras from elm, ash and maple; and seeds from woody vegetation, such as buttonbush, provide food resources that may be preferred during some time in the annual cycle of waterfowl. Samaras, for example maple, elm and ash, are a good source of lipids and are consumed regularly by female wood ducks in preparation for laying eggs. Furthermore, some fruits and seeds may be produced more consistently than acorns. Red maple produces a good crop of samaras yearly, and red elm produces abundant seed every 2-4 years.

The importance of terrestrial invertebrates as a food source in lowland hardwoods is overlooked at times. As waters recede in the spring, dry areas are colonized by terrestrial invertebrates. These invertebrates become available to foraging birds when sites are reflooded and are an especially important food in the spring diet of wood ducks.



# CHAPTER 6. GREENTREE RESERVOIR MANAGEMENT: RESPONSES TO WATER AND FOREST MANIPULATION

GTRs were developed to attract waterfowl during fall and winter. Thus, intensively managed GTRs consistently provide important habitats among years because they are flooded from a more dependable water supply than is possible from fall and winter precipitation. However the consistent pattern of early, deep flooding among years is very different than the highly variable flooding characteristic in pristine lowland hardwoods. Modified flooding regimes resulted in conditions that compromised the value of GTR's for target organisms. GTR problems are often associated with waterfowl use and/or tree vigor and mortality. Effects of modified flooding on forest conditions was a concern of managers since the first GTRs were developed. Initially GTRs were drained before trees broke winter dormancy to protect trees from flooding stress. The timing and type of water manipulations that attract waterfowl also have impacts on factors (e.g., decomposition) that determine the productivity of lowland hardwoods. Despite a number of obvious management problems associated with GTRs, carefully managed GTRs can continue to have the potential to enhance habitat conditions for waterfowl and other wildlife (Table 15). Thus, the challenge for managers is to provide resources for wetland wildlife without compromising forest productivity, and minimize interference with ecosystem processes that result in food and cover for wildlife.

## WATER MANAGEMENT

Water manipulation in lowland hardwood wetlands is the most commonly employed technique to provide habitat for migrating and wintering waterfowl. Historically the desired flooding regime for providing waterfowl hunting opportunities begins in September in the upper MAV and November or later in the lower MAV. However, consistent use of a flooding schedule based on the same calendar date among years is undesirable if long-term productivity of the forest is one of the management priorities. In general, changes in leaf color mark the beginning of tree dormancy and indicate the earliest opportunity to initiate fall flooding with minimal impacts on tree vigor and forest productivity. Water manipulations that emulate naturally fluctuating water regimes provide the most diverse habitat for wildlife. When impounded areas are maintained at full capacity, waterfowl have limited access to resources where water depths exceed 12 inches. Thus, well-timed, gradual changes in water level are effective means for providing desirable foraging depths for waterfowl. Emulation of natural

Table 15. Management practices in greentree reservoirs: causes and mechanisms to minimize impacts.

| Impacts | Causes of impacts | Mechanisms to minimize impact | Management practices |
|---|---|---|---|
| Altered hydrology | Constant water levels; water levels too deep | Mimic natural flooding regime; stoplog structure required | Precise water level control |
| Shift to more water tolerant plant community | Water levels too deep; flooding into growing season | Shallow flooding; flooding through dormant season only; stoplog structure required | Precise water level control timing of flooding |
| Loss of productivity | Nutrient loss; nutrients unavailable; reduced decomposition | Mimic natural flooding regime, depth and duration of flooding; stoplog structure required | Control timing of flooding |
| Decreased acorn production | Forest stands too dense | Silvicultural treatment | Thin stands |
| Lack of regeneration | Reduced light; stands too dense | Silvicutural treatment; flooding does not overtop seedlings | Thin stands; unit not flooded deeply year following treatment |
| Decline in waterfowl use | Reduced productivity, food resources; lack of water; monotypic habitat, lack of diversity | Ensure habitat diversity; provide wetland complex | Variable flooding regimes within and among years |

water regimes requires modification of the timing and pattern of fall flooding and spring drawdown among years (Fig. 1, page 1).

## Forest Vegetation

Forest vegetation provides nest sites, protective cover and foods for waterfowl. GTR management influences plant species composition because levees and repetitive flooding schedules modify natural hydrological regimes. Repetitious annual flooding of GTRs differs from the fluctuating hydroperiod of unmodified lowlands and compromises the ecological processes of natural systems (Table 15). For example, sites within levees remain flooded for longer periods and often at greater depths than in unmodified forested systems because they retain water more effectively. Annual flooding with a consistent duration and depth causes a shift in forest vegetation to a more water tolerant plant community. In Mississippi and Missouri GTRs, pin and Nuttall oaks tend to be replaced gradually by the more water tolerant overcup oak. From a waterfowl management perspective, loss of pin or Nuttall oaks is undesirable because of the gradual loss of small acorns and the gradual replacement by more water tolerant oaks (overcup oak) which have acorns too large for use by ducks. To minimize the shift in tree species composition to a more water tolerant forest community, variations in water manipulations are essential within and among years (Table 15).

## Desirable Woody Species Composition

Pin oaks, as well as other oaks that produce small acorns, are desirable for waterfowl because they produce important mast that can be consumed easily. Furthermore, litter from oaks provides a desirable substrate for the invertebrate community. Nevertheless, monotypic stands of oaks do not provide all resources required by wetland wildlife. Trees that sometimes are considered undesirable because they do not produce small acorns may produce other important seeds or fruits for wildlife.

In addition to plant foods or cover, litter from many tree species (red maple, sweetgum, ash, elm, cottonwood, etc.) contribute to ecosystem processes and provide nutrients for invertebrates. Good cavity producing trees such as cypress, blackgum and sycamore do not have seeds valued as food, but nest cavities formed in these species are essential for the cavity nesting wood duck and hooded merganser. Similarly, structural characteristics of lowlands provide habitat components for molt, courting and other behavioral requirements of waterfowl. These values of wetlands are enhanced when forests have a diverse composition rather than a monoculture (Table 15).

## Invertebrate Response

Although long-term effects of GTR management on invertebrate distribution and abundance are unknown, changes in macroinvertebrate populations and communities may be occurring as a result of current management practices (Table 14, page 25). Therefore, emulation of natural flooding regimes may be one way to maintain desirable macroinvertebrate communities in GTRs.

Present knowledge of the effects of timing, depth and duration of flooding suggests that water manipulation can be the single most important element in enhancing macroinvertebrate production. Invertebrate availability for ducks requires: 1) Use of shallow flooding (6 inches or less). Optimal feeding depths for most ducks that use forested wetlands is about 2-10 inches. 2) Partial drawdowns to concentrate or make macroinvertebrates available during periods when waterfowl are present in abundance. 3) Extended or gradual drawdowns to prolong macroinvertebrate availability. These drawdowns produce a "feather edge" that allows ducks to feed extensively on invertebrates during gradual drawdown. 4) Discouraging consistent flooding into the growing season and encouraging effective drainage. Wetland macroinvertebrates are adapted to seasonally flooded areas, and extension of flooding into the growing season or incomplete removal of water may shift community structure to a community characteristic of more prolonged flooding. Alternatively, the semiaquatic and terrestrial invertebrate communities, which also provide food for ducks, can be impacted. 5) Gradual flooding to optimize use of food resources while reducing the potential to make waters anoxic. 6) Maintaining a wetland complex. A GTR must be part of a more diverse wetland community, because diversity of wetland types ensures that a variety of invertebrates are available, even in years of low production. Single tree openings, moist-soil habitats and marshes in association with the forested areas are essential to provide a diverse invertebrate food base for waterfowl.

### Litter and Decomposition

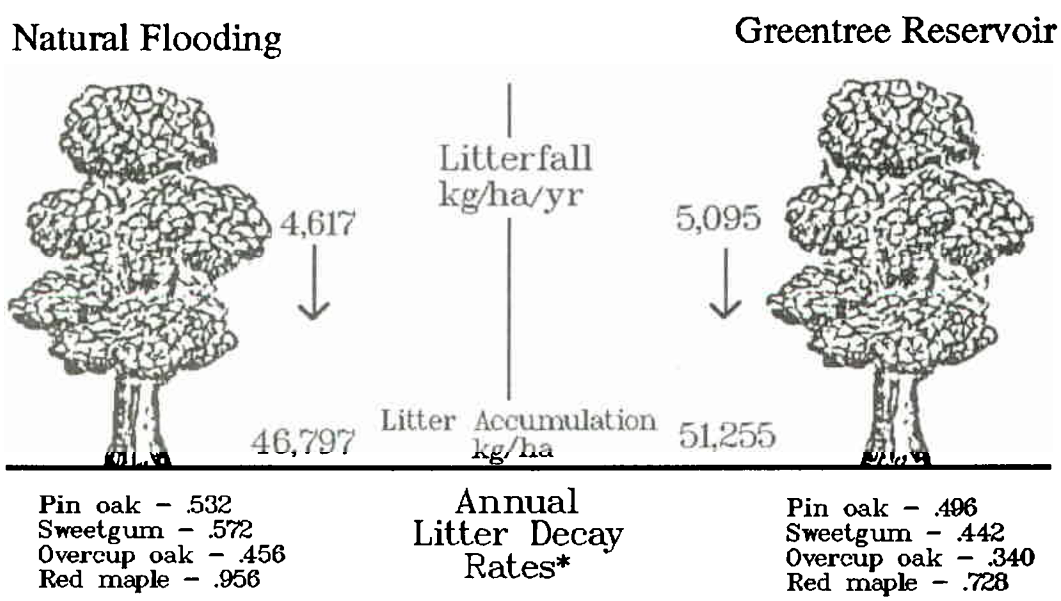
Litter accumulation in lowland hardwoods is an important energy and nutrient source for decomposer organisms and serves as a major component of nutrient exchange with the soil. Large litter accumulations result from slow rates of decomposition and/or high rates of litter production. When litter accumulations become large they are a bottleneck to energy and nutrient flow, and may result in nutrient limitation to plants.

Flooding influences rates of decomposition, litter production and litter accumulation; therefore timing, duration and depth of flooding are critical for effective GTR management. In southeastern Missouri, GTRs had greater litterfall production and slow rates of decomposition and consequently more litter accumulating on the forest floor (Fig. 16). Further nutrient analyses showed that, although nitrogen inputs from litterfall and the amount of nitrogen in the soil were similar, litter on GTR sites contained much more nitrogen than on naturally flooded sites (Fig. 17).

These higher nutrient levels are associated with slower decomposition rates and greater litter production on GTR sites. Because a large litter accumulation ties up many nutrients, fewer nutrients are available for plants. The consequence of this difference of nutrient availability between naturally flooded lowlands and GTR sites may result in lower productivity on GTRs compared to naturally flooded sites. Thus, GTRs must be managed to assure decomposition rates and associated release of nutrients conducive to maintaining productivity similar to sites with natural flooding. Stagnant water or stable water levels should be avoided because they promote anoxic conditions which in turn inhibit decomposition rates. Therefore, GTR management strategies should include fluctuating water levels as well as those promoting slow-water movements throughout the impounded area.

### Nutrient Losses

Nutrient status of the water column must be considered during water manipulation and particularly during drawdowns. Fluctuating water regimes increase decomposition rates and




*The smaller the number, the slower the rate of decay.

Fig. 16. Relation among litterfall production, litter accumulation and litter decomposition on naturally flooded and greentree reservoir areas in southeast Missouri.

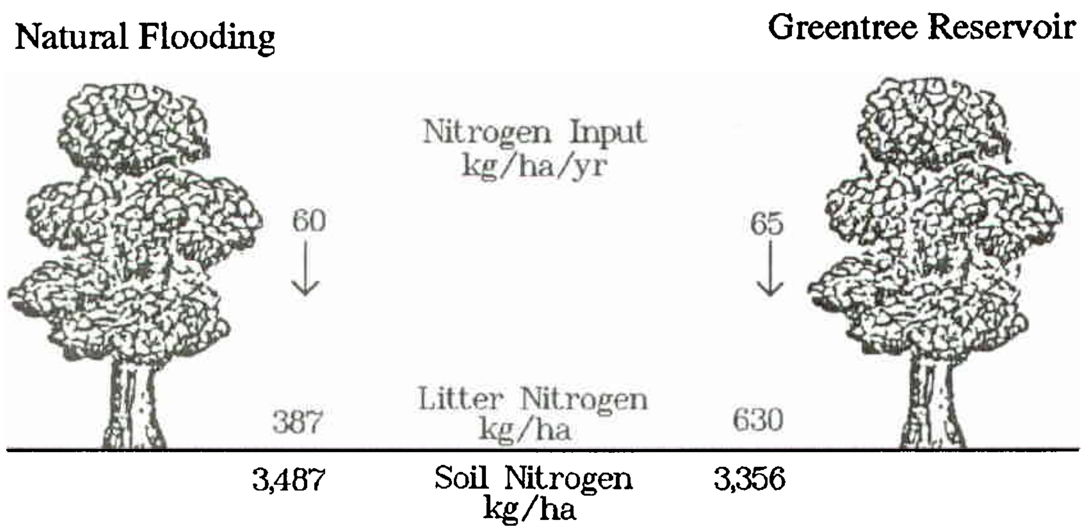



Fig. 17. Relation among nitrogen input, litter nitrogen and soil nitrogen on naturally flooded and greentree reservoir areas in southeast Missouri.

promote nutrient release from litter. Released nutrients present in dissolved form are readily available for plant or microbial uptake. The abundance of algae in GTRs is suggestive that soluble nutrients are readily available.

Nutrients in a southern Missouri GTR reached peak levels in early spring. Rapid drawdowns during this period have the potential to export nutrients from the reservoir. When a Missouri GTR was drawndown rapidly during the period of peak nutrient availability in the water column, phosphorus was exported from the reservoir. Such export may influence productivity because phosphorus is readily soluble and often limiting to plant growth. Thus, gradual drawdowns are important to minimize nutrient loss. Nutrients tend to be trapped and remain on site in the form of dense mats of aquatic plants, such as duckweed or algae, when drawdowns are slow. These plants accumulate soluble nutrients, such as nitrogen and phosphorus, in large quantities, and have the potential to keep nutrients on a site because the gradual removal of water allows algae and duckweed to remain within the reservoir during the drawdown.

## FOREST MANAGEMENT

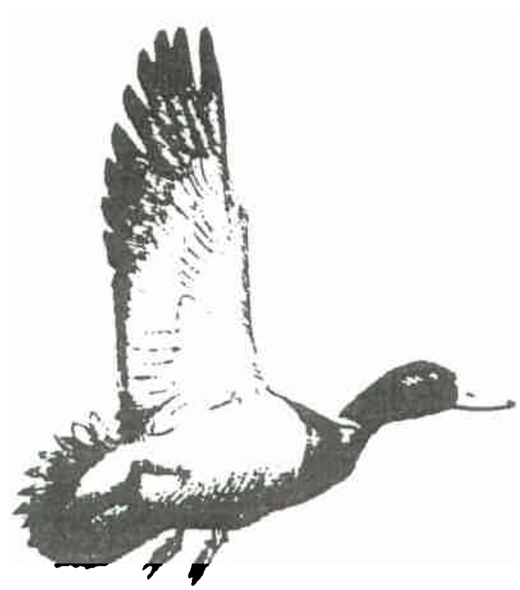
### Regeneration and Reforestation

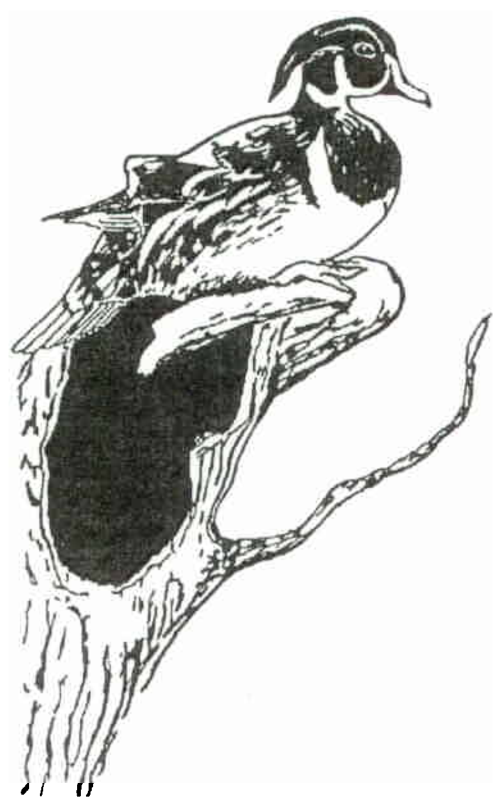
GTR management is accomplished primarily by employing various water manipulations, but it becomes necessary to use forest management practices at some point to prevent loss of tree vigor, shift in species composition, or tree mortality or to promote regeneration. Pin oaks, for example, typically grow fast, have numerous seeds, and favorable germination rates, are short-lived (80-100 years to reach maturity) and are intolerant of shade. As pin oak stands develop, their crowns provide enough shade to eliminate regeneration. In Missouri GTRs thousands of seedlings are produced, but regeneration is practically nonexistent because seedlings do not survive. Seedlings not only die during winter after being overtopped with water, but any seedlings that survive winter flooding usually die within 2-3 years because of shading.

Because reestablishment of pin oaks requires adequate sunlight, forested sites with closed canopies must be modified before regeneration is possible. Growth is most rapid and survival is best when pin oak seedlings have 2-3 hours of full sunlight. When fully stocked pin oak stands are thinned, pin oak response is immediate and rapid. The best protocol for reestablishing members of the red oak group in GTRs is unknown and is undoubtedly somewhat different for each site. However, some type of manipulations, including clearcutting (on small plots, <2 acres) or selective thinning, will be necessary on forested sites. A recent study in Missouri suggests that intermediate cuts result in the best regeneration responses. Thinning reduced the basal area from 80-120 to 30. Furthermore reforestation should be considered because of the difficulties of managing bottomland habitats and the potential to add to the managed forest base by increasing the acreage in forested habitats.

### Acorn Production

In general, dormant season flooding of GTRs influences acorn production of lowland oaks. Factors that enhance acorn production include: 1) Larger oak trees (>10 inches dbh) produce a greater biomass of acorns than smaller trees; thus, larger trees should be retained in preference to smaller ones, when thinning is warranted. 2) Periodic thinnings may be necessary to maintain high basal areas and to produce rapidly growing trees with large crowns. Stocking levels for pin oak should be about 10 $yd^2$/acre. 3) Individual trees of certain oak species are consistently better acorn producers than others. Selection for thinning should be done in late summer or fall when acorns are visible, and favor the most productive trees. 4) Reduced production and vigor of some oaks is related to inadequately aerated soil in the growing season. Timely and complete withdrawal of water in spring may improve aeration during the growing season.





# CHAPTER 7. DESIGN, DEVELOPMENT AND CONSTRUCTION OF GREENTREE RESERVOIRS

GTRs are primarily developed and managed to attract migratory and wintering waterfowl, and to serve either as refuges or as hunting areas. Although there are basic requirements for establishment of GTRs, design and development must be guided by initial considerations that include:

1) The intended use as a refuge or hunting area dictates differences in design and operation and may include decisions on placement of borrow ditches, access for hunters or timing of flooding and drawdowns.

2) Design and development of GTRs should incorporate biological needs of waterfowl and other wildlife.

3) Juxtaposition of other wetland types.

4) Awareness of potential vegetation problems.

5) Knowledge of local site conditions by managers and other personnel.

These initial considerations are important factors that influence type, cost of development and operation of GTRs (Table 16).

## BASIC REQUIREMENTS

A successful GTR will depend on the quality and quantity of suitable topography and soils, water supply and quality, mast-producing trees and duck populations (Table 16). Although each of these basic requirements or conditions may vary in quality and quantity, each is essential for attracting waterfowl.

### Topography and Soils

Topography suitable for establishing a GTR site should be flat or with a slight slope, usually less than 5%. Soils should have low permeability to inhibit subsurface drainage and allow for maintenance of proper water levels. Soils that are predominantly clay provide ideal substrates to enhance water level control.

### Discharge of Water

Much of the damage to trees in GTRs is related to prolonged and/or deep flooding. If intensive manipulations are to be successful in reducing this damage, water must be discharged effectively. Thus, each unit should be drained independently and the discharge ditches must be adequate to permit transfer of water from all impoundments. Caution is suggested when developing the drainage system to assure that the clay pan is not opened directly to the ground water table. Such errors in development in the past have been very costly and may preclude effective management on the entire area.

### Water Source and Supply

A dependable and adequate water supply is necessary to make timely and successful manipulations (Table 16). Potential water sources include: storage reservoirs, irrigation projects, streams, rivers, lakes, wells and rainfall. Storage reservoirs, from which water can be released by gravity flow, are cost effective because they provide a dependable water supply that can be easily regulated with water control structures. Rainwater is the most economical means of flooding a GTR, but rainfall is the least dependable because precipitation is highly variable among seasons and years.

Permanent streams provide a dependable water supply via diversion or pumping. The costs of water control structures, pumps and diversion ditches are high. Pumping water from wells, streams, rivers or lakes allows more complete water control, but pumping is the least economical method of flooding GTRs because of

Table 16. Factors influencing development and design of greentree reservoirs.

| |
|---|
| Initial Considerations |
| Intended use |
| Biological considerations |
| Waterbird communities |
| Plant species composition |
| Input by managers and other natural resource personnel |
| Basic Requirements |
| Topography, location |
| Soil type, texture, structure |
| Water source/supply |
| Forest vegetation, mast producers |
| Waterbird populations |
| Impoundments, Levees and Water Control Structures |
| Size and number of impoundments |
| Levee construction |
| Discharge and header ditches |
| Supply pipelines |
| Water control structures |
| Access roads |
| Inspection and Maintenance |
| Site inspections |
| Levee and road maintenance |
| Water control structures |

high operational costs. Some streams or lakes in agricultural areas have high levels of herbicides or pesticides and are not desirable for use.

### Forest Vegetation

Monitoring general changes in vegetation is very important in order to prescribe proper management for specific forest resources. This requires a basic understanding of forest ecology, silviculture and other management practices necessary to maintain forest vigor and to perpetuate oaks and other desirable shade intolerant species.

Bottomland oaks are the major mast-producing species used by waterfowl in GTRs. Oaks that produce smaller acorns: pin, Nuttall, willow, cherrybark, water and swamp chestnut oak (Appendices 1 and 2) are preferred by waterfowl. Although oaks are usually identified as the most important mast producers, other mast producing species of importance include: hickories and bald cypress in fall, and ashes, elms and maples in spring (Appendices 1 and 2).

### Waterfowl

The greatest waterfowl response to GTR development occurs when a site falls within a major migration corridor and is part of a wetland complex. GTRs usually have the best potential for bird use when sited near a river, lake, reservoir or refuge. Isolated GTRs of several hundred acres can attract waterfowl to areas with little wetland habitat, regions with limited importance to waterfowl or areas where extensive wetland habitat has been lost to agriculture. However use of isolated GTRs will never be as high or as diverse as when a GTR is part of a wetland complex with many types of wetland habitats.

## IMPOUNDMENTS, LEVEES AND WATER CONTROL STRUCTURES

### Size and Number of Impoundments

In general, the most effective management for GTRs is possible when the sites range in size from 100 to 500 acres. Single units of more than 500 acres are difficult to manage, reduce options for varying waterfowl habitat conditions and have greater potential to compromise productivity of the forested system. Thus, several smaller units provide more options and are more easily managed than a single large unit. Multiple units provide several alternatives during each season including: 1) varying the timing and depth of flooding, 2) varying the timing of drawdown or 3) allowing some units to remain somewhat dryer to promote regeneration of desirable tree species.

### Levee Construction

The height and width of levees depends on topography, depth of flooding and size of the impoundment. On sites where topography is flat, and potential impoundment size is small, a levee height of 2–3 ft is sufficient. Usually the maximum height of the levee should be 12-18 inches above maximum water depth. In large reservoirs; sites with the potential for deeper flooding or sites with irregular topography, higher levees may be required. In areas that receive substantial backwater or flash flooding as well as managed flooding, a low levee that is submerged quickly and uniformly is damaged less than a large protective levee. Levee damage can be reduced further by rip-capping or establishing dense well-rooted vegetation on low sites along the levees. Natural drainage patterns will identify the best locations for the levees.

Levees should be large enough (crown width about 10 ft) to support mowing equipment and deter burrowing activity of muskrats, beaver or other burrowing animals. Side slopes must be at least 3:1, but 4:1 or 5:1 is better. A slope of 5:1 is easier to maintain and mow, and deters burrowing animals more effectively than a 3:1 slope. Borrow areas can be established either inside or outside the levees. For GTRs where hunting is a major objective, location of borrow areas is critical because it will influence hunter access; sometimes bridges must be constructed for access. When the primary purpose of a GTR is a refuge, borrow areas inside the levees provide deep water habitats for diving waterfowl and other wildlife.

Levees built on contours are highly desirable. Such levees take advantage of natural changes in topography and provide maximum areas of flooding with optimum water depths. Contour levees also have the potential to provide several smaller units that can be managed independently for waterfowl with greater potential to emulate natural hydrological regimes.

## Water Control Structures

Permanent water control structures are essential. The number, size and location of water control structures depend on size of the impoundment and terrain. Structures should be located low enough to drain the impoundment completely and large enough to allow for rapid drainage or to handle flood waters. Placement of structures is aided by knowledge and observation of natural drainage patterns. Some forested sites have undulating surfaces or small ridges that trap water when levees are constructed. Thus some units may require multiple outlet structures to ensure complete drainage. Excess floodwaters are best handled by emergency spillways that are incorporated into a levee and rip-rapped. In some cases the rip-rap should be grouted.

Stoplog water control structures provide effective water regulation and are essential if natural hydrological regimes are to be emulated (Fig. 18). A typical stoplog structure is composed of a corrugated, galvanized steel or PVC drain pipe running through the levee, connected to a concrete box lacking top and front panels. Stoplogs are inserted between grooved recesses in the concrete or galvanized steel box and should be of several different widths to enable water level changes as small as 1 inch. For longevity, galvanized steel pipe should be treated with a water repellant tar. In some instances the extra expense of aluminum structures is worth the additional expense. Recently some companies have fabricated PVC culvert and stoplog strucutres. These are usually less expensive but are more easily damaged by vandals and freezing.

Appropriate changes in water levels are made by selecting a combination of appropriately sized stoplogs. If stoplogs are sized and numbered, water level changes can be made quickly and accurately. Redwood or treated lumber is suitable material. Ducks Unlimited has developed a system of metal stoplogs that seal well and can be modified to make their addition or removal easier. Furthermore the weight of the metal allows stoplogs of different heights to

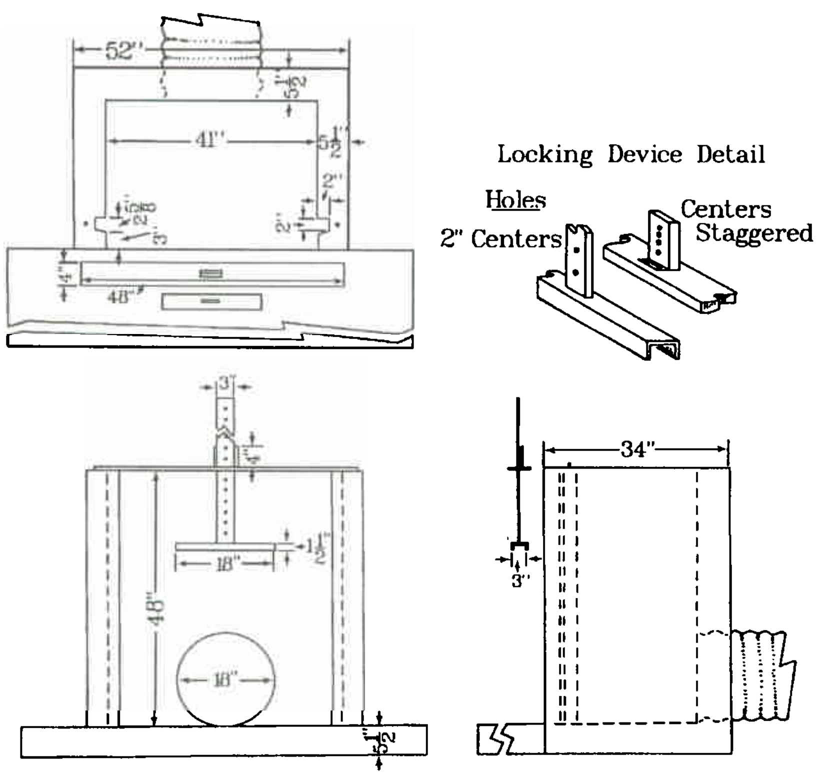



Fig. 18. Water Control Structures.

be interchanged easily. If seepage occurs between the stoplogs, dumping sawdust or straw just above the stoplog structure usually stops leakage quickly.

### Drainage

Adequate drainage from GTRs is essential. Discharge ditches should be large enough to transport water effectively. Ditches should be kept free of debris and vegetation and should never be dug so deeply that they connect directly with the aquifer.

### Access Roads

Placement and number of access roads leading to a GTR are important considerations. Unnecessary road construction removes additional forested habitat. Disturbance to wildlife is an increasingly important factor in management. Thus, roads should be kept to a minimum and placement should allow managers access to control structures in a way that reduces disturbance to foraging areas.

## INSPECTION AND MAINTENANCE

GTRs should be inspected regularly to monitor the condition of levees, water control structures and drainage systems. Special efforts should be made to inspect all water control structures, levees and other equipment to assure proper operation. Pumps should be monitored biannually to determine their efficiency and pumping capacity. Most diesel pumps will likely require replacement every 5 to 7 years whereas electric pumps have longer life spans. The expected life of a well is rarely more than 10 years. Maintenance activities are costly and include removing debris from water control structures, replacing rip-rap, mowing, and reseeding levees. Keeping the drainage system in excellent operating condition is one of the most critical aspects of GTR management. Levees should remain free of woody vegetation. Mowing and burning are commonly used control techniques. Burrowing animals using levees should be controlled annually to keep levee damage to a minimum.

Inspections should not be limited to the physical conditions of levees, water control structures or roads. Annual inspections to detect biological changes resulting from management procedures are critical to maintaining long-term productivity (see Chapter 7, Monitoring and Assessing Greentree Reservoir Management Strategies, page 42). Vegetation and wildlife responses should be monitored to evaluate site use and to identify manipulations that either enhance or have adverse impacts on desirable vegetation.

Managers must have the flexibility to regularly inspect sites. Programs where personnel must travel long distances between GTRs are inefficient and result in degraded habitat or reduced waterfowl usage.

# CHAPTER 8. GREENTREE RESERVOIR MANAGEMENT STRATEGIES

Management strategies for GTRs fall into 2 general categories: water management and forest regeneration. The focus of this handbook is on water management. Detailed procedures for forest regeneration are complex and are treated superficially in this handbook. Water management strategies that have minimal impacts on the natural function of lowland hardwoods and that promote long-term productivity of GTR habitats have not been fully developed and tested. This problem primarily relates to the slow development or establishment of a forested system and, thus, the difficulty in developing a comprehensive understanding of forested wetlands. In cases where acute mortality or obvious damage to trees has been identified within short time periods, procedures that appear to reduce or prevent undesirable effects have been developed. Within this context of intensive management, most GTR management scenarios are closely related to procedures that attempt to reduce or prevent tree mortality and damage. Unfortunately, the more subtle responses to management actions are difficult to detect and in some cases adverse impacts are not obvious for 10-15 years. Beneficial or negative results from subtle impacts of management may not be identified for 30-60 years.

## WATER MANAGEMENT

The best approach to develop effective water management strategies is to recognize natural functions in lowland hardwood habitats and attempt to duplicate the characteristic hydrological regime of a site.

The following assumptions must be considered when developing water management strategies for GTRs.

1. Lowland forests typically have a variety of woody species that are adapted to different flooding regimes. Each of these species has a different level of tolerance to the timing, depth and duration of flooding (Fig. 8, Table 4).

2. Lowland forests subjected to natural flooding regimes are likely to be dry or lack surface water accumulation until after tree senescence in fall.

3. Under natural flooding regimes, lowland forests are more likely to be wet or have surface water accumulations after trees break dormancy in spring.

4. Trees in the red oak group are not shade-tolerant and require light for seedling survival to the sapling stage.

5. Seedlings of the red oak group that are over-topped with dormant season flooding exhibit high mortality.

6. Natural hydrological regimes are variable within and among years.

7. Butt swelling is characteristic of trees in the red oak group that have been subjected to dormant season flooding at the same time and to the same depth for 10 or more years.

8. Slow flooding to shallow depths maintains oxygen levels favorable for invertebrates and provides ideal foraging depths for mallards and wood ducks.

9. Deep water reduces the availability of invertebrate communities to dabbling ducks.

10. Slow drawdowns make invertebrates and other food resources available over a long time period and conserve nutrients within the system.

11. Biomass and composition of the invertebrate community are related to the litter type and duration of flooding.

12. In most cases the number of GTR units that can be independently flooded or drawndown on an area is small; thus, there are limited options for a variety of water conditions on a single area.

### Guidelines for Managing a Wetland Complex

The following guidelines are suggested where 5 units totaling 900 acres are available for flooding on an annual basis in the upper MAV (Fig. 19, Table 17).

1. Water levels at the lowest elevation in any unit should not exceed a depth of 18 inches (hereafter referred to as functional capacity).

2. Surface water can be present in 3 units by 1 November but no more than a total of 400 acres should have surface water.

3. No more than 1 of the 3 units should be flooded to 80% of functional capacity by 1 November.

4. Flood an additional 100 acres by 15 November. Surface water can be present on 4 of the 5 units by this date.

5. A maximum of 3 units should be flooded to full functional capacity by pumping between 15 December and 15 January.

6. Water should not be pumped into 1 unit annually, but the unit can be flooded to some degree by rainfall.

7. Flooding of units should be gradual; in no case should a unit be flooded rapidly and deeply early in the season.

8. Water levels within 3 units should be varied (raised and lowered at least twice) during the dormant season.

9. All units should be drawndown slowly to conserve soluble nutrients and to optimize exploitation of food resources by wildlife

10. Drawdown of 2 units can be initiated by 1 January. A slow drawdown of 3 units should be scheduled to match the annual spring migration of mallards. Attempts should be made to spread the drawdown over a 4- to 6-week period.

11. The initiation of flooding, depth and duration should never be the same in a unit in 2 consecutive years. By rotating the time, length and duration of flooding among the 5 units there is the potential to more closely emulate the long-term hydrological regime common to lowland hardwood systems.

12. Two units should be scheduled for partial drawdown during the northward movement of mallards but 1 of these units should not be fully drained until 1 May in order to supply prebreeding habitat for nesting female wood ducks and brood habitat for young wood ducks less than 3 weeks of age.

13. The overall strategy for these 5 units is to flood 1 unit to functional capacity early in the year, but 1 unit should not receive any water from pumping each year. The remaining 3 units can be flooded to various levels of pool capacity from 1 November to 1 May.

14. If deep flooding occurs after the start of the growing season, the water should be reduced to a lower level rapidly.

## FOREST REGENERATION

The desired oak species in GTRs usually do not produce a significant crop of acorns until they are 25-30 years of age, and peak production may not occur until trees are 50-75 years of age. Many of these same species have life spans that are less than 100 years. Thus, managers must make attempts to perpetuate flooded forested habitats for wetland wildlife. Unfortunately management strategies that focus on long-term productivity and regeneration of forest types, especially shade intolerant oaks, are poorly developed.

One important strategy is reforestation. Direct seeding of acorns has proven to be a good method for reestablishing oaks in the MAV (on impacted ground) (see Selected Readings for detailed infor-

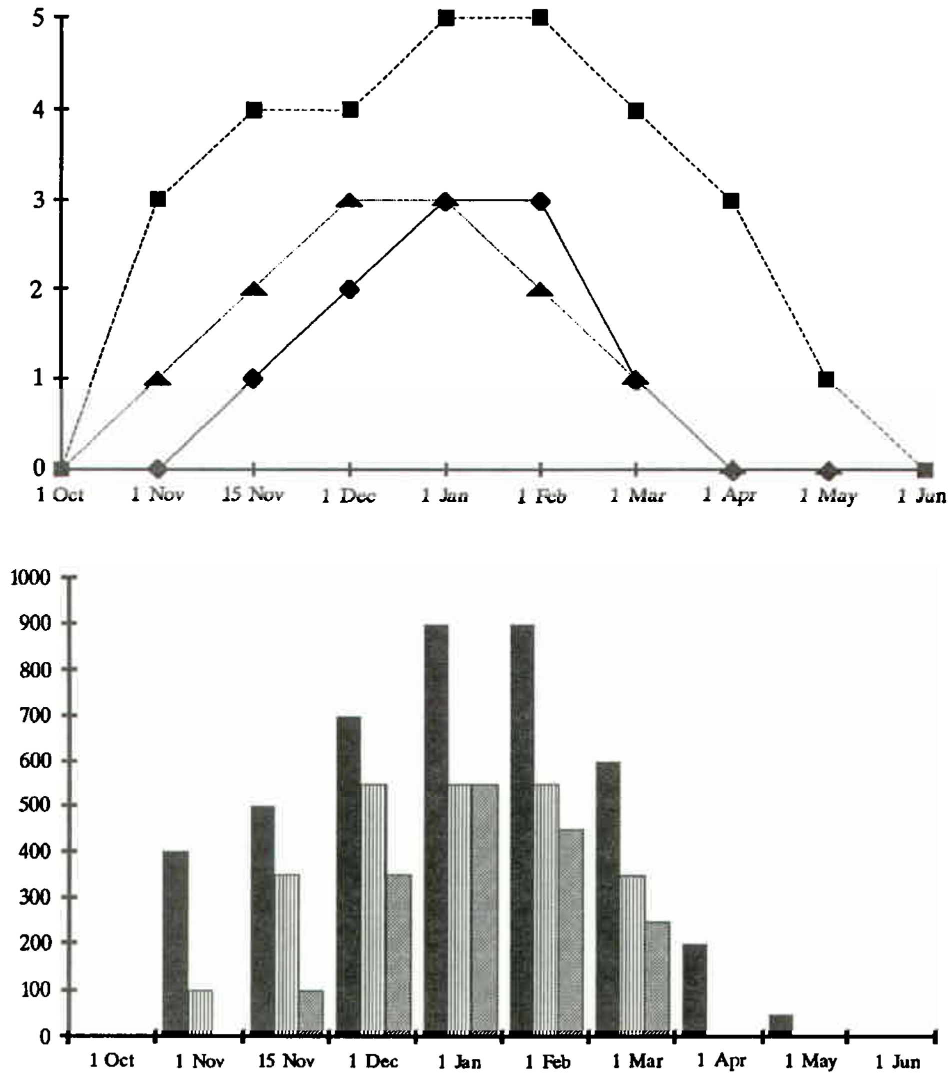



Fig. 19. Suggested flooding regimes for an area with 5 GTRs that cover 900 acres.

Table 17. Recommended annual flooding schedule of 5 Units[a] for a greentree reservoir management plan.

| Date | Surface water | | 80% functional capacity | | Full functional capacity | |
|---|---|---|---|---|---|---|
| | Maximum no. units | Maximum acres | Maximum no. units | Maximum acres | Maximum no. units | Maximum acres |
| 1 Oct | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 Nov | 3 (1,3,4) | 400 | 1 (1) | 100 | 0 | 0 |
| 15 Nov | 4 (1,3,4,5) | 500 | 2 (1,5) | 350 | 1 (1) | 100 |
| 1 Dec | 4 (1,3,4,5) | 700 | 3 (1,3,5)[b] | 550 | 2 (1,5) | 350 |
| 1 Jan | 5 (1,2,3,4,5)[b] | 900 | 3 (1,3,5)[b] | 550 | 3 (1,3,5) | 550 |
| 1 Feb | 5 (1,2,3,4,5)[b] | 900 | 2 (1,2,4)[b] | 550 | 3 (3,5) | 450 |
| 1 Mar | 4 (2,3,4,5) | 600 | 1 (4) | 350 | 1 (5) | 250 |
| 1 Apr | 3 (3,4,5) | 200 | 0 | 0 | 0 | 0 |
| 1 May | 1 (5) | 50 | 0 | 0 | 0 | 0 |
| 1 Jun | 0 | 0 | 0 | 0 | 0 | 0 |

[a] Hypothetical units, acres: Unit 1, 100; Unit 2, 200; Unit 3, 200; Unit 4, 350; Unit 5, 250.
[b] Unit 2 contributes acres via natural flooding caused by precipitation.

mation on regeneration). Acorns must be collected and stored under cool conditions. Planting soon after collections are made saves storage costs and ensures a high percent of germination. There is disagreement over the importance of cultivating newly established plantations. Some experts emphasize the need to reduce competition, whereas others have had success without controlling herbaceous vegetation.

Manipulations to regenerate forested sites have met with variable success. There are 3 schools of thought concerning the types of manipulations that assure regeneration of forest stands with a desirable oak component for waterfowl: natural regeneration, clearcutting and selective cutting. Good examples of the response to these 3 approaches can be found in the South, but differences in response at different sites are confusing and difficult to interpret. In some cases regeneration is achieved by clearcutting, whereas the same manipulations at other times and places result in poor responses. Reasons for the variability in response to treatments undoubtedly are related to differences in the formative processes for soils on that site, as well as specific environmental conditions associated with manipulations. These factors might include soil saturation, drought, floods, insects, rodents, acorn production and production of light-seeded species. Such variation in responses to clearcutting and selective cutting should be expected when conducted at different sites and at different times during the annual and long-term wetland cycle. Furthermore, the modified hydrological regimes of GTRs dictate that regeneration of forest types will be more difficult within intensively managed GTRs (Table 18).

In western Tennessee, skilled forest managers have had reasonably good success in regenerating lowland hardwood forests. A primary premise has been that oaks naturally occur in even-aged stands. Thus, the most desirable growing conditions do not occur in single-tree openings of less than 1 acre. Thus the response to small group selective cutting methods has been limited. A good strategy is to create at least 1 acre but no more than 5 acre openings on a 10-15 year cutting cycle. Enough of these openings should be located to completely regenerate the forest acreage during the rotation period. These small openings are also advantageous to diversify the food base by creating conditions for moist-soil plants. Herbaceous vegetation can be expected to produce seeds for 2-3 years before woody growth reduces herbaceous productivity. Old trees must be left in the system to benefit cavity nesting species and those species associated with older age classes of trees. Providing habitat for certain forest interior species is much more complicated than just leaving some old trees. Large contiguous blocks of older forests are required by some species. A carefully selected cutting schedule that retains

Table 18. Considerations in regenerating the forest within a GTR.

| Approach | Benefits | Problems |
|---|---|---|
| Modify a small area annually or every few years over an 80 year rotation by clearcutting | Costs are spread over time; more likely to coincide with a good acorn year; promotes an uneven -aged stand; promotes diversity of food resources | Difficult to find an operator to remove trees; may have to pay to have trees harvested; may have to alter flooding regime for several years to prevent seedling mortality |
| Manipulate a large area over a short time period by clearcutting for several years | Easier to locate operator for harvest; lowers cost of manipulation; potential for good moist-soil | Acorns may not be available during the year of harvest; less diversity in food resources; more likely for light-seeded species to invade site; less likely to coincide with a good acorn year; promotes an even-aged stand; low mast availability for many years |
| Modify a small area annually every few years over an 80 year rotation by thinning | Costs are spread over time; some mast producing trees still present for food production and acorn source; more likely to coincide with a good acorn year; promotes an uneven-aged stand; promotes diversity of food resources | Difficult to find an operator to remove trees; may have to pay for harvest; potential damage to mast-bearing trees not removed. |
| Protect buffer strips | Protect habitat for cavity nesters | May have reduced mast production |

the larger area of intact forest is required if these forest interior birds are to be successful breeders. Obviously the acreage of older trees should not be included in the part of the GTR that is being manipulated to regenerate the forest. Within 2-3 years after seedlings are established, new growth should be tall enough that seedlings are not likely to be overtopped by water levels at the functional capacity of the GTR. During the first 2-3 years some GTR flooding is possible but functional capacity of the GTR should not be reached.

The need to manipulate water levels to enhance the potential for regeneration emphasizes the importance of having several small GTR units rather than 1-2 very large units. Several small units provide the potential to have diverse hydrological regimes that are more conducive for water conditions that allow regeneration.

We must recognize that the failure to manage for desirable regeneration from a long-term perspective will likely result in a GTR with a predominance of shade tolerant species. This approach either requires the same personnel to continue to work with the same sites for long time periods or to coordinate long-term objectives and practices as there are changes in personnel. It is extremely important not to have massive management actions conducted over extensive acreages during a single season or even over a small number of years. For example if thinning practices get the initial desired response in 4-6 years, it is essential that the next stage of the regeneration process such as canopy removal be conducted in a timely manner. Furthermore manipulating an entire GTR creates similar conditions across the entire unit and may yield poor results. These suggested management practices have variable results depending on the site, age of the stand, environmental conditions and water management practices at the time of and following the manipulations.

Effective GTR management is very difficult and perplexing. Wetlands dominated by herbaceous vegetation may show good responses within a few months and certainly within a few years. However the diverse structure and long developmental period for forested wetlands make them more difficult to manage compared to marsh or moist-soil systems. Interactions for successful management of a single species are complex as evidenced from the diverse requirements for wood ducks or hooded mergansers (Fig. 20). Wood ducks restrict their activities to forested wetlands, whereas hooded mergansers can successfully exploit herbaceous systems. However, a manager of lowland hardwood wetlands must consider a large cross-section of animal use. Because these interactions are much more complex, refinements in manipulations are a difficult challenge for the wetland forest manager (Fig. 20).

Germination of acorns from shade intolerant oaks can occur under a closed canopy; however, in order for these seedlings to remain in the understory, openings in the overstory are extremely important to permit sunlight to reach the forest floor. Once regeneration reaches 4-6 feet in height, a removal of some overstory will assure that regeneration competes with the shade tolerant species when they are present. In some cases selective cutting also may be necessary to further encourage a desirable stand. The longer a stand exists before efforts are made for regeneration, the greater the potential for similar conditions to develop that might influence the abundance of shade tolerant species. When intensive manipulation is warranted, small regeneration cuts (1-5 acres) can be made throughout the stand every 10-15 years to perpetuate the oaks and assure a constant supply of acorns. Such small openings are more reflective of natural conditions where single trees disappear from the canopy. GTRs can be managed under these guidelines, but flooding depths on the GTR should be lower during the early stages of tree development. Small regeneration cuts also should create ideal areas for abundant moist-soil plants for waterfowl. Moist-soil production should last for several years before woody vegetation reduces the abundance and seed production of herbaceous vegetation.

Mast production will probably taper off after a tree reaches 60-75 years of age. Pin oaks will mature at approximately 75-85 years of age. Because of these characteristics, regeneration of desirable species must be planned decades in advance. Failure to do this will ultimately result in a GTR that supports only shade and water tolerant species that have limited waterfowl use.

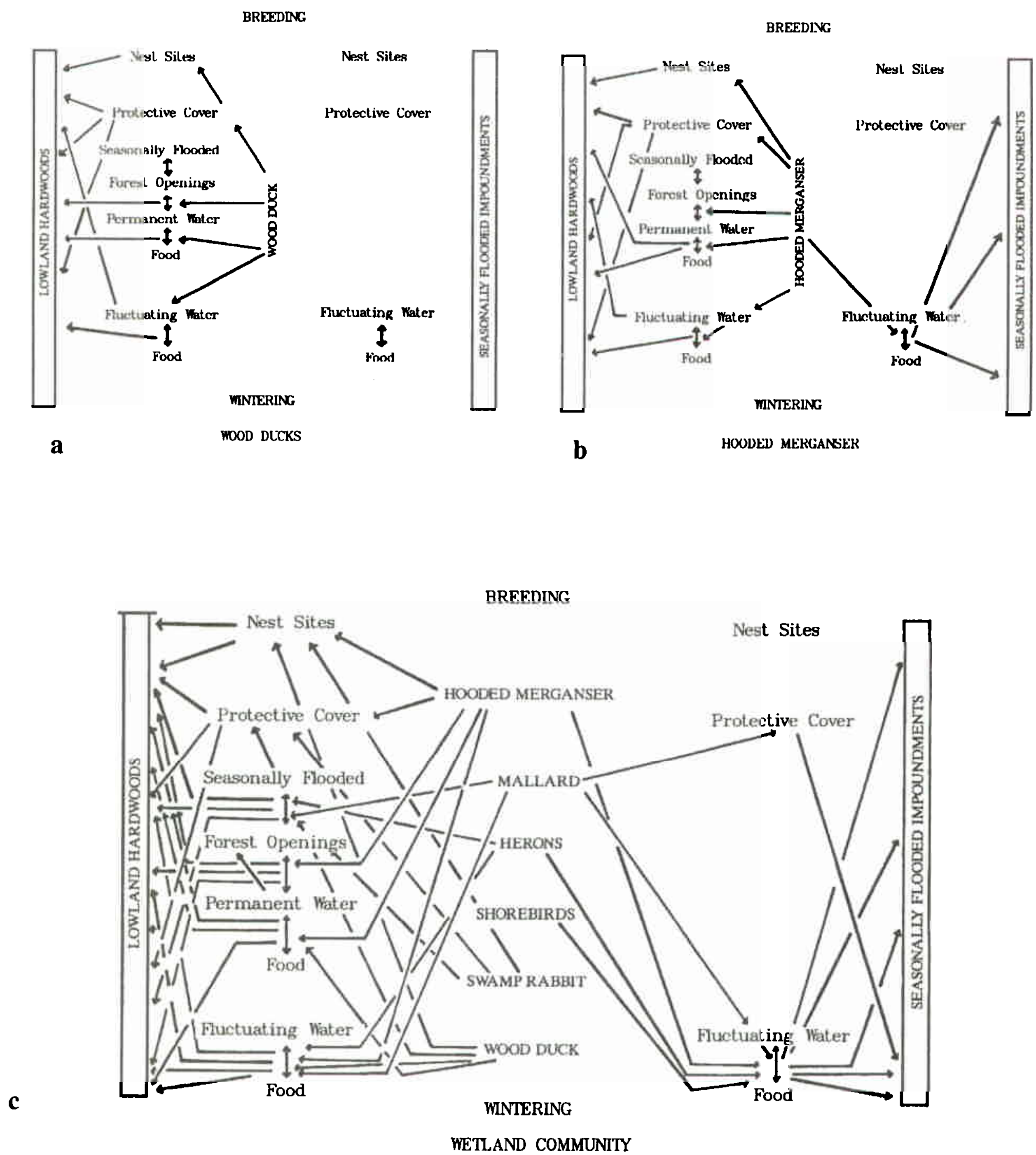



Fig. 20. Habitat use of lowland hardwoods and moist-soil by: a) wood ducks, b) hooded mergansers and c) just a few members of the diverse lowland hardwood wetland animal community.

# CHAPTER 9. MONITORING AND ASSESSING GREENTREE RESERVOIR MANAGEMENT STRATEGIES

Wetland structure and function of lowland hardwoods vary locally and regionally because each area has a unique set of hydrological variables, soil types and plant communities. Recognition of these unique characteristics within each GTR is the basis for developing more effective management strategies. Once these factors are identified, opportunities to impact the ecological processes related to maintenance or enhancement of wetland productivity is more likely. Monitoring carefully selected variables within lowland hardwood habitats as a means to assess manipulations is an essential and challenging aspect of GTR management.

## INITIAL CONSIDERATIONS

Monitoring GTRs should be developed for management purposes and *not as a research effort.* Thus selection of variables should be based on management goals, time, manpower, expertise, funds and cost-effectiveness. Ideally, monitoring should be conducted in conjunction with normal operations and during key events of the annual cycle. Data should be kept on a unit by unit basis and not pooled for the entire area.

Selected variables for monitoring are dependent upon management goals (Table 19), and range in frequency from one to several assessments annually. Long-term climatic conditions are available from the National Oceanographic and Atmospheric Administration Center for Climatic Data, Asheville, North Carolina, (NOAA) but knowledge of site specific variation can be helpful in developing or modifying management plans.

Table 19. Characteristics of lowland hardwoods that have value for monitoring and assessing the effectiveness of management strategies.

**Primary variables**

Climate
- Annual and long-term variation in precipitation
- Annual temperature variation
- Length of growing season

Water levels
- Timing, depth and duration of flooding
- Animal and plant responses to flooding

Forest and herbaceous vegetation
- Composition and proportion of mast producers
- Density and diversity of key species of value in food production

Waterfowl
- Life cycle events
- Behavioral activities
- Disturbance
- Habitat use

Animal control
- Burrowing animals
- Rough fish

Food production
- Inspection of mast producers

**Secondary variables**

Water quality
- Nutrient status and oxygen levels
- Sedimentation
- Toxic chemicals and herbicides

Soils
- Fertility
- Residual herbicides

Invertebrates
- Invertebrate density, biomass and dominant taxa

Wetland complex
- Diversity
- Number, size and juxtaposition

# CHAPTER 9. MONITORING AND ASSESSING GREENTREE RESERVOIR MANAGEMENT STRATEGIES

Wetland structure and function of lowland hardwoods vary locally and regionally because each area has a unique set of hydrological variables, soil types and plant communities. Recognition of these unique characteristics within each GTR is the basis for developing more effective management strategies. Once these factors are identified, opportunities to impact the ecological processes related to maintenance or enhancement of wetland productivity is more likely. Monitoring carefully selected variables within lowland hardwood habitats as a means to assess manipulations is an essential and challenging aspect of GTR management.

## INITIAL CONSIDERATIONS

Monitoring GTRs should be developed for management purposes and *not as a research effort.* Thus selection of variables should be based on management goals, time, manpower, expertise, funds and cost-effectiveness. Ideally, monitoring should be conducted in conjunction with normal operations and during key events of the annual cycle. Data should be kept on a unit by unit basis and not pooled for the entire area.

Selected variables for monitoring are dependent upon management goals (Table 19), and range in frequency from one to several assessments annually. Long-term climatic conditions are available from the National Oceanographic and Atmospheric Administration Center for Climatic Data, Asheville, North Carolina, (NOAA) but knowledge of site specific variation can be helpful in developing or modifying management plans.

Table 19. Characteristics of lowland hardwoods that have value for monitoring and assessing the effectiveness of management strategies.

**Primary variables**

- Climate
  - Annual and long-term variation in precipitation
  - Annual temperature variation
  - Length of growing season
- Water levels
  - Timing, depth and duration of flooding
  - Animal and plant responses to flooding
- Forest and herbaceous vegetation
  - Composition and proportion of mast producers
  - Density and diversity of key species of value in food production
- Waterfowl
  - Life cycle events
  - Behavioral activities
  - Disturbance
  - Habitat use
- Animal control
  - Burrowing animals
  - Rough fish
- Food production
  - Inspection of mast producers

**Secondary variables**

- Water quality
  - Nutrient status and oxygen levels
  - Sedimentation
  - Toxic chemicals and herbicides
- Soils
  - Fertility
  - Residual herbicides
- Invertebrates
  - Invertebrate density, biomass and dominant taxa
- Wetland complex
  - Diversity
  - Number, size and juxtaposition

## PRIMARY VARIABLES

Primary variables are those that are easiest or most economical to monitor or are available from other sources.

1) CLIMATE—Precipitation and temperature cycles and length of the growing season are important climatic variables useful in establishing schedules for flooding and drawdown. Climatic data are often collected to determine short- and long-term variation. Local weather stations provide long-term trends and variations for a given locale; these are now available on computer discs from NOAA.

2) WATER LEVELS—Accurate records of timing, depth and duration of flooding facilitates an understanding of the interaction among biotic and abiotic variables. Vegetation phenology and chronology of animal activities aid in determining the correct timing of flooding. Proper timing enhances the potential for maximum food production as well as use of food resources. Water level manipulations require close scrutiny and careful consideration because they impact vegetation and animal response, and provide diverse habitat conditions. For example, it is important to determine area flooded in relation to water gauge readings. Furthermore the costs of manipulations and long-term consequences of modified flooding regimes must be considered. Efforts also must be made to associate gauge readings with area flooded at different depths: surface water, 80% of functional capacity and 100% functional capacity.

3) FOREST AND HERBACEOUS VEGETATION—General changes in vegetation are of more value in making management decisions than detailed vegetative analyses. Data on species composition are most important, particularly the number of mast producers; data inputs of lesser value are basal areas, tree conditions, tree growth and regeneration. Cover maps with the assistance of aerial photography can be good tools to monitor changing conditions.

4) WATERFOWL—Observations on waterfowl behavior and habitat use can provide important information to improve management of GTRs. Time of day, water conditions, distribution among habitat types, behavioral activities and response to disturbance are some of the variables worthy of consideration. Waterfowl use should be monitored at least biweekly during peak use. Information should be kept on a unit by unit basis and should not be pooled across all units.

5) ANIMAL CONTROL—Control of burrowing animals becomes necessary when levees are threatened. Beavers are the most important species that damage levees but other species like muskrats and groundhogs also have important effects.

6) FOOD PRODUCTION—Important mast producers should be inspected regularly to ensure that trees are healthy.

## SECONDARY VARIABLES

Secondary variables are those which are more difficult and costly to monitor. In some cases regional data might be available from other sources.

1) WATER QUALITY—Water quality or nutrient status is important to overall productivity in lowland hardwoods. A monitoring program can document nutrient levels in water as well as indicate potential problems that may adversely affect waterfowl directly or indirectly. Degradation of water quality is associated with the presence of toxic chemicals, herbicides, high salinities, low oxygen levels or excessive sedimentation.

2) SOILS—Soil fertility influences lowland hardwood productivity. Fertility varies among different forest types within lowlands, even when soils are classified as the same type throughout a region. The presence of residual pesticides and herbicides as well as fertility factors including, Ca, Mg, K, N and P are important variables to monitor.

3) INVERTEBRATES—General invertebrate surveys identify the presence of dominant taxa that are important waterfowl foods. The patchy distribution of invertebrates and their rapid changes in population size dictate that there is little value in intensive sampling of invertebrates for management purposes. Furthermore, invertebrate sampling requires taxonomic identification and is very time consuming.

## ASSESSMENTS OF LONG-TERM CHANGES

Agencies have developed strategies to predict long-term changes. One approach commonly used is Habitat Suitability Index (HSI) models available for waterfowl. Models, developed for a given waterfowl species, have some potential to provide habitat information useful for impact assessment and habitat management. However, these models are not designed to be used in day to day management operations associated with long-term changes.

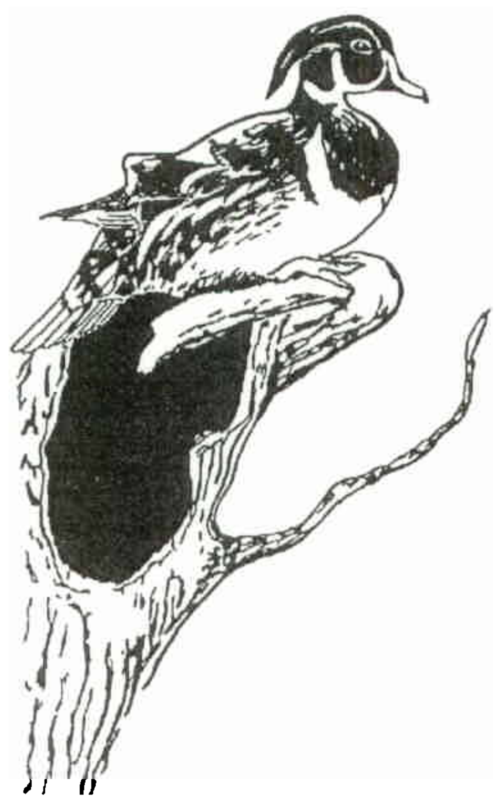
For example, a food component of the habitat suitability model for mallards in lowland hardwoods uses variables that might be part of a monitoring program: percent canopy cover of trees, proportion of tree canopy composed of oak species >10 inches dbh, number of oak species and mean number of days flooded during the winter period. As an HSI value approaches 1.0, the more suitable the habitat becomes for mallards. Use of the index to compare specific sites within an area, between areas, or from year to year for the same area, gives a basis for assessing success of GTR management.

The U.S. Fish and Wildlife Service, in response to the need to better understand long-term changes in lowland hardwood wetlands, has developed FORFLO, a computer simulation model of lowland hardwood succession and habitat change. One of the applications of this model is to assess long-term effects of GTR management. Currently applied to the Felsenthal National Wildlife Refuge in Arkansas, GTRs, FORFLO is designed to assess forest composition changes and tree growth.

Many of the same parameters used in FORFLO are common to those used to develop HSI values (Table 20), including canopy cover, diversity of mast-producing trees, tree size, mortality and hydrology. HSI models have some potential to assess current suitability of wildlife habitat and FORFLO can be used to predict future habitat conditions. A monitoring program, in conjunction with HSI or FORFLO models, has some potential to evaluate GTR management and provide insights to enhance management.

Table 20. Habitat information and Habitat Suitability Index model variables predicted by FORFLO (from Brodey and Pendleton 1987).

| Forest characteristic | Critical habitat information or HSI model variable |
|---|---|
| Forest type | Cypress-tupelo swamp<br>Upland bottomland hardwood<br>Nonforested (marsh or open water) |
| Species composition | Individual tree species<br>Abundance of individual species<br>Importance values |
| Tree size | Diameter at breast-height (dbh)<br>Basal area |
| Mast production | Individual mast-producing tree species<br>Abundance of individual mast-producing tree species |
| Canopy closure | Total closure<br>Bottomland hardwood closure<br>Cypress-tupelo closure<br>Mast-producing tree species closure |
| Tree mortality | Individual dead trees, snags |
| Hydrology | Annual flood duration<br>Growing season flood duration<br>Average water depth during growing season |



# SUGGESTED READING


**Lowland hardwood ecosystems**

Forsythe 1985
Fredrickson 1979a; 1979b
Gosselink and Lee 1987
Korte and Fredrickson 1977
Larson et al. 1981
McDonald et al. 1979
Wharton 1980
Wharton et al. 1981
Wharton et al. 1982

**Macroinvertebrates in lowland hardwoods**

Batema et al. 1985
Cummins 1973
Hubert and Krull 1973
Krull 1969
Merritt and Cummins 1978
Murkin and Kadlec 1986
Parsons and Wharton 1978
Reid 1985
White 1985
Wiggers et al. 1991
Zizer 1978

**Waterfowl use in lowland hardwoods**

Fredrickson and Heitmeyer 1988
Hall 1962
Hunter 1978

**Tree ecology and physiology**

Bedinger 1979
Black 1984
Brown and Peterson 1983
Conner et al. 1981

**Herbaceous plants**

Fredrickson and Taylor 1982

**Soils**

Broadfoot 1967
Cook and Powers 1958
Harter 1966

**Fish**

Finger and Stewart 1987

**Hydrology**

Fredrickson and Reid 1990
Sklar et al. 1979

**Greentree Reservoirs**

Mitchell and Newling 1978
Newling 1981
Rudolph and Hunter 1964
Schlaeger 1984
Smith 1984

**Acorn production**

Francis 1983
McQuilken and Musbach 1977
Minckler and James 1965

**Forest regeneration**

Johnson 1979
Johnson and Biesterfeldt 1970
Johnson and Krinard 1985, 1987

**Decomposition and nutrient cycling**

Borman and Likus 1967
Brinson 1977
Brinson et al. 1980
Brinson et al. 1981
Cameron and LaPoint 1978
Conner and Day 1976
Day 1979; 1982; 1983; 1984
Gomez and Day 1982
Kadlec 1982
Kitchens et al. 1973
Mitsch et al. 1979
Moore 1970
Peterson and Rolfe 1982a; 1982b; 1985
Schlesinger 1978
Shure et al. 1986
Wylie 1987
Wylie and Jones 1986

**Mallards**

Bellrose 1980
Heitmeyer and Fredrickson, 1981
Fredrickson and Heitmeyer, 1988
Kaminski and Gluesing 1987
Krapu 1981
Reinecke et al., 1987, 1989

**Wood ducks**

Bellrose, 1980
Drobney 1980; 1990
Drobney and Fredrickson 1979
Fredrickson and Drobney 1979

### Wood ducks (cont.)

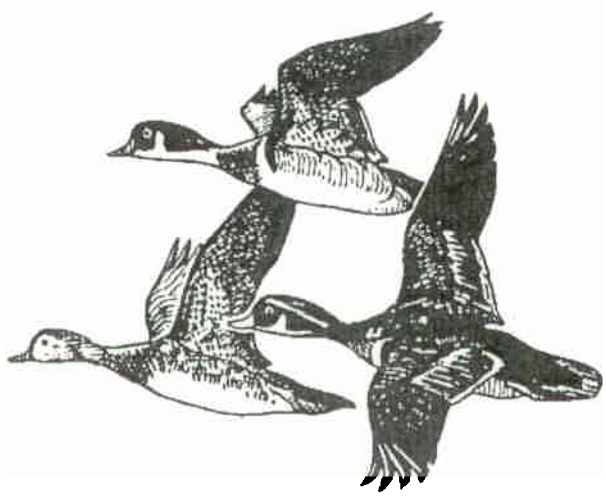
Fredrickson and Heitmeyer, 1988
Fredrickson and Graber, 1990
Haramis 1990
Heitmeyer and Fredrickson 1990
Nichols and Johnson 1990
Soulliere 1990

### Monitoring

Allen 1986
Brodey and Pendleton 1987

### Lowland Hardwood Management

Fredrickson 1980
Gosselink and Lee 1987
Klimas et al. 1981
Malecki et al. 1983
McDermott and Minckler 1961
Merz and Brakhage 1964
Mitsch 1975



## SELECTED LITERATURE


Allen, A. W. 1986. Habitat Suitability Index Models: Mallard (Winter habitat, Lower Mississippi Valley). U.S. Fish and Wildl. Serv. Biol. Rep. 82(10.132). 37pp.

Batema, D. L., G. S. Henderson and L. H. Fredrickson. 1985. Wetland invertebrate distribution in bottomland hardwoods as influenced by forest type and flooding regime. Pages 196-202 *in* Proc. Fifth Central Hardwoods Conf., Dep. For., Univ. Illinois, Urbana-Champaign.

Bellrose, F. C. 1980. Ducks, geese and swans of North America. Stackpole Books, Harrisburg, PA. and Wildlife Management Institute, Washington, DC. 480pp.

Bedinger, M. S. 1979. relation between forest species and flooding. Pages 427-435 *in* P. E. Greeson, J. R. Clark and J. E. Clark, eds. Wetland functions and values: the state of our understanding. Am. Water Resour. Assoc., Minneapolis, MN.

Black, R. A. 1984. Water relations of *Quercus palustris*: field measurements on an experimentally flooded stand. Oecologia 64:14--20.

Bonner, F. T. 1977. Handling and storage of hardwood seeds. Pages 145--152 *in* Proc. Second Symp. on Southeastern Hardwoods. U.S. For. Serv. State and Private For., Atlanta, GA.

Bormann, F. H. and G. E. Likens. 1967. Nutrient cycling. Science 155:424--429.

Brinson, M. M. 1977. Decomposition and nutrient exchange of litter in an alluvial swamp forest. Ecology 58:601--609.

_____, H. D. Bradshaw, R. N. Holmes and J. E. Elkins Jr. 1980. Litterfall, stemflow and throughfall nutrient fluxes in an alluvial swamp forest. Ecology 61:827--835.

_____, A. E. Lugo and S. Brown. 1981. Primary productivity, decomposition and consumer activity in freshwater wetlands. Annu. Rev. Ecol. Syst. 12:123--161.

Broadfoot, W. M. 1967. Shallow-water impoundment increases soil moisture and growth of hardwoods. Soil Sci. Soc. Am. J. 31:562- 564.

Brodey, M. and E. Pendleton. 1987. FORFLO: a model to predict changes in bottomland hardwood forests. U.S. Fish and Wildl. Serv., Natl. Wetlands Res. Cent., Slidell, LA.

Brown, S., and D. L. Peterson. 1983. Structural characteristics and biomass production of two Illinois bottomland forests. Am. Mid. Nat. 110:107--117.

Cameron, G. N. and T. W. LaPoint. 1978. Effect of tannins on the decomposition of Chinese tallow leaves by terrestrial and aquatic invertebrates. Oecologia 32:349-366.

Conner, W. H. and J. W. Day Jr. 1976. Productivity and composition of a baldcypress-water tupelo site and a bottomland hardwood site in a Louisiana swamp. Am. J. Botany 63:1354--1364.

_____, J. G. Gosselink and R. T. Parrondo. 1981. Comparison of the vegetation of three Louisiana swamp sites with different flooding regimes. Am. J. Botany 68:320-331.

Cook, A. H. and C. F. Powers. 1958. Early biochemical changes in the soils and waters of artificially created marshes in New York. New York Fish and Game J. 5:9-65.

Cummins, K. W. 1973. Trophic relations of aquatic insects. Annu. Rev. Entomology 18:103--206.

Day, F. P. Jr. 1979. Litter accumulation in four plant communities in the Dismal Swamp, Virginia. Am. Midl. Nat. 102:281-289.

_____. 1982. Litter decomposition rates in the seasonally flooded Great Dismal Swamp. Ecology 63:670--678.

_____. 1983. Effects of flooding on leaf litter decomposition in microcosms. Oecologia 57:180-184.

_____. 1984. Biomass and litter accumulation in the Great Dismal Swamp. Pages 386--392 *in* K. C. Ewel and H. T. Odum, eds. Cypress swamps. Univ. Florida Press, Gainsville.

Drobney, R. D. 1990. Nutritional ecology of breeding wood ducks: a synopsis for wetland management. Pages 62-67 *in* L. H. Fredrickson, G. V. Burger, S. P. Havera, D. A. Graber, R. E. Kirby, and T. S. Taylor, eds. Proc. 1988 N. Am. Wood Duck Symp., St. Louis, MO.

Drobney, R. D. and L. H. Fredrickson. 1979. Food selection of wood ducks in relation to breeding status. J. Wildl. Manage. 43:109–120.

Finger, R. R. and E. M. Stewart. 1987. Response of fishes to flooding regimes in lowland hardwood wetlands. Pages 86-92 *in* W. J. Matthews and D. C. Hines, eds. Evolution and community ecology of North American stream fishes. Univ. Oklahoma Press.

Forsythe, S. W. 1985. The protection of bottomland hardwood wetlands of the lower Mississippi Valley. Trans. N. Am. Wildl. and Nat. Resour. Conf. 50:566-572.

Francis, J. K. 1983. Acorn production and tree growth of Nuttall oak in a greentree reservoir. Research Note SO–289. U.S. For. Serv., Southern For. Exp. Stn., New Orleans, LA.

Fredrickson, L. H. 1979a. Floral and faunal changes in lowland hardwood forests in Missouri resulting from channelization, drainage, and impoundment. U.S. Fish and Wildl. Serv., FWS/OBS–78/91. 130pp.

_____. 1979b. Lowland hardwood wetlands: current status and habitat values for wildlife. Pages 296–306 *in* P. E. Greeson, J. R. Clark and J. E. Clark, eds. Wetland functions and values: the state of our understanding. Am. Water Resour. Assoc., Minneapolis, MN.

_____. 1980. Management of lowland hardwood wetlands for wildlife: problems and potential. Trans. N. Am. Wildl. and Nat. Resour. Conf. 45:376–386.

_____., and R. D. Drobney. 1979. Habitat utilization by post-breeding waterfowl. Pages 119–123 *in* T. A Bookhout, ed. Waterfowl and wetlands–an integrated review. N. Cent. Sect., The Wildlife Soc., Washington, DC.

_____. and D. A. Graber. 1990. Habitat ecology and management. Pages 381-385 *in* L. H. Fredrickson, G. V. Burger, S. P. Havera, D. A. Graber, R. E. Kirby, and T. S. Taylor, eds. Proc. 1988 North Am. Wood Duck Symp., St. Louis, MO.

_____. and M. E. Heitmeyer. 1988. Waterfowl use of forested wetlands in southeastern U.S.—an overview. Pages 302–323 *in* M. W. Weller, ed. Waterfowl in winter—a symposium and workshop. University of Minnesota Press, Minneapolis, January 1985, Galveston, TX.

_____. and F. A. Reid. 1987. Prototype handbook–Managing waterfowl habitats: breeding, migrating, wintering.

_____. and F. A. Reid, 1990. Impacts of hydrologic alteration on management of freshwater wetlands. Static Wetland Manage. Symp. 51st Midwest Fish and Wildl. Conf., Springfield, IL.

_____. and T. S. Taylor. 1982. Management of seasonally flooded impoundments for wildlife. U.S. Fish and Wildl. Serv. Resour. Publ. No. 148. Washington, DC. 29pp.

Gomez, M. M. and F. P. Day Jr. 1982. Litter nutrient content and production in the Great Dismal Swamp. Am. J. Botany 69:1324- 1321.

Gosselink, J. G. and L. C. Lee. 1987. Cumulative impact assessment in bottomland hardwood forests. Cent. for Wetland Resour., Louisiana State Univ., Baton Rouge. LSU-CEI-86-09. 113pp.

Hall, D. L. 1962. Food utilization by waterfowl in green timber reservoirs at Noxubee National Wildlife Refuge. Proc. Annu. Conf. SE Assoc. Game and Fish Comm. 16:184–199.

Haramis, G. M. 1990. Breeding ecology of the wood duck: a review. Pages 19–34 *in* L. H. Fredrickson, G. V. Burger, S. P. Havera, D. A. Graber, R. E. Kirby, and T. S. Taylor, eds. Proc. 1988 N. Am. Wood Duck Symp., St. Louis MO.

Harter, R. D. 1966. The effect of water level on soil chemistry and plant growth of the Magee Marsh Wildlife Area. Ohio Game Monogr. No. 2, Ohio Div. Wildl., Columbus. 36pp.

Heitmeyer, M. E. and L. H. Fredrickson. 1981. Do wetland conditions in the Mississippi Delta hardwoods influence mallard recruitment? Trans. N. Am. Wildl. and Nat. Resour. Conf. 46:44–57.

_____ and _____. 1990. Abundance and habitat use of wood ducks in the Mingo Swamp of southeastern Missouri. Pages 103–113 *in* L. H. Fredrickson, G. V. Burger, S. P. Havera, D. A. Graber, R. E. Kirby and T. S. Taylor, eds. Proc. 1988 N. Am. Wood Duck Symp., St. Louis, MO.

_____, _____ and G. F. Krause. 1989. Water and habitat dynamics of the Mingo Swamp in southeastern Missouri. U.S. Fish and Wildl. Serv., Fish and Wildl. Res. 6. 26pp.

Hubert, W. A. and J. N. Krull. 1973. Seasonal fluctuations of aquatic macroinvertebrates in

Oakwood Bottoms green-tree reservoir. Am. Midl. Nat. 90:177–185.
Hunter, C. G. 1978. Managing green tree reservoirs for waterfowl. Pages 217-223 *in* Intl. Waterfowl Symp., New Orleans, LA.
Johnson, R. L. 1979. Adequate oak regeneration - a problem without a solution? Pages 59–65 *in* Management and utlization of oak. Proc. Seventh Annu. Hardwood Symp. Hardwood Res. Council. Cashiers, NC.
_____. and R. C. Biesterfeldt. 1970. Forestation of hardwoods. Forest Farmer 15:36–38.
_____. and R. M. Krinard. 1985. Regeneration of oaks by direct seeding. Pages 56–65 *in* Proc. Third Symp. SE Hardwoods, Dothan, AL. U.S. For. Serv., Southern. For. Exp. Stn., New Orleans, LA.
_____. and _____. 1987. Direct seeding of southern oaks–a progress report. Pages 10–16 *in* Proc. Fifteenth Annu. Hardwood Symp. Hardwood Res. Council, Memphis, TN.
Kadlec, J. A. 1987. Nutrient dynamics in wetlands. Pages 393–419 *in* K. R. Reddy and W. H. Smith, eds. Aquatic plants for water treatment and resource recovery. Magnolia Publishing Inc.
Kaminski, R. M. and E. A. Gluesing. 1987. Density- and habitat-related recruitment in mallards. J. Wildl. Manage. 51:141–148.
Kitchens, W. M. Jr., J. M. Dean, L. H. Stevenson and J. H. Cooper. 1973. The Santee swamp as a nutrient sink. Pages 349-366 *in* F. G. Howell, J. B. Gentry and M. H. Smith, eds. Mineral cycling in southeastern ecosystems. ERDA Conference - 740513, Nat. Tech. Info. Serv., U.S. Dep. Comm., Springfield, VA.
Klimas, C. V., C. O. Martin and J. W. Teaford. 1981. Impacts of flooding regime modification on wildlife habitats of bottomland hardwood forests in the Lower Mississippi Valley. U.S. Army Engineer Waterways Exp. Stn., Tech. Rep. EL–81–13, Vicksburg, MS. 137pp.
Korte, P. A. and L. H. Fredrickson. 1977. Loss of Missouri's lowland hardwood ecosystem. Trans. N. Am. Wildl. and Nat. Resour. Conf. 42:31-46.
Krapu, G. L. 1981. The role of nutrient reserves in mallard reproduction. Auk 98:29-38.
Krull, J. N. 1969. Seasonal occurrence of macroinvertebrates in a greentree reservoir. New-York Fish and Game J. 16:119–124.
Larson, J. S., M. S. Bedinger, C. F. Bryan, S. Brown, R. T. Huffman, E. C. Miller, D. G. Rhodes and B. A. Touchet. 1981. Transition from wetlands to uplands in southeastern bottomland hardwood forests. Pages 223-274 *in* J. R. Clark and J. Benforado, eds. Wetlands of bottomland hardwood forests. Proc. of a workshop on bottomland hardwood forest wetlands of southeastern U.S., Lake Lanier, GA. June 1-5, 1980. Elsevier Sci. Publ. Co., New York.
Malecki, R. A., J. R. Lassoie, E. Rieger and T. Seamans. 1983. Effects of long-term artificial flooding on a northern bottomland hardwood forest community. For. Sci. 29:535-544.
McDermott, R. E. and L. S. Minckler. 1961. Shooting area management of pin oak. Trans. North Am. Wildl. and Nat. Resour. Conf. 26:111-121.
McDonald, P.O., W. E. Frayer and J. K. Clauser. 1979. Documentation, chronology and future projections of bottomland hardwood habitat losses in the lower Mississippi alluvial plain. Vol. I. U.S. Fish and Wildl. Serv., Washington DC. 133pp.
McKnight, J. S., D. D. Hook, O. G. Langdon, and R. L. Johnson. 1981. Flood tolerance and related characteristics of trees of bottomland forests of the Southern United States. Pages 29-65 *in* J. R. Clark and J. Benforado, eds. Wetlands of bottomland forests: Proceedings of a workshop on bottomland hardwood forest wetlands of the southeastern United States. Elsevier Scientific Publishing Company, New York.
McQuilken, R. A. and R. A. Musbach. 1977. Pin oak acorn production on greentree reservoirs in southeastern Missouri. J. Wildl. Manage. 41:218–225
Merritt, R. W. and K. W. Cummins. 1978. An introduction to the aquatic insects of North America. Kendall/Hunt Publ. Co. 441pp.
Merz, R. W. and G. K. Brakhage. 1964. The management of pin oak in a duck shooting area. J. Wildl. Manage. 28:233–239.
Minckler, L. S. and D. Janes. 1965. Pin oak acorn production on normal and flooded areas. Res. Bull. 898, Univ. Missouri, Agric. Exp. Stn., Columbia. 15pp.
Mitchell, W. A. and C. J. Newling. 1986. Greentree reservoirs. Section 5.5.3, U.S. Army

Corps of Engineers Wildlife Resources Management Manual, U.S. Army Engineer Waterways Exp. Stn., Tech. Rep. EL-86-9 Vicksburg, MS.

Mitsch, W. J. 1979. Interactions between a riparian swamp and a river in southern Illinois. Pages 63-72 *in* R. R. Johnson and J. F. McCormick, ed. Strategies for protection and management of floodplain wetlands and other riparian ecosystems. Pro. Natl. Riparian Ecosystem Symp., December 11-13, 1978, Callaway Gardens, GA, U. S. For. Serv. Gen. Tech. Rep. WO-12, Washington, DC.

_____, C. L. Dorge and J. R. Wiemhoff. 1979. Ecosystem dynamics and a phosphorus budget of an alluvial cypress swamp in southern Illinois. Ecology 60:1116-1124.

Moore, W. G. 1970. Limnological studies of temporary ponds in southeastern Louisiana. Southwestern Nat. 15:83-110.

Murkin, H. R. and J. A. Kadlec. 1986. Responses by benthic invertebrates to prolonged flooding of marsh habitat. Canadian J. Zool. 64:65-72.

Newling, C. J. 1981. Ecological investigation of a greentree reservoir in the Delta National Forest, MS, U.S. Army Engineer Waterways Exp. Stn., Miscellaneous Paper EL-81-5., Vicksburg, MS.

Nichols, J. D. and F. A. Johnson. 1990. Wood duck population dynamics: a review. Pages 53-75 *in* L. H. Fredrickson, G. V. Burger, S. P. Havera, D. A. Graber, R. E. Kirby and T. S. Taylor, eds. Proc. 1988 N. Am. Wood Duck Symp., St. Louis, MO.

Parsons, K. and C. H. Wharton. 1978. Macroinvertebrates of pools on a Piedmont river floodplain. Georgia J. Sci. 36:25-33.

Peterson, D. L. and G. L. Rolfe. 1982a. Precipitation components as nutrient pathways in floodplain and upland forests of central Illinois. For. Sci. 28:321-332.

_____ and _____. 1982b. Nutrient dynamics and decomposition of litterfall in floodplain and upland forests of Central Illinois. For. Sci. 28:667-681.

_____ and _____. 1985. Temporal variation in nutrient status of a floodplain forest soil. For. Ecol. and Manage. 12:73-82.

Reid, F. A. 1985. Wetland invertebrates in relation to hydrology and water chemistry. Pages 72-79 *in* M.D. Knighton, ed. Water impoundments for wildlife: a habitat management workshop. U. S. For. Serv., St. Paul, MN.

Reinecke, K. J., R. C. Barkley and C. K. Baxter. 1987. Water resources and the ecology of mallard wintering in the Mississippi Alluvial Valley. Pages 325-337 *in* M. W. Weller, ed. Waterfowl in winter - a symposium and workshop. January 1985, Galveston, TX Univ. Minnesota Press, Minneapolis.

_____, R. M. Kaminski, D. J. Moorhead, J. D. Hodges and J. R. Nassar. 1989. Pages 203-243 *in* L. H. Smith, R. L. Pederson and R. M. Kaminski, eds. Habitat management for migrating and wintering waterfowl in North America. Texas Tech Univ. Press., Lubbock 560pp.

Rudolph, R. R. and C. G. Hunter. 1964. Green trees and greenheads. Pages 611-618 *in* J. P. Lindusky, ed. Waterfowl tomorrow. U. S. Dep. Int., Washington, DC.

Schlaegel, B. E. 1984. Long-term artificial annual flooding reduces nuttall oak bole growth. Research Note SO-309. Dep. of ??? New Orleans, LA. 3pp.

Schlesinger, W. H. 1978. Community structure, dynamics and nutrient cycling in the Okefenokee cypress swamp forest. Ecol. Monogr. 48:43-65.

Shure, D. J., M. R. Gottschalk and K. A. Parsons. 1986. Litter decomposition processes in a floodplain forest. Am. Midl. Nat. 115:314-327.

Sklar, F. H. and W. H. Conner. 1979. Effects of altered hydrology on primary production and aquatic animal populations in a Louisiana swamp forest. Pages 191-208 *in* J. W. Day Jr., D. D. Culley Jr., R. E. Turner and A. J. Mumphrey, Jr., eds. Proc. Third Coastal Marsh and Estuary Manage. Symp. Louisiana State Univ., Div. Continuing Ed., Baton Rouge.

Smith, D. E. 1984. The effects of greentree reservoir management on the development of basal swelling damage and in the forest dynamics of Missouri bottomland hardwoods. PhD dissertation. Univ. Missouri, Columbia. 126pp.

Soulliere, G. J. 1990. Review of wood duck nest-cavity characteristics. Pages 129-138 *in* L. H. Fredrickson, G. V. Burger, S. P. Havera, D. A. Graber, R. E. Kirby, and T. S. Taylor, eds.

Proc. 1988 N. Am. Wood Duck Symp., St. Louis, MO.

Wharton, C. H. 1980. Values and functions of bottomland hardwoods. Trans. N. Am. Wildl. Nat. Resour. Conf. 45:341-353.

_____, V. W. Lambour, J. Newsom, P. V. Winger, L. L. Gaddy and P. Mancke. 1981. The fauna of bottomland hardwoods in southeastern U.S. Pages 87-160 *in* J. R. Clark and J. Benforado, eds. Wetlands of bottomland hardwood forests. Proc. workshop on bottomland hardwood forest wetlands of southeastern U.S. Lake Lanier, GA. June 1-5, 1980. Elsevier Sci. Publ. Co., New York.

_____, W. M. Kitchens and T. W. Sipe. 1982. The ecology of bottomland hardwood swamps of the southeast a community profile. U. S. Fish and Wildl. Serv., FWS/OBS-81/37.

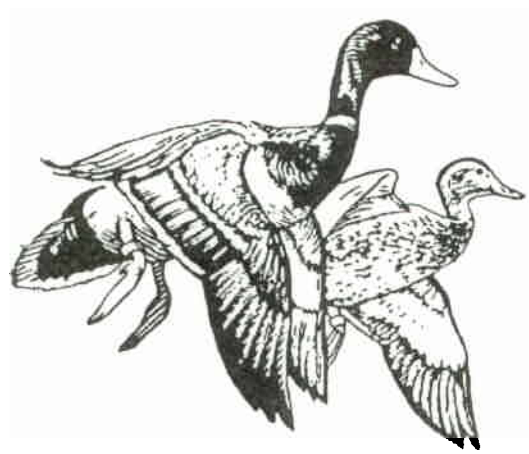
White, D. C. 1985. Lowland hardwood wetland invertebrate community and production in Missouri. Arch. Hydrobiol. 103:509-533.

Wiggens, G. B., R. J. MacKay and I. M. Smith. 1981 Evolutionary strategies of animals in annual temporary pools, Arch. Hydrobiol./Suppl. 58:97-206.

Wylie, G. D. 1987. Decomposition and nutrient dynamics of litter of *Quercus palustris* and *Nelumbo luten* in a wetland complex of southeast Missouri, USA. Arch. Hydrobiol. 111:95-106.

_____ and J. R. Jones. 1986. Limnology of a wetland complex in the Mississippi Alluvial Valley of southeast Missouri. Arch. Hydrobiol./Suppl. 74:288-314.

Zizer, S. W. 1978. Seasonal variations in water chemistry and diversity of the phytophilic macroinvertebrates of three swamp communities in southeastern Louisiana. Southwestern Nat. 23:545-562.



# APPENDIX 1. SYNOPSIS OF SELECTED TREE SPECIES OCCURRING IN GREENTREE RESERVOIRS

This appendix is intended to provide wetland managers a summary of pertinent information related to the biology of selected trees occurring in GTRs. Information on some of the more important trees include a general description, influence of soils and topography on growth, key life history events, significant problems, diseases and pests and the importance to wildlife.

## RED MAPLE (*Acer rubrum*)

### General Description

Red maple is a large tree 100–120 feet tall. The leaves are typically 3-lobed, but in the variety (*A. rubrum* var. *drummondii*) frequently found in bottomlands, the leaves are 5-lobed. The fruit is in the form of a V or U and matures in late spring; the winged seed is 3/4 inch long. The bark is gray and smooth in young trees, fissured or scaly and dark brown in older trees.

### Habitat Conditions

Red maple grows on a variety of soil types, but does best where soil moisture conditions are at extremes; either very wet or quite dry. The best development of red maple occurs on soils that are moderately well-drained at low to moderate elevations. Red maple is also common on slow draining flats and depressions. Associated trees in bottomlands include water oak, overcup oak, swamp cottonwood, water locust, pin oak, elms, sweet bay and green ash.

### Life History

Red maple is one of the first trees to flower in the spring (February–March). Good seed crops are produced almost every year. The fruit, a samara, ripens from March to June. Seed dispersal is by wind. Seeds germinate in early summer soon after falling; some do not germinate until the following spring. Red maple is a short- to medium-lived tree. Growth is rapid early after establishment, but slows as trees age. Red maple is shade tolerant and longer lived than several of its associates. Red maple is considered a pioneering or subclimax species.

### Problems, Diseases or Pests

Red maple is especially sensitive to wounding and is slow to heal, consequently rot fungus is common. The species is host to many insects that reduce its vigor and growth making it susceptable to decay. Red maple is also susceptable to fire as well as ice and snow damage.

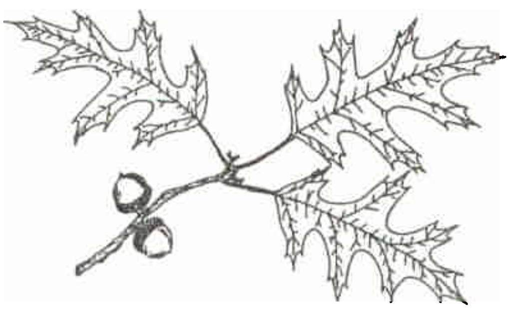
### Importance to Wildlife

Red maple provides browse for deer and the samaras provide food for ducks. Samaras are especially important for supplying plant proteins and lipids to wood ducks during the breeding season. Large trees provide cavities for wood ducks and other smaller birds.

## PIN OAK (*Quercus palustris*)

### General Description

Pin oak is a medium-sized tree 70–90 feet high with a diameter of 2–3 feet. Lower portion of the trunk has many small, tough, drooping branches that persist for many years after dying. The crown is typically pyramidal. Leaves are 5–7 narrow lobed; lobes forked and bristle-tipped. Acorns are small, 1/2 inch long; often striped with dark lines; enclosed 1/3 of the way with saucer shaped cup.



### Habitat Conditions

Pin oak grows well on wet sites and heavy soils with poor internal drainage. On these soils or flats, pin oak commonly grows in nearly pure stands. On deeper, better drained, but heavy soils, pin oak grows in association with other species, such as red maple, overcup oak, green ash, elms, sweetgum, willow oak and cherrybark oak.

### Life History

Acorns develop in 16–18 months, ripen and fall in September–November and germinate the following spring. Trees normally bear seed between 40–80 years, but as early as 20 years old in open grown trees. Seed is disseminated by water, wind, squirrels and birds. Pin oak seedlings require 1/3 sunlight, otherwise they will not survive under shade. Although pin oak is shade intolerant, seedlings will survive 2–3 years in shade and will respond to thinning of the stand. Pin oak is less shade tolerant than elm, hackberry and ash, but more shade tolerant than cottonwood and willow. Pin oak is considered a subclimax species, but if freed from overhead shade, it will pre-empt climax species.

### Problems, Diseases or Pests

Because of a thin bark, pin oak is highly susceptable to fire injury. Heartwood decay entering fire scars is the most serious disease. Oak wilt disease is potentially catastrophic. Minor problems include cankers, blisters and rusts. Wood borers are potential insect pests, usually attacking damaged trees.

### Importance to Wildlife

Pin oak acorns are especially attractive to several wildlife species including, waterfowl, deer, turkey, squirrels and other birds. It's most important wildlife use is in waterfowl management where GTR shallow flooding makes small acorns available for waterfowl, particularly mallards and wood ducks.

## NUTTALL OAK (*Quercus nuttalli*)

### General Description

Nuttall oak is a medium-sized tree 60–90 feet tall. Leaves are 4–8 inches long, usually 5–7 lobed, separated by deep sinuses. The acorn is narrowly ovoid, 3/4 to 1 1/2 inches long, reddish-brown and 1/4 to 1/2 enclosed in a deep, thick cup. The bark is dark gray-brown and smooth in young trees and broken into broad flat ridges when older.

### Habitat Conditions

Nuttall oak grows well on heavy, poorly drained alluvial clay soils. Typically the species grows on clay flats that are normally covered by 3–8 inches of water during winter. Nuttall oak is generally not found in permanent swamps or on well-drained loam soils. Nuttall oak is associated with water oak, willow oak, sweetgum, American elm, green ash, water hickory, sugarberry, pecan and overcup oak.

### Life History

Flowers appear with leaves in March and April. Acorns ripen between September and October and fall between September and February. Seed production begins at about age 20. Good seed crops are produced every 3–4 years. Water and birds help disperse seeds. Seeds germinate in spring on moist soils with 1 inch or more of leaf litter optimal. Reproduction is prolific, but seedlings are killed by high water. Seedlings are established in shade or open, but survival is nil in shade. Nuttall oak grows rapidly, but is considered a shade intolerant species.

### Problems, Diseases and Pests

A variety of borers and carpenter worms attack trunks and other borers infest twigs, branches and roots. Weevils often damage developing fruits. Bark pocket is a serious insect caused defect. Oak leaf miner defoliates trees and retards growth rates. Leaf blister disease also causes defoliation. Heart and butt rot enter trees after fire damage.

### Importance to Wildlife:

Because of the small acorn size Nuttall oak are consumed by deer, turkey, squirrels and waterfowl. Bottomland hardwood forests in which Nuttall oak occurs are desirable habitat for several wildlife species, especially waterfowl.

## WILLOW OAK (*Quercus phellos*)

### General Description

Willow oak is a medium to large tree 85-100 feet high. Leaves resemble those of willow are narrowly spear-shaped and 1/2 to 1 inch wide by 3-5 inches long. Acorns are 1/2 inch long, egg-shaped and often striped; cup is saucer-shaped, covering 1/4 of the nut. The bark of mature trees is dark brown and rough to shallowly fissured.

### Habitat Conditions

Willow oak grows on a variety of alluvial soils. Growth rates and quality of trees depend on soil and site characteristics. Site quality decreases with increases in clay content and potassium. Growth rates are better in the higher topographic regions of flooded zones. Willow oak is often associated with cherrybark oak, American elm, green ash, water oak, pin oak, laurel oak and sugarberry.

### Life History

Flowers appear between February and May before leaves unfold. Fruits mature from August to October of the second year. Acorn production starts when trees are 20 years old and good crops are produced annually. Acorns germinate the spring after seed fall. The best seedbed is moist, well aerated soil with an inch or more of leaf litter. Willow oak is a subclimax tree, intolerant to shade, but responds well when exposed to sunlight.

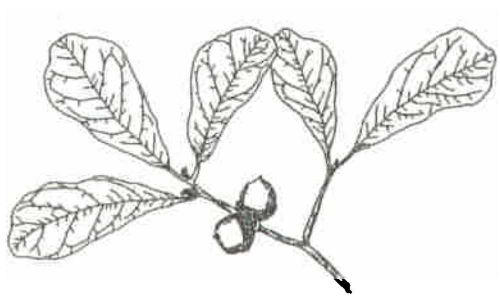
### Problems, Diseases and Pests

Willow oak is susceptible to fire, and damaged trees are subject to butt rot. Other diseases common to the species are trunk cankers and heart rot. Insect pests include: bark scarrers, trunk borers and twig galls. Squirrels and nut weevils reduce acorn crops.

### Importance to Wildlife

Willow oak acorns are consumed by squirrels, deer and turkey. The acorns are particularly important in the diet of waterfowl using flooded bottomlands. Other birds including quail, grackles, blackbirds and bluejays feed on these small acorns.

## WATER OAK (*Quercus nigra*)



### General Description

Water oak is a medium-sized tree, 60-70 feet tall. Leaves are not lobed but are club-shaped, about 2-4 inches long and 1-2 inches wide near the broadened tip. The acorn is 1/2 inch in diameter, globe-shaped and covered with a thin, saucer-shaped cup. The bark is black; young smooth bark becomes rougher with age.

### Habitat Conditions

Water oak grows on a variety of bottomland soils, with the best sites on alluvial bottoms having well drained, silty clay or loam soils. Principal associates on these sites are sweetgum, willow oak, Nuttall oak, winged elm, sugarberry, green ash, blackgum and honey locust.

### Life History

Water oak flowers between February and May before leaves unfold. Fruit matures from August to October of the second year. Seed production begins at 20 years of age, and good mast crops occur every year. Seed dissemination is primarily by animals and water. The best seedbed is moist, well aerated soil with 1 inch or more of leaf litter. Seedling survival and growth is best when there is abundant moisture throughout the growing season. Water oak is shade intolerant and a subclimax species. Although it germinates under shaded conditions, light is required for continued growth.

### Problems, Diseases and Pests

Water oak is susceptable to fire at all ages. Trees not killed by fire are damaged and susceptable to butt rot. Heart rot is another common disease of water oak. Major insect pests include: bark scarrers and trunk borers. Squirrels and nut insects reduce acorn crops.

### Importance to Wildlife

The small acorns are readily consumed by squirrels, turkey, quail, deer and mast consuming songbirds. In flooded bottomland hardwoods mallards, pintails and wood ducks feed on the acorns.

## CHERRYBARK OAK (*Quercus falcata* var. *pagodaefolia*)

### General Description

Cherrybark oak is a large tree attaining heights of 100–130 feet. Leaves are variable in shape, but in general the oval to egg-shaped leaf has the broadest part above the middle. There are 5–11 narrow, long-pointed lobes, with the base broadly pointed. The acorn is 1/2 inch long; cup is flat, saucer-shaped and encloses about half of the nut. The bark is dark brown or nearly black; the pattern created by shallow fissures and cross cracks resembles the bark of black-cherry.

### Habitat Conditions

Cherrybark oak develops best on a loamy, well-drained soil. Although it is a lowland tree, the species is seldom numerous on wet or swampy soils, and only occurs on well-drained clay soils. Cherrybark oak is associated with willow oak, pin oak, American elm and sweetgum.

### Life History

Acorn production begins at about 25 years. Cherrybark oak flowers appear with leaves in March and April. Acorns ripen and fall between September and November of the second year. Mast crops occur every 1–2 years and are disseminated by squirrels and flooding. Cherrybark oak is shade intolerant and requires full sunlight for development. The species is one of the hardiest, fastest growing and longest-lived bottomland oak species. It often occurs as individual trees in mixed stands, but at times they occur in groups.

### Problems, Diseases and Pests

Fire and severe winds are important in breaking branches where wood boring insects can enter. Other insect pests include: oakworms, timber beetles and carpenter worms. Acorns are susceptible to weevils and filbert worms.

### Importance to Wildlife

Squirrels, turkey, blue jays, red-bellied and red-headed woodpeckers, mallards, wood ducks, nut-hatches, grackles, raccoons and deer all consume cherrybark oak acorns. Although they are desirable wildlife food, the scattered distribution of this species makes it less valuable than pin or willow oak.

## OVERCUP OAK (*Quercus lyrata*)

### General Description

Overcup oak is a medium-sized tree, 50–75 feet tall. Leaves are egg-shaped, being broadest just above the middle; base of leaf is wedge-shaped; with irregular lobes. Acorns are 1/2–1 inch long; nut is 2/3 to almost completely enclosed in a deep, round and knobby cap. Bark of overcup is brownish-gray and broken into scaly ridges.

### Habitat Conditions

Overcup oak is commonly found on the lower, poorly drained parts of bottomlands. The species is prevalent in sloughs and backwater areas. Species often associated with overcup oak in bottomlands include red maple, bald cypress, tupelo gum, water locust, sugarberry, persimmon, pin oak, water oak, willow oak, Nuttall oak, elm and green ash.

### Life History

Flowering of overcup oak occurs in March and April as leaves are unfolding. Acorns mature in 12 months, ripen in September or October and drop soon after. Trees bear seeds at about 25 years of age, with good seed crops every 3–4 years. Seed dissemination is primarily by floodwater. Acorns are dormant over winter, germinating in spring after floodwaters recede. Reproduction is prolific, but many seedlings are killed by high waters. Seeds germinate in open or shade, but seedlings grow better in openings. Growth is variable and depends on soil type and soil moisture. It is more shade tolerant than other bottomland oaks. Overcup oak is often overtopped by associates, but persists many years as a climax species.

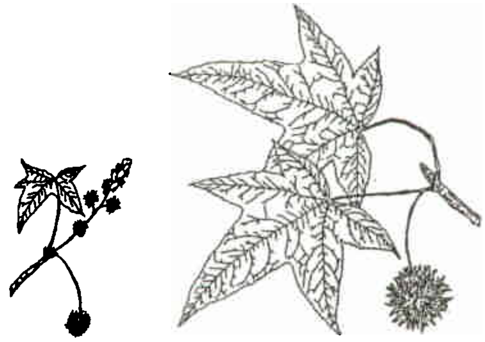
### Problems, Diseases and Pests

Overcup oak has a reputation for heavy trunk borer damage because of carpenter worms. Bark pocket is caused by sap-feeding beetles, and metallic wood borers render the species worthless for timber. Overcup oak is fairly resistent to fire damage and has no serious fungal diseases. Defoliates include: moths, butterflies, gall insects and beetles.

### Importance to Wildlife

Waterfowl do not readily consume overcup oak acorns because of their large size and knobby caps. However, other wildlife species including deer and squirrels eat the large nut. Songbirds and ground feeders profit from droppings of squirrel and deer. The species provides some cavities for wood ducks or dens for other wildlife.

## SWEETGUM (*Liquidamber styraciflua*)



### General Description

Sweetgum is a large tree, reaching heights of 120–150 feet. The star-shaped leaves with 5 saw-toothed lobes are attached to long petioles. Twigs often develop corky wings, especially when young. Gray or dark brown bark is deeply furrowed in narrow ridges. The hard ball-like fruit often remains on the tree into winter. The ball is filled with many small, winged seeds.

### Habitat Conditions

Sweetgum is tolerant of different soils and sites, but grows best on rich, moist, alluvial clay and loam soils of river bottoms. In the lower Mississippi Valley, site indices for sweetgum increase with the amount of exchangeable potassium in soil, and decrease as percent of clay increases. Because of its wide distribution and adaptation to a variety of sites, sweetgum is associated with over 65 tree and 30 shrub species. More common associates in bottomlands include: pin oak, willow oak, cherrybark oak, Nuttall oak, elms, green ash, persimmon, overcup oak and red maple.

### Life History

Sweetgum flowers are sensitive to cold and easily damaged by frost. Seeds are disseminated in fall by wind. Seed production begins at 20–30 years of age; abundant seed crops are produced until age 150. Young sweetgum have long conical crowns that usually prune themselves readily. The tree has a tendency to fork at a definite stage in development. It is classed as moderately intolerant to shade. Young sweetgum endures some shade and crowding, but mature trees are less able to withstand competition. This tree is considered a pioneering species in bottomland hardwood succession, but because of its wide range of growing conditions and adaptability, it persists in later successional stages as well.

### Problems, Diseases and Pests

Fall frosts can kill the late summer shoot growth of sweetgum. Although very resistant to disease and insect attack, the tree is highly susceptible to death or injury by fire. Fire scars may furnish entry points for insects and disease, but wounds quickly become covered by a gum exudate from the tree. Other minor problems associated with tree vigor include: sweetgum blight, cankers, tent caterpillers, moths and a variety of beetles.

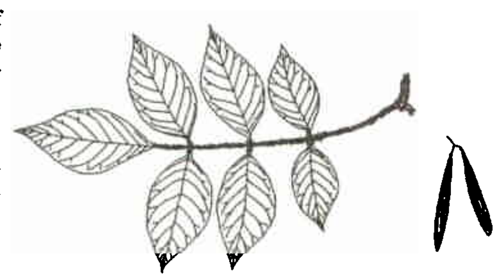
### Importance to Wildlife

Sweetgum is not a primary food source for wildlife. Some species of birds and mammals use seeds, bark or wood of the species as a food source. Goldfinches regularly use sweetgum seeds as part of their winter diet. Seeds also appear in the diets of squirrels and quail. The bark and wood provide up to 75% of the diet of beaver in the southeastern U.S.

## GREEN ASH (*Fraxinus pennsylvanica*)

### General Description

Green ash is a small to medium tree averaging 30–60 feet in height. Leaves are compound with 7–9 spear-shaped leaflets which are 3–6 inches long; edge of leaflets are fine-toothed except near base. Fruits occur in clusters; seeds are winged, and are paddle-shaped and narrow. The bark is gray with ridges crossing frequently to form a diamond pattern.



### Habitat Conditions

Natural stands of green ash are confined to bottomlands. It is most common on alluvial soils along rivers, and less frequently in swamps. Typically green ash are common in areas subject to flooding once or twice a year, although they can remain healthy when flooded up to 40% of the time during the growing season. In bottomlands it is often associated with sugarberry, red maple, sweetgum, pecan, willow oak, pin oak, Nuttall oak, American elm, black willow, eastern cottonwood and sycamore.

### Life History

Flowers appear before leaf-out in March or April. Fruit develops within a month and ripens by September or October. Seeds fall soon after ripening and continue to fall until winter or early spring. Seeds are disseminated primarily by wind. Green ash is intolerant to moderately tolerant of shade and is an early succession species on alluvial soils, as a pioneer or following cottonwood or black willow. It becomes less dominant in elm-ash-maple stands where it is considered a subclimax species because maple and elm grow faster.

### Problems, Diseases and Pests

Many insects occasionally feed on green ash. The more serious pests include: carpenter worms which bore into large limbs and trunks and allow entrance of rot fungi, and a couple of species of sawflies which defoliate the trees. Diseases of minor importance are rot fungi, rusts and leaf spot.

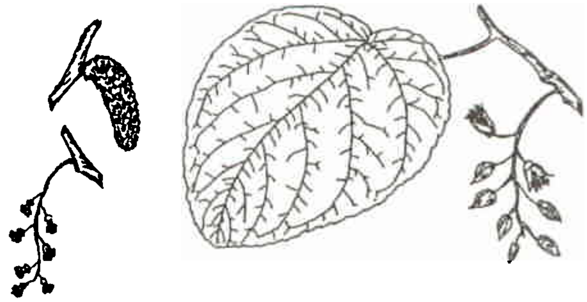
### Importance to Wildlife

Samaras are consumed by waterfowl, especially wood ducks. Samaras are particularly important in years when acorn crops fail. Fruits are also taken by songbirds and gamebirds. White-tailed deer utilize green ash twigs and foliage as browse.

## SWAMP COTTONWOOD (*Populus heterophylla*)

### General Description

A medium sized tree up to 100 feet tall. Egg to heart-shaped leaves; blunt-pointed at tip and indented at base; coarsely toothed, with teeth blunt. Fruit is a cluster of alternately arranged capsules, each capsule containing seeds in a cottony mass. The bark is dark red-brown and deeply fissured when young, but older trees have long, narrow, loose plates.



### Habitat Conditions

Swamp cottonwood usually occurs on heavy clay soils, with optimal growth and development in deep, moist soils of shallow swamps and low lying areas. The species generally is found in sites too wet for eastern cottonwood. Swamp cottonwood occurs sparsely throughout its range. The species is associated with bald cypress, water tupelo, water hickory, red maple, water locust, overcup oak, black willow, persimmon and pumpkin ash.

### Life History

Flowers appear before leaves unfold from March to May. Fruit ripens and seeds fall from April to July. Trees bear seed when 10 years old. Large amounts of seed are produced each year and dissemination is by wind and water. Seeds are viable for a very short time and must reach wet, bare mineral soil with abundant sunlight for germination to occur. Swamp cottonwood requires sunlight throughout early development and continuous supply of moisture throughout the growing season. The absence of this soil under large trees prevents swamp cottonwood from seeding itself naturally. It matures in about 40 years. Trees grow alone or in small patches. Although growth is fast, swamp cottonwood is shade intolerant.

### Problems, Diseases and Pests

Insects cause minor damage to swamp cottonwood. Poplar canker disease attacks seedlings. The major hazard for swamp cottonwood is fire which causes severe damage at all ages.

### Importance to Wildlife

Because of its infrequent occurrence throughout its range, swamp cottonwood is not well used by wildlife. Where it occurs, the tree is utilized by certain songbirds, beaver, rabbit, squirrel and white-tailed deer.

## SUGARBERRY (*Celtis laevigata*)

### General Description

Sugarberry is a medium sized tree, 60–80 feet tall. Leaves are lance-shaped or short egg-shaped with long-pointed and often hooked tips; bases are lopsided; edges are smooth except a few remote teeth near the tip. The fruit is fleshy, berry-like on long stalks and orange or yellow in color. The bark is gray-brown to silver-gray, with young bark smooth and older bark with warty projections.

### Habitat Conditions

Sugarberry is most common on clay soils of broad flats or shallow sloughs within floodplains. It is widely distributed in bottomlands except in the deeper swamps. Common associates are: eastern cottonwood, sweetgum, pin oak, Nuttall oak, willow oak, green ash, American elm, black willow, water hickory and overcup oak.

### Life History

Flowers appear with the leaves from March to May. Fruit ripens in September to October. Seed production starts when trees are about 15 years old (30–70 optimum). Sugarberry produces a good seed crop most years, some every year. Seeds are distributed by birds and water. Seeds are dormant over winter and germinate in the spring. Sugarberry is tolerant of shade and responds well when released.

### Problems, Diseases and Pests

The bark of sugarberry is thin and easily injured by fire, making it subject to serious butt rot. Leaf petiole galls are common on the tree. Other diseases and insects do not cause major damage. Sugarberry often causes severe problems when managing stands where a high component of shade intolerant species such as oaks are desirable. This species must be controlled on many sites if oak stands are to be perpetuated.

### Importance to Wildlife

The fruit of sugarberry is consumed by doves, quail and turkey as well as about 25 species of songbirds. Squirrels also eat the fruits. Deer occasionally browse twigs and foliage.

## RED ELM (*Ulmus rubra*)

### General Description

Red elm is a medium size tree averaging a height of 60–70 feet. Leaves are 5–7 inches long and 2–3 inches wide; leaves are egg-shaped with the broadest part above the middle; the base is slightly uneven and the tip is drawn out to a long, narrow point. The edges of leaves are doubly toothed. The seed is surrounded by a thin, papery wing. Bark is reddish-brown and furrowed with platey ridges.

### Habitat Conditions

Best growth of red elm is on moist, rich soils of lower slopes, streambanks, river terraces and bottomlands. The species is commonly scattered throughout its range. Chief associates in bottomlands are green ash, pin oak, overcup oak, willow oak, cherrybark oak, sweetgum and cottonwood.

### Life History

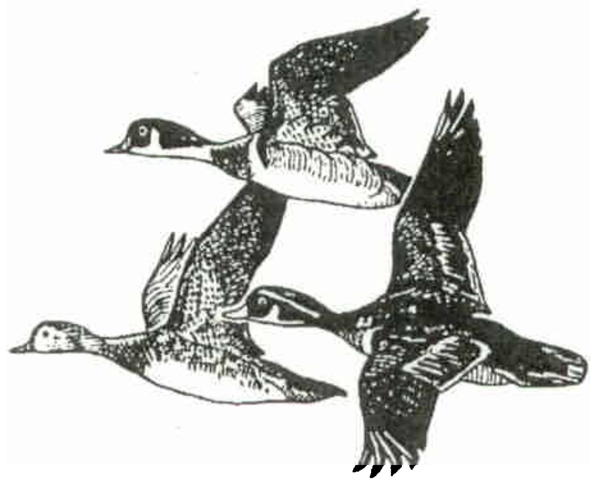
Flowers appear 10–15 days before the leaves in late February to early May. The winged samara is about 3/4 inch long and matures when leaves are half expanded. Fruit ripens and falls between April and June. Red elm has good seed production at 2–4 year intervals. Seed production starts when trees are 15 years old (optimum 25–125 years). Seeds are dispersed by wind and water. Red elm can maintain itself in subclimax or climax forests because it has good shade tolerance. However, growth is reduced to a minimum in shade.

### Problems, Disease and Pests

Red elm is susceptible to fire, Dutch elm disease and some wilts. Other diseases that cause damage but do not kill trees include several rots and cankers. Insect pests include wood borers, cankerworms, tent caterpillars and aphids.

### Importance to Wildlife

The value of red elm to wildlife is not great, but samaras are consumed by waterfowl, especially wood ducks. It may become more important as wildlife food during years of low acorn production. Seeds are also eaten by finches and squirrels. Deer occasionally browse on twigs and foliage. The tree crown is attractive to nesting songbirds.

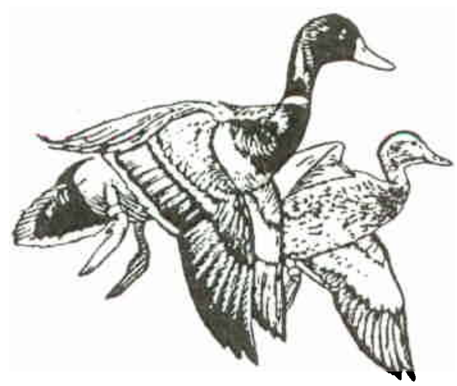


# APPENDIX 2. SYNOPSIS OF SELECTED WATERFOWL SPECIES USING GREENTREE RESERVOIRS

The three most commonly hunted waterfowl species using lowland hardwoods forests are highlighted in this report because of their: 1) abundance in bottomland hardwood habitat, 2) adaptation to bottomland hardwood wetlands or exploitation of resources in these wetlands and 3) frequent use of GTRs. Information is provided on distribution, habitat requirements, food habits and significant biological events in the annual cycle.

## MALLARD
(*Anas platyrhynchos*)

### Distribution



The mallard is the most abundant and widely distributed duck in the Northern Hemisphere, ranging from the Arctic to the subtropics in Europe, Asia and North America. The breeding range of the mallard in North America is widespread throughout Alaska; in Canada from British Columbia eastward to southern Quebec; and in the U.S. south to southern California, Arizona, northern New Mexico and eastward across the Great Plains to the Great Lakes and New England. Mallards usually winter in the southern half of the U.S., but will winter throughout the U.S. wherever food and open water are available. The largest portion of wintering mallards occur within the MAV, extending from Cape Girardeau, Missouri, to the Gulf of Mexico. The greatest wintering concentration is in northeastern Arkansas.

### Habitat Requirements

Because mallard breeding is widespread, nesting habitat is variable. Mallards generally nest in upland sites; the critical feature of the breeding habitat is the presence of shallow surface feeding areas, usually within 100 yards of the nest site. Wintering habitat in the MAV is located in the remnant of the once vast overflow swamps, moist-soil impoundments and agricultural fields. Throughout their range mallards are associated with forested sites either in the parklands or boreal forests during breeding or in forested riparian corridors throughout the West and Midwest.

### Food Habits

Mallards are highly adaptable in their use of both natural and cultivated foods. Because they use a variety of habitats, their food habits are diverse. Within forested wetland habitats used by mallards, oak acorns, smartweeds, wild millet or barnyard grass and macroinvertebrates are primary foods. Mallards typically feed by subsurface dabbling on foods found within the litter of bottom substrates. Mallards utilize agricultural crops for feeding more than any other duck. Important agricultural crops include corn, rice, milo, soybeans, barley and wheat.

### Annual Events in Bottomland Hardwoods Forests

Mallards begin arriving in the upper MAV in large numbers by early November and most depart again by mid-March; thus, they are on the wintering areas for about 4-5 months. During this time mallards undergo the fall-winter molt, complete pairing and initiate (or complete) the winter-spring molt. Females store nutrients to be used in spring migration and for reproduction as well. Forested wetlands appear to provide all the nutritional and habitat requirements of mallards through winter. Upon arrival, they tend to concentrate on recently flooded openings with shallow depths (<2–10 inches) in forested and marsh habitats. As they complete the fall molt, they feed primarily on moist-soil seeds and aquatic insects. After molt, pairing begins and during most years most birds are paired by early January. During pairing, mallards generally forage in flooded forests where they consume acorns or they feed on corn in agriculture fields. At midday pairs are often located in sloughs, overcup oak zones and scrub/shrub habitats. Once pairing is complete, mallards use shallowly flooded forests, consuming acorns and crustacean invertebrates until spring migration begins.

## WOOD DUCK (*Aix sponsa*)

### Distribution

The wood duck is widely distributed throughout the eastern deciduous forest in North America. The MAV is the prime breeding and wintering area of the wood duck with most breeding associated with wooded wetlands along the Mississippi River. The wintering area lies south of a line from Columbus, Ohio, west to St. Louis, Missouri, and southwest to Wichita, Kansas, with most birds wintering in the deep South and east Texas. A smaller population is centered in the Pacific Flyway west of the Sierra Nevadas. The interior population ranges over states of the Mississippi Flyway and into the eastern states of the Central Flyway.

### Habitat Requirements

Wood duck habitat requirements restrict their primary distribution to wooded wetlands. Thus, they are most abundant along creeks, rivers, floodplain lakes, swamps and beaver ponds. Breeding habitat must contain an adequate food source, suitable cover, tree cavities for nesting, available water and suitable brood-rearing areas. Trees important in providing desirable nest cavities include bald cypress, sycamore, silver maple, black ash, black willow, American elm, sweetgum and red maple. Trees should have low branches, providing overhead and lateral cover. Shrubs, such as buttonbush, that have strong stems rising and spreading out about 2 feet above the water are desirable. Water depths of less than 18 inches provide optimal foraging. Brood-rearing habitat should include a source of aquatic invertebrates for ducklings, water persistent throughout the brood rearing period and dense overhead cover. Postbreeding habitat requires less wooded and more herbaceous cover for resting. Wintering wood ducks use the more permanent water where buttonbush, swamp privet, bald cypress and water tupelo occur. Oak zones are exploited when flooding makes mast and other food sources available.

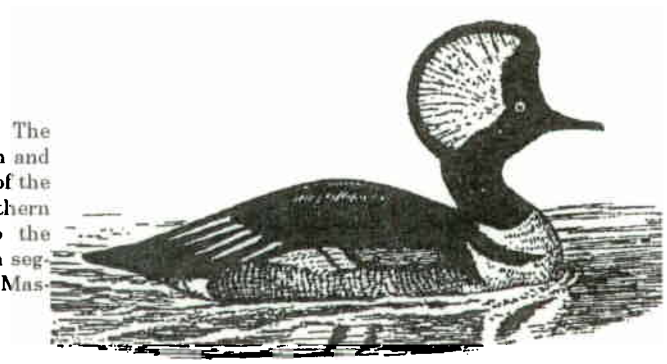
### Food Habits

Acorns are the favored food of wood ducks and are collected from shallowly flooded swamps and overflow bottomland hardwoods. When acorns are lacking, these ducks consume seeds from bald cypress, hickories, buttonbush, ashes, elms, maples, and aquatic plants (arrow arum, pondweeds, wild rice, burreed, duckweed and watershield). Animal foods, particularly aquatic and semi-aquatic macroinvertebrates, are important for females during prelaying and egg-laying periods. Wood ducks typically feed by pecking at foods on or slightly below the water's surface.

### Annual Events in Bottomland Hardwood Forests

Bottomland hardwood forests provide all the habitat and food resources necessary for wood ducks to complete their annual cycle. Most wintering is restricted to southern portions of the MAV where birds use the more deeply flooded areas including bald cypress, water tupelo, overcup oak and scrub/shrub habitats. Wood ducks return to breeding areas in the northern MAV and elsewhere beginning in late February and concentrate on sloughs, rivers, scrub/shrub and overcup oak habitats. During egg-laying wood ducks forage in the shallowly-flooded forests and consume invertebrates. Females keep the newly hatched broods in flooded-forest sites for a few weeks before moving to more deeply flooded habitats such as scrub/shrub which have more dense cover. Night roosting occurs in these scrub/shrub habitats or in robust emergent vegetation. In early fall wood ducks concentrate in the northern regions of the MAV. Wood ducks use flooded forests of overcup oak, bald cypress and water tupelo, as well as scrub/shrub for fall courtship and pairing.

## HOODED MERGANSER
*(Mergus cucullatus)*



### Distribution

Hooded mergansers are endemic to North America. The breeding range is similar to the wood duck, with a western and eastern breeding population. The primary breeding range of the eastern segment is along the Mississippi River, the northern Great Lakes and southern Canada from Manitoba to the maritime provinces. The winter distribution of the eastern segment is found mostly along the Atlantic coast from Massachusetts to northern Florida and along the Gulf Coast.

### Habitat Requirements

Although hooded mergansers can be found near most water bodies, the preferred habitat is wooded sloughs, streams and swamps. Normally hooded mergansers nest in tree cavities and have requirements similar to wood ducks. Preferred breeding habitat consists of wooded, clear-water streams, with the nest cavity near the water's edge. Unlike the wood duck, foraging hooded mergansers can exploit deeper and more rapidly moving water as long as it is free of turbidity. Hooded mergansers also are wary of human disturbance.

### Food Habits

The food habits of hooded mergansers are not as well known as those of wood ducks or mallards, but common foods consist of small fish, tadpoles, molluscs, crayfish and other small crustaceans and aquatic insects. Within the MAV acorns are also consumed. Hooded mergansers are divers in relatively shallow waters (about 20 inches) and their narrow, serrated bills with curved nails are an adaptation for obtaining active prey like fish and crayfish. Both good light and clean water are requisites for good foraging habitat.

### Annual Events in Bottomland Hardwood Forests

Hooded mergansers generally concentrate their use of forested wetlands in the deeper, more permanently flooded sloughs, backwaters, rivers, dead tree habitats, beaver ponds, scrub/shrub and overcup oak zones. Use of different wetland types depends on seasonal dynamics of crayfish abundance and availability. During prebreeding and breeding scrub/shrub habitats are important. Hooded mergansers use forested areas in the upper MAV less in midwinter than in spring, summer and fall. The lower MAV is used extensively throughout the year.

# APPENDIX 3. SYNOPSIS OF SELECTED MACROINVERTEBRATES OCCURRING IN GREENTREE RESERVOIRS

This appendix provides information on the biology of macroinvertebrates occurring in GTRs. Information on some of the more important species includes a general description, feeding habits, key life history events, ecology and behavior and importance to wildlife. Three classifications are also provided: Taxonomic—a traditional taxonomic classification including the class, order, family and some representative genera. Trophic—a classification of organisms based on feeding habits. Invertebrates are classed as shredders, collector-gatherers, collector-filterers, scrapers and predators (Table 9, p. 17). Adaptive—a classification based on adaption to a wet/dry cycle including overwintering residents, overwintering spring recruits, overwintering summer recruits and nonwintering spring recruits (Table 2, p. 9).

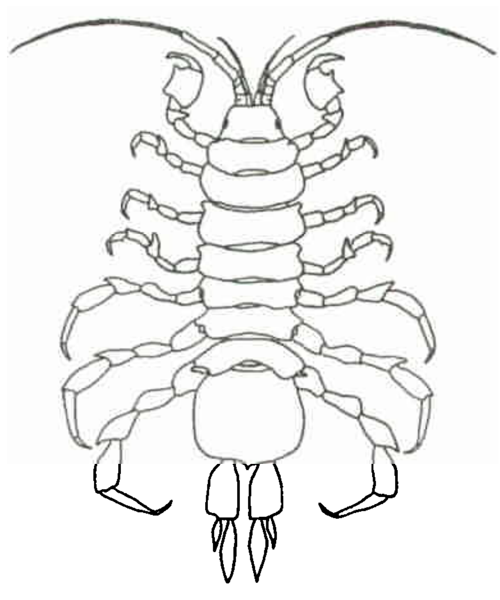
## ISOPOD (Aquatic sowbug)

### Classification

Crustacea-Isopoda-*Ascellus*; Shredder; Overwintering resident.

### General Description

Most species are 0.2–0.8 inch long. Unlike amphipods, body is flattened dorsoventrally. Eyes are dorsal and unstalked. Each thoracic segment bears a pair of long walking legs; the first pair modified for grasping. Coloration may be blackish, brown, dusky, reddish or yellowish; some species are variously marked or mottled.



### Feeding Habits

Isopods are characterized as scavengers, feeding on dead and injured aquatic animals as well as both green and decaying leaves, grass and aquatic vegetation. They are detritivores and omnivores.

### Life History

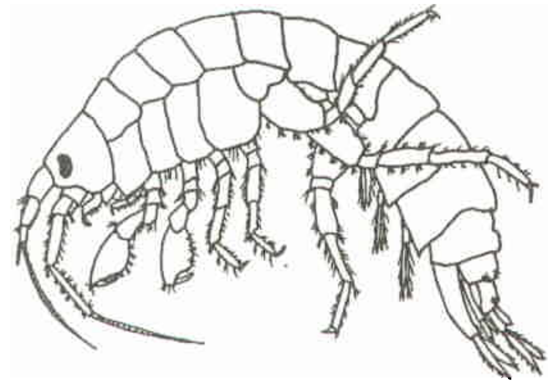
Development is direct; newly hatched young have adult-like appendages. Number of instars is unknown, but may be about 15. Molting is completed in a few minutes up to 3 days. Life span is 1 year or less. Adults or eggs can overwinter or survive summer drought.

### Ecology

Isopods usually remain under leaves, vegetation and debris. They move slowly, generally by crawling and are primarily inhabitants of unpolluted waters, rarely more than 3 feet deep. Most species are not adapted for withstanding adverse environmental conditions, such as drought or temporary waters; a notable exception are some members of the genus *Ascellus* which are common in forested habitats

### Importance to Wildlife

They are a primary food source for waterfowl, less so for fish and are probably consumed by predaceous aquatic insects. Some isopods act as intermediate hosts for parasitic nematodes of birds and fish. Isopods are important nutrient links between detrital resources and waterfowl.



## AMPHIPOD (Scud, Sideswimmer)

### Classification

Crustacea-Amphipoda-*Crangonyx*, *Gammarus*; Shredder; Overwintering resident.

### General Description

Most species are 0.2–0.8 inch long. Their bodies are laterally compressed, resulting in sideways motion, hence the name sideswimmer. Eyes are well developed and unstalked. Each thoracic segment has a pair of legs; the first pair modified for grasping. They are represented by a wide range of colors: light brown, greenish, bluish, purple, dark brown and reddish. When preserved they are usually white or cream colored.

### Feeding Habits

Amphipods are voracious feeders on all kinds of plant and animal matter. They browse on the film of microscopic plants, animals and organic detritus covering leaves, stems and other substrates. They are considered omnivores, detritivores and general scavengers.

### Life History

Direct development occurs with newly hatched young having adult appendages. Growth is in stages (instars) with number of instars depending on species. Intervals between molts (3–40 days) depend on food, temperature and species. Life cycle is usually completed in 1 year or less (univoltine). Amphipods overwinter as adults or eggs and survive summer drought in leaf litter layers.

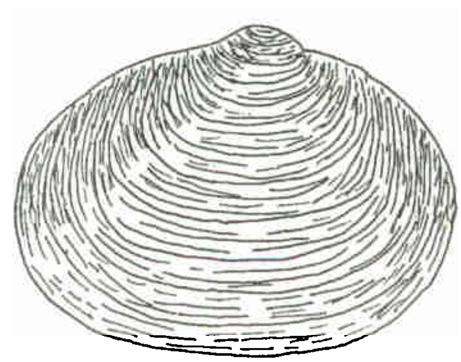
### Ecology

Amphipods are cold stenotherms, strongly thigmotactic and react negatively to light. During daylight they will hide in vegetation or under organic debris. They perform skittering motions when moving on substrate, and rapid undulating swimming above the substrate. They are restricted to shallow waters and waters of low to moderate carbonate content. Abundant oxygen is necessary.

### Importance to Wildlife

A primary food source for fish and waterfowl, amphipods are also consumed by other birds, predaceous aquatic insects and amphibians. They act as intermediate hosts for a variety of parasites including tapeworms of waterfowl and fish, and serve as an important nutrient link between detrital resources and waterfowl.

## FINGERNAIL CLAM (Seed Shell, Pill Clam)



### Classification

Mollusca; Bivalvia-Sphaeriidae-*Pisidium*; Collector-filterer; Overwintering resident.

### General Description

Most species are 0.08–0.8 inch long, but rarely more than 0.4 inch. The shell is thin and fragile. Concentric growth rings are not prominent. Coloration is whitish to brown. Their small size and color give rise to the common name, fingernail clam.

### Feeding Habits

Food generally consists of zooplankton, phytoplankton and organic debris. Feeding mechanisms are specialized for removal of suspended microscopic particles from the water. When clams burrow below the surface, they rely solely on organic debris.

### Life History

Fingernail clams are hermaphroditic (both sexes). Young develop in marsupium (expanded gills) of the adult which can contain from 1 to 60 young in various stages of development. When released, immature individuals are fully formed, having shell and features of an adult. Reproduction continues throughout the year. Life span is 12–18 months.

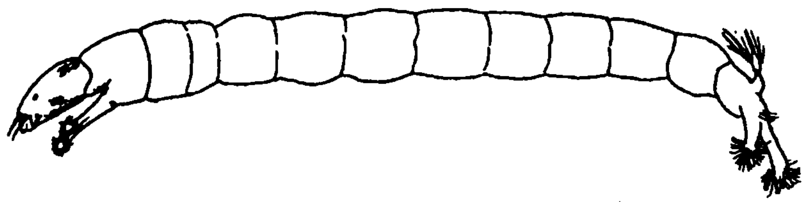
### Ecology

Fingernail clams are active burrowers and are found up to 10 inches deep in bottom substrates and forest litter layers. More abundant in shallow water (<6.5 feet), they can be found as deep as 98 feet. All types of bottom substrates except clay and rock are occupied. They are adapted to a wider range of environmental conditions than most clams, with a pH as low as 6.0 and $CaCO_3$ of only 2.0 mg/L Potassium above 7.0 mg/L is toxic. They are adversely affected by poor water quality, such as high turbidity or elevated ammonium levels. Fingernail clams may be transported by mud and debris on feet of birds, especially waterfowl.

### Importance to Wildlife

Fingernail clams are eaten regularly by numerous fish and waterfowl. They may become infested with parasitic water mites and serve as prey for some diptera (marsh fly larvae). Fingernail clams are an important nutrient link between detrital resources and waterfowl.

## CHIRONOMID (Midge, Bloodworm)



### Classification

Insecta-Chironomidae-*Chironomus*, *Pentanura*; Collector-gatherer, Collector-filterer or Predator; Overwintering spring recruit.

### General Description

The larvae are elongated, cylindrical, slender and range from 0.08 to 1.2 inches long. Their body is composed of a head, thorax and abdomen. They have a pair of prolegs on the first thoracic and last abdominal segments. Anal gills are sometimes present. Colors vary from white, yellow, bluish, pinkish to deep red. Hemoglobin in blood gives some worms the deep red color and the common name of bloodworm.

### Feeding Habits

Chironomids are chiefly herbivores and feed on algae, higher aquatic plants and organic debris. However, some species are predators, chiefly on oligochaetes and insect larvae.

### Life History

Chironomids have 4 distinct life states: egg, larvae, pupa and adult. Eggs are deposited singly, or in masses or strings on the surface, bottom or aquatic vegetation. Larval stages, with 4 instars, last from 2 weeks to 4 years depending on species, temperature and food conditions. Pupa remain hidden in debris until emergence takes place. Adults, which are aerial/terrestrial, are short-lived, do not feed and serve only to reproduce and disperse. The adults are non-biting dipterans.

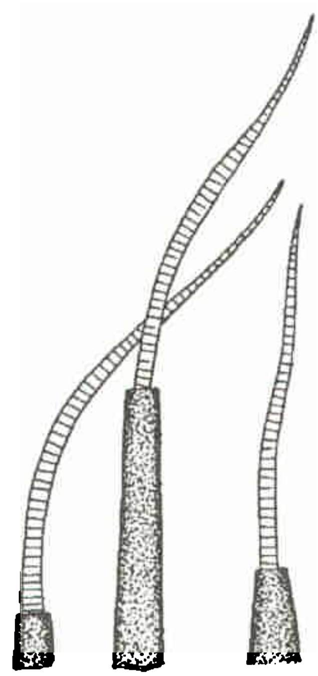
### Ecology

Chironomid larvae occur everywhere in aquatic vegetation and on the bottoms of all types of freshwater habitats in great abundance (>50,000/$m^2$). Many species construct fragile tubes composed of algae, fine silt or sand grains cemented together. Some species overwinter in larval hibernation cocoons. Chironomids can withstand poor water quality and very low oxygen levels.

### Importance to Wildlife

Chironomid larvae regularly are consumed by waterfowl and serve as an important nutrient link between detrital resources and waterfowl.

## OLIGOCHAETE (Aquatic worm)



### Classification

Oligochaeta-Lumbricidae; Collector-gatherer; Overwintering resident.

### General Description

Unlike terrestrial worms, aquatic worms are smaller and more delicately constructed. Size ranges from 0.04 to 1.2 inches. The body is thin and internal organs can be seen easily in living organisms. Number of segments range from 7 to 500 depending on the species. Hair-like structures (setae) occur sporadically on all but the first segment; number, arrangement and type of setae are important in species identification.

### Feeding Habits

Bottom substrates are ingested during feeding, with the organic portion being retained and digested and the remainder passing through the gut. Foods consist of algae, diatoms and miscellaneous plant and animal debris. Oligochaetes generally are classed as omnivores.

### Life History

Reproduction in aquatic worms is either by budding (asexual) or by syngamic reproduction typical of terrestrial earthworms. Cocoons containing embryos are deposited in vegetation and debris. Their life cycle takes 1–2 years. The capacity to regenerate lost or damaged segments varies within the group.

### Ecology

Locomotion on substrates is a crawling movement, involving contractions of the muscular body wall. Aquatic worms mix bottom mud and debris much like terrestrial worms mix soil. Temperature, although usually not limiting, often determines the abundance of worms. Some forms encyst in hardened cases of mucus when water is 43°F or lower. Most species thrive in low concentrations of dissolved oxygen; some species even endure extended anoxic periods.

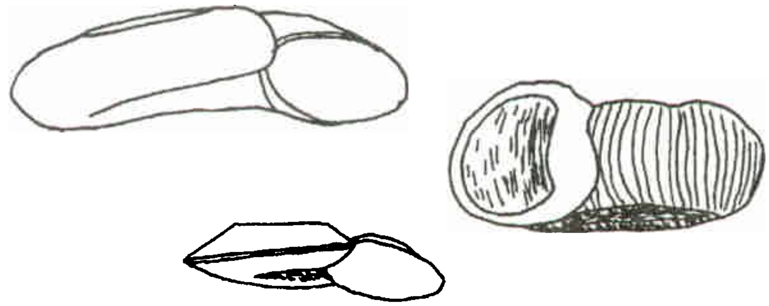
### Importance to Wildlife

Oligochaetes often are eaten by waterfowl. They serve as an important nutrient link between detrital resources and waterfowl.

## PLANORBID SNAIL (Orb snail)

### Classification

Gastropoda-Planorbidae-*Gyraulus*, *Promenetus*; Scraper; Overwintering resident.



### General Description

Planorbid snail shells are disk-like or orb-like or exhibit a low spiral. Lengths of shells range from 0.08 to 2.75 inches. The animal inside the shell is usually grayish, brownish or blackish, often flecked or mottled with yellow or white.

### Feeding Habits

Most planorbid snails are herbivores. Food consists chiefly of algae which covers submerged surfaces such as leaves. However, dead plant and animal matter are also digested. Mouthparts (radula) are used to scrape material from the surface.

### Life History

Planorbid snails are hermaphroditic—both male and female reproductive organs in same individual. Eggs are deposited in gelatinous masses on the substrate. Early developmental stages occur in the egg mass. Young snails have the basic morphological features of adults. Their life cycle generally lasts 9–15 months, although some species have life spans of 2–4 years.

### Ecology

Planorbid snails require the presence of adequate dissolved solids and calcium for shell formation. Fewer numbers of species occur in waters low in calcium carbonate. Low pH and dissolved oxygen also limit the number of species. Most require neutral to alkaline pH (≥7.0) and ample supplies of oxygen. Most species occur in water <10 feet deep.

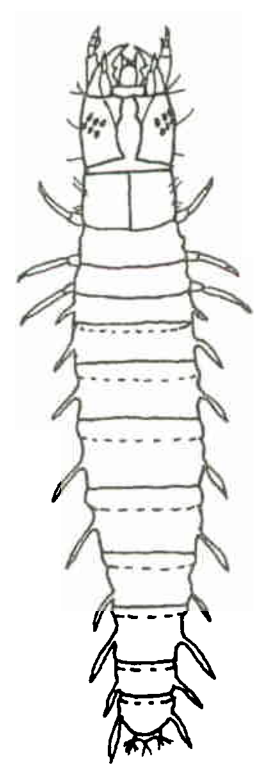
### Importance to Wildlife

Planorbid snails are an important food source for fishes, waterfowl, shorebirds and occasionally amphibians. Some species of planorbid snails serve as intermediate hosts for trematodes.

## HYDROPHILID (Water scavenger beetle)

### Classification

Insecta-Coleoptera; Hydrophilidae-*Berosus*, *Tropisternus*; Collector-gatherer (larvae), Predator (adult); Non-wintering spring migrant.



### General Description

Hydrophilidae characterized by short, clubbed antennae, often concealed beneath the head. Most species are blackish, but some are yellow or brown. Body lengths range from 0.04 to 1.6 inches. They differ from the similar dytiscid beetles by the fact that hydrophilids move hind legs alternately when swimming and that their ventral surface is not strongly convex.

### Feeding Habits

Larvae are primarily scavengers, feeding on decaying vegetation, hence the name water scavenger beetles. However, larvae also consume algae and other living plant material. The adults are predators, primarily on other aquatic insects.

### Life History

Hydrophilids undergo complete metamorphosis. Some species deposit eggs that remain uncovered, but most enclose eggs in cases or cocoons. Larvae have 3 instars. The pupal stage usually lasts less than 3 weeks. The adult usually overwinters, and has 1 generation per year; some species have 2 generations.

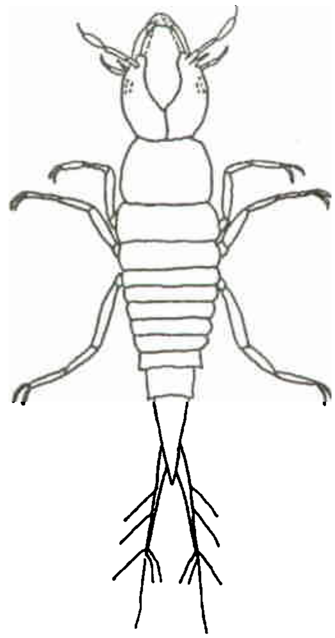
### Ecology

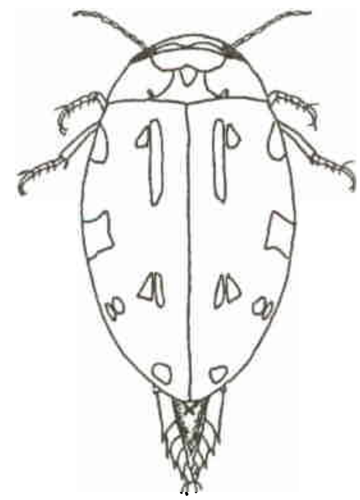
Hydrophilids are common in quiet, shallow pools or ponds. Some species are good swimmers, most crawl on vegetation and bottom substrates. Hydrophilids must return periodically to the surface to replenish their oxygen supply.

### Importance to Wildlife

Hydrophilids are consumed by waterfowl, particularly wood ducks, and larvae serve as an important link between detrital resources and waterfowl.

## DYTISCID (Predaceous diving beetle)





### Classification

Insecta-Coleoptera; Dytiscidae-*Agabus*, *Coptoto-mus*; Predator; Non-wintering spring recruit.

### General Description

Adults range in size from 0.04 to 1.6 inches. They are shiny black or brownish black, often marked with dull yellow, green or bronze. Antennae are long and thread-like. Hind legs are adapted for swimming; legs are more or less flattened, elongated and hairy. Larvae are elongated and spindle shaped. The head is large and round, oval or elongated; mouthparts (mandibles) are sickle shaped.

### Feeding Habits

Adults and larvae are both carnivorous with voracious feeding habits. Food consists of many aquatic animals. Larvae lunge and clutch prey in their sickle shaped mandibles, which are adapted for piercing and sucking.

### Life History

Their life cycle is generally completed in 1 year. Eggs are deposited on litter, under objects or within living plant tissue. Either larvae or adults overwinter depending on when eggs hatch.

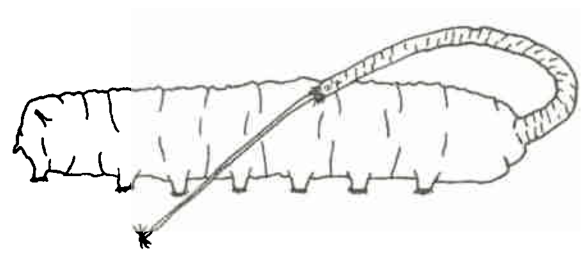
### Ecology

Most species are efficient and graceful swimmers. Dytiscids need a clean substrate and aquatic vegetation. Few species occur in muddy waters.

### Importance to Wildlife

Dytiscids are often consumed by waterfowl.

## SYRPHID (Rat-tailed maggot, Flower fly)



### Classification

Insecta-Syrphidae-*Eristalis*; Collector-gatherer; Overwintering spring recruit.

### General Description

Bodies range in length 0.2 to 1.0 inch and are covered with fine spines. The thoracic and abdominal segments are wrinkled and indistinct. Larval flower flies have seven pairs of ventral prolegs and an elongated caudal respiratory tube. Flower flies are more commonly known as "rat-tailed maggots" because of their ability to extend the respiratory tube.

### Feeding Habits

Primarily a detritivore, syrphids feed on decaying plant and animal matter. A few species, however, are predators.

### Life History

Syrphids undergo complete metamorphosis with egg, larval, pupal and adult stages.

### Ecology

Rat-tailed maggots are typically found burrowing in sewage, bottoms of polluted streams and decaying vegetation of ponds and temporary waters. Consequently they are indicators of poor water quality. They use shallow waters so that their telescoping respiratory tubes can extend into air above the water surface and thus allow them to inhabit waters low in oxygen.

### Importance to Wildlife

A very important fall food source for waterfowl in GTRs, they may serve as an important nutrient link between detrital resources and waterfowl.

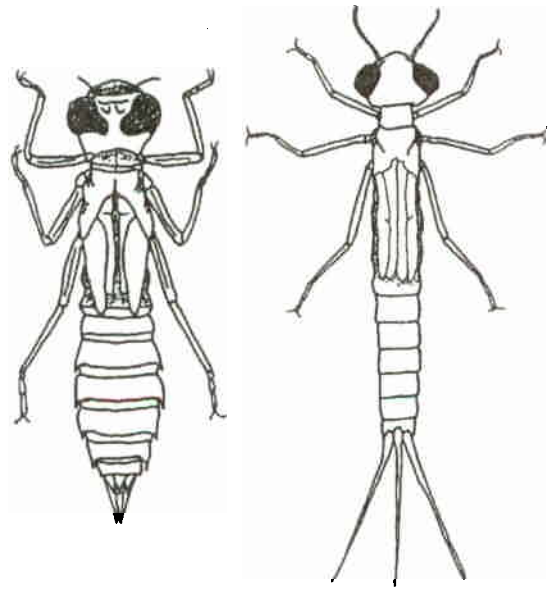
## ODONATE (Dragonfly, Damselfly)

### Classification

Insecta-Odonata; Libellulidae, Lestidae-*Libellula, Lestes*; Predator; Overwintering summer recruit.

### General Description

A wide range in body size occurs for nymphs: dragonflies, 0.5–1.75 inches; and damselflies, 0.4–0.9 inch. These are robust or elongated insects, often appearing grotesque. Generally gray or green in color, their bodies can be smooth or rough, sometimes covered with algae. Damselflies are more slender than dragonflies. Damselflies also have three leaf-like gills at the tip of the abdomen.



### Feeding Habits

Although all odonates are carnivores, feeding habits and feeding mechanisms vary. Some actively seek and stalk prey, while others remain motionless until prey are near enough to strike. Food consists of other aquatic insects, annelids, small crustaceans, mollusks and larval fish.

### Life History

Odonates undergo incomplete metamorphosis, with egg, nymph and adult stages. Eggs can be scattered on the water surface or deposited in masses in floating algal mats, sand, mud, aquatic plants or moss near waters' edge. Most species have 11 to 14 nymphal instars, length of each instar varying depending on species, temperature and food supply (3 days–6 months). Their life cycle usually lasts 1 year, but can vary from months to 4 years. Nymphs undergo changes in size and body parts until emergence of adult.

### Ecology

Odonate nymphs climb vegetation, move slowly through organic debris or burrow into bottom substrates. They are found in lakes, ponds, streams and temporary waters. Some species are able to withstand long periods of dessication. Odonates are rarely found in polluted waters.

### Importance to Wildlife

Odonates are often consumed by waterfowl. They are an important food for wood ducks.

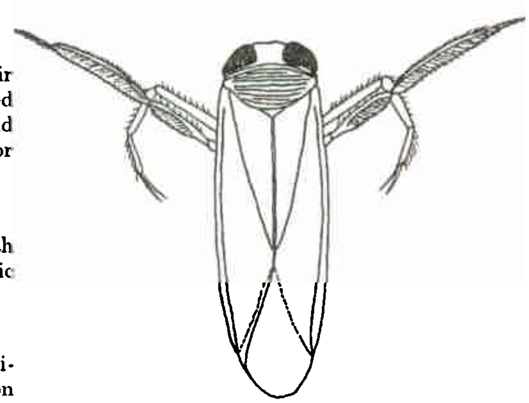
## CORIXID (Water boatman)

### Classification

Insecta-Hemiptera; Corixidae-*Sigara*; Collector-gatherer or Piercer-herbivore; Non-wintering spring recruit.

### General Description

Corixids are medium to small invertebrates, usually less than 0.5 inch long. Their bodies are somewhat flattened above, color is dark grayish, usually mottled or marked with yellow, brown or black. Hind legs are modified for swimming: long, flattened and fringed with hairs. Middle legs are also long, but are slender and not modified for swimming.



### Feeding Habits

Corixids gather food from the bottom by sweeping material into their mouths with short front legs. Food consists of debris and a variety of algae, protozoa and microscopic animals. Mouthparts are used to pierce tissue and suck out contents.

### Life History

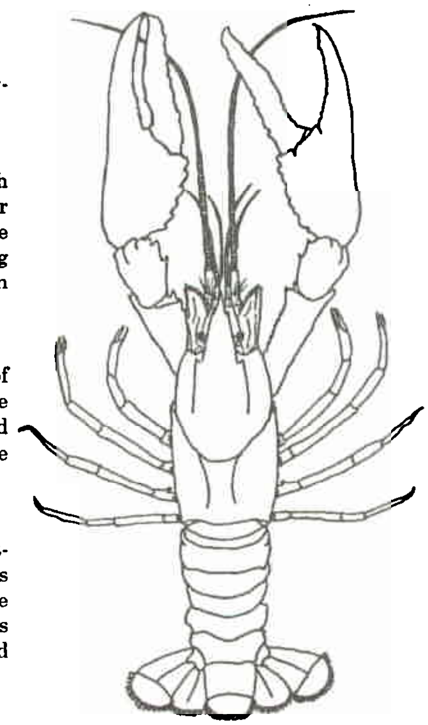
Metamorphosis is incomplete. Eggs are attached to stems of aquatic plants. Typically 5 nymph stages occur. Corixids have 1, 2 or 3 generations per year depending on species, temperature and food conditions. Nymphs or adults overwinter by hibernating in mud or debris.

### Ecology

Corixids occur everywhere in shallow ponds, lakes and stagnant pools, and spend most of their time on the bottom. They generally swim in a quick, darting manner with oarlike movements of hind legs. Adults are strong fliers and will readily leave an area because of high temperatures or overcrowding.

### Importance to Wildlife

Corixids are consumed by waterfowl.



## DECAPODA (Crayfish, Crawfish)

### Classification

Crustacea-Decapoda; Astacidae-*Cambarus*, *Procambarus*; Collector-gatherer; Overwintering resident.

### General Description

All are more or less cylindrical, ranging in length from 0.4 to 5.9 inches. Crayfish have 19 pairs of homologous appendages: 2 pairs of antennae, 1 short and 1 long; 5 pair of overlapping appendages used chiefly for handling food; 5 pair of walking legs, the first 3 pairs clawed; 5 pair of abdominal appendages (swimmerets) used during reproduction; and 2 pair of appendages that form the tail fan. Coloration ranges from blackish, brownish, red, orange and green. Mottling is common.

### Feeding Habits

Crayfish are omnivores, but seldom resort to predation. Foods consist of all kinds of succulent aquatic vegetation, with animal food a minor portion of the diet. Crayfish are considered scavengers. Clawed appendages are used for crushing and picking up food and tearing it into pieces. Pieces are passed forward to appendages making up the mouthparts.

### Life History

Fertilized eggs adhere to swimmerets and upon hatching young crayfish remain attached until about the third instar. A total of 5–10 instars occur depending on species and temperature. During the early instars the body and appendages gradually assume adult proportions. Life span may last 6–7 years, but generally less. Molt continues throughout the life cycle and is modified and controlled largely by temperature and light.

### Ecology

Adults remain hidden under debris during daylight, but move about and feed from dusk to dawn. Found in all types of waters, crayfish generally inhabit shallow waters, seldom deeper than 3 feet. Most species tolerate wide ranges of temperature, pH and carbon dioxide. Crayfish chimneys, which indicate the presence of a burrow, serve no known purpose, other than as a depot for mud pellets expelled during burrowing.

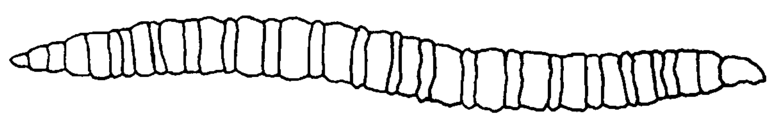
### Importance to Wildlife

Consumed by waterfowl, and especially important in the diet of hooded mergansers, crayfish are also consumed by wading birds, frogs, turtles, raccoons, otters and minks. Crayfish also serve as hosts for a number of parasites.

## TABANID (Horsefly)

### Classification

Insecta-Diptera; Tabanidae-*Chrysops*, *Tabanus*; Collector-gatherer or Predator; Overwintering spring recruits.



### General Description

Larvae are 0.6–1.6 inches long; body is elongated, cylindrical and tapered at both ends. Color is generally white, yellowish, greenish or brownish. The body is composed of a minute head, 3 thoracic segments, 8 abdominal segments and a posterior siphon, used in respiration. Bumpy projections on top, bottom and side of the organism are small and they often have fused prolegs.

### Feeding Habits

Some species feed primarily on organic debris, scavenging both plant and animal material. Other species are predators, feeding mostly on snails, oligochaetes and insect larvae.

### Life History

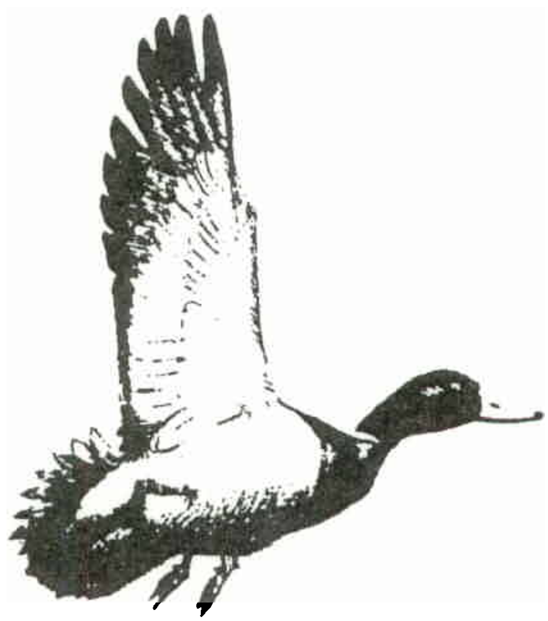
Tabanids undergo complete metamorphosis. Eggs are laid in masses on foliage or sticks above the water surface. When larvae hatch they fall into the water. Length of the larval stage is variable, but may last up to 3 years. Tabanids pupate in soil above water level. Their life cycle lasts 1–4 years, depending on species, temperature and food conditions.

### Ecology

Tabanid larvae usually remain under leaves, vegetation and other debris. They are widely distributed, but usually found in slow moving, shallow waters.

### Importance to Wildlife

Tabanids are consumed by fish and waterfowl. They may serve as an important nutrient link between detrital resources and waterfowl.



# APPENDIX 4. COMMON AND SCIENTIFIC NAMES OF PLANTS COMMONLY OCCURRING IN GREENTREE RESERVOIRS

## WOODY VEGETATION: TREES

### ACERACEAE

Box elder maple (*Acer negundo*)
Drummond red maple (*A. rubrum drummondii*)
Silver maple (*A. saccharinum*)
Sugar maple (*A. saccharum*)

### CORYLACEAE

Blue beech, Ironwood (*Carpinus caroliniana*)
Hophornbeam (*Ostrya virginiana*)
River birch (*Betula nigra*)

### EBENACEAE

Persimmon (*Diospyros virginiana*)

### FAGACEAE

Pin oak (*Quercus palustris*)
Nuttall oak (*Q. Nuttallii*)
Willow oak (*Q. phellos*)
Cherrybark oak (*Q. falcata* var. *pagodaefolia*)
Water oak (*Q. nigra*)
Overcup oak (*Q. lyrata*)
Shumard oak (*Q. Shumardii*)
Swamp chestnut oak (*Q. Michauxii*)
Live oak (*Q. virginiana*)
Laurel oak (*Q. laurifolia*)

### HAMAMELIDACEAE

Sweetgum (*Liquidambar Stryraciflua*)

### JUGLANDACEAE

Water hickory (*Carya aquatica*)
Shagbark hickory (*C. ovata*)
Bitternut hickory (*C. cordiformis*)
Pignut hickory (*C. glabra*)
Pecan (*C. illinoensis*)

### LEGUMINOSAE

Honey locust (*Gleditsia triacanthos*)
Water locust (*G. aquatica*)

### MAGNOLIACEAE

Sweetbay (*Magnolia virginiana*)

### NYSSACEAE

Water tupelo (*Nyssa aquatica*)
Blackgum (*N. sylvatica*)

### OLEACEAE

Green ash (*Fraxinus pennsylvanica*)
Pumpkin ash (*F. profunda*)
Water ash (*F. caroliniana*)

### PINACEAE

Pond pine (*Pinus serotina*)

### PLATANACEAE

American sycamore (*Platanus occidentalis*)

### SALICACEAE

Common cottonwood (*Populus deltoides*)
Swamp cottonwood (*P. heterophylla*)
Black willow (*Salix nigra*)
Ward willow (*S. caroliniana*)

### TAXODIACEAE

Bald cypress (*Taxodium distichum*)
Pond cypress (*T. ascendens*)

### ULMACEAE

Sugarberry (*Celtis laevigata*)
Hackberry (*C. occidentalis*)
Water elm (*Planera aquatica*)
American elm(*Ulmus americana*)
Red elm (*U. rubra*)

## WOODY VEGETATION: SHRUBS AND SMALL TREES

### ANNONACESE

Paw paw (*Asimina triloba*)

### AQUIFOLIACEAE

Possum haw holly (*Ilex decidua*)
American holly (*I. opaca*)

### CAPRIFOLIACEAE

Black haw (*Viburnum prunifolium*)
Arrowwood (*V. dentatum*)

### CELLASTRACEAE

Wahoo (*Euonymus atropurpureus*)

### CORNACEAE

Flowering dogwood (*Cornus florida*)
Stiff dogwood (*C. foemina*)

### LAURACEAE

Sassafras (*Sassafras albidum*)
Spice bush (*Lindera benzoin*)

### LEGUMINOSAE

Indigo bush, Lead plant (*Amorpha fruticosa*)

### MORACEAE

Red mulberry (*Morus rubra*)
White mulberry (*M. alba*)

### OLEACEAE

Swamp-privet (*Forestiera acuminata*)

### PEDALIACEAE

Southern black haw (*Viburnum rufidulum*)
Walter's viburnum (*V. obovatum*)
Elderberry (*Sambucus canadensis*)

### ROSACEAE

Green hawthorne (*Crataegus viridis*)
Parsley haw (*C. marshallii*)
Redbud (*Cercis canadensis*)
Blackberry (*Rubus allegheniensis*)
Dewberry (*R. hispidus*)

### RUBIACEAE

Buttonbush (*Cephalanthus occidentalis*)

## WOODY VEGETATION: VINES

### ANACARDIACEAE

Poison ivy (*Rhus radicans*)

### APOCYNACEAE

Climbing dogbane (*Trachelospermum difforme*)

### BIGNONIACEAE

Cross-vine (*Bignonia capreolata*)
Trumpet creeper (*Campsis radicans*)

### CAPRIFOLIACEAE

Japanese honeysuckle (*Lonicera japonica*)

### CELASTRACEAE

American bitter-sweet (*Celastrus scandens*)

### LEGUMINOSAE

Wisteria (*Wisteria frutescens macrostachya*)

### LILIACEAE

Cat greenbrier (*Smilax glauca*)
Common greenbrier (*S. rotundifolia*)

### POLYGONACEAE

Buckwheatvine (*Brunnichia cirrhosa*)

**RANNUNCULACEAE**

Swamp leather flower (*Clematis crispa*)

**STYRACACEAE**

Snow-bell (*Styrax americana*)

**VITACEAE**

Cat grape (*Vitis palmata*)
Grayback grape (*Vitis cinerea*)
Muscadine (*Vitis rotundifolia*)
Virginia creeper (*Parthenocissus quinuefolia*)
Peppervine (*Ampelopsis arborea*)

## HERBACEOUS VEGETATION

**ALISMACEAE**

European waterplantain (*Alisma plantago-aquatica*)
Common burhead (*Echinodorus cordifolius*)
Arrowhead (*Sagittaria latifolia*)

**AMARANTHACEAE**

Pigweed (*Amaranthus* sp.)

**AMARYLLIDACEAE**

Spider lily (*Hymenocallis occidentalis*)

**ASCLEPIADACEAE**

Swamp milkweed (*Asclepias incarnata*)
Milkweed (*A. perennis*)

**COMPOSITAE**

Aster (*Aster* sp.)
Giant ragweed (*Ambrosia trifida*)
Common ragweed (*A. artemisiifolia*)
Tickseed sunflower (*Bidens aristosa*)
Beggar ticks (*B. comosa*)
Devils beggarticks (*B. frondosa*)
Tickseed sunflower (*B. polylepis*)
Joe-pye-weed, Late boneset (*Eupatorium serotinum*)
Sneezeweed (*Helenium flexuosum*)
Common cocklebur (*Xanthium strumarium*)
Fire weed (*Erechtites hieracifolia*)
Butterweed (*Senecio glabellus*)

**COMMELINACEAE**

Dayflower (*Commelina virginica*)

**CONVOLVULACEAE**

Morningglory (*Ipomoea coccinea*)

**CRUCIFERAE**

Marsh yellow cress (*Rorippa islandica*)

## CYPERACEAE

Fox sedge (*Carex vulpinoidea*)
Sedge (*C. brevior*)
Sedge (*C. tribuloides*)
Hop sedge (*C. lupulina*)
Chufa flatsedge (*Cyperus esculentus*)
Redroot flatsedge (*C. erythrorhizos*)
Straw-colored flatsedge (*C. strigosus*)
Umbrella sedge (*C. virens*)
Longspike spikerush (*Eleocharis macrostachya*)
Blunt spikerush (*E. obtusa*)
Squarestem spikerush (*E. quadrangulata*)
Goose grass (*Fimbristylis autumnalis*)
Horned rush (*Rhynchospora macrostachya*)
Softstem bulrush (*Scirpus validus*)
Smooth sawgrass (*Cladium mariscoides*)

## EUPHORBIACEAE

Virginia copperleaf (*Acalypha virginica*)
Spotted euphorbia (*Euphorbia maculata*)

## GRAMINEAE

Broomsedge bluestem (*Andropogon virginicus*)
Hairy crabgrass (*Digitaria sanguinalis*)
Common barnyardgrass (*Echinocloa crusgalli*)
Barnyardgrass (*E. muricata*)
Rice cutgrass (*Leersia oryzoides*)
Sprangletop (*Leptochloa panicoides*)
Faber bristlegrass (*Seteria faberi*)
Glaucous bristlegrass (*S. glauca*)
Giant cane (*Arundinaria gigantea*)
Meadow fescue (*Festuca elatior*)

## HYPERICACEAE

Marsh St. John's wort (*Hypericum tubulosum*)

## JUNCACEAE

Common rush (*Juncus effusus*)
Poverty rush (*J. tenuis*)

## LABIATAE

American bugle weed (*Lycopus americanus*)

## LEMNACAE

Common duckweed (*Lemna minor*)
Star duckweed (*L. trisulca*)

## LYTHRACEAE

Tooth-cup (*Ammannia coccinea*)

## MALVACEAE

Prickly sida (*Sida spinosa*)
Rose mallow (*Hibiscus lasiocarpos*)

## NYMPHAEACEAE

American lotus (*Nelumbo lutea*)

**ONAGRACEAE**

Common marshpurslane (*Ludwigia palustris*)
Creeping marshpurslane (*L. repens*)
Seed box (*L. alternifolia*)

**OPHIOGLOSSACEAE**

Grape-fern (*Botrychium dissectum*)

**POLYGONACEAE**

Swamp smartweed (*Polygonum hydropiperoides*)
Curltop ladysthumb (*P. lapathifolium*)
Pennsylvania smartweed (*P. pensylvanicum*)
Virginia knotweed (*P. virginianum*)
Swamp dock (*Rumex verticillatus*)

**RANUNCULACEAE**

Low spearwort (*Ranunculus pusillus*)
Water plantain spearwort (*R. laxicaulis*)

**RUBIACEAE**

Rough buttonweed (*Diodia teres*)
Buttonweed (*D. virginiana*)

**SAURURACEAE**

Lizard's tail (*Saururus cernuus*)

**SCROPHULARIACEAE**

False pimpernel (*Lindernia anagallidea*)

**TYPHACEAE**

Common cattail (*Typha latifolia*)

**UMBELLIFERAE**

Water parsley (*Sium suave*)

# APPENDIX 5. COMMON AND SCIENTIFIC NAMES OF SELECTED ANIMALS COMMONLY OCCURRING IN GREENTREE RESERVOIRS.

## INVERTEBRATES

### TURBELLARIANS

Flatworms (*Planaria* spp.)

### NEMATODES

Roundworms (Nematoda)

### ANNELIDS

Oligochaeta
- Lumbriculid worms (*Lumbriculus* spp.)
- Naidid worms (*Dero* spp.)
- Tubificid worms (*Tubifex* spp.)

Hirudinea
- Leeches (*Erpobdella* spp.)

### MOLLUSCS

Bivalvia
- Fingernail clams (*Pisidium* spp., *Sphaerium* spp.)

Gastropoda
- Pond snails (*Physa* spp., *Lymnae* spp.)
- Orb snails (*Promenetus* spp, *Gyraulus* spp.)
- Viviparid snails (*Vivivapus* spp.)

### ARTHROPODS

Arachnids
- Spiders (*Pirata* spp., *Dolomedes* spp.)
- Mites (Acari)

Insects
- Springtails (Collembola)
- Mayflies (*Caenis* spp.)
- Damselflies (*Enallagma* spp., *Ischnura* spp.)
- Dragon flies (*Gomphus* spp.)
- Backswimmers (*Notonecta* spp.)
- Water boatman (*Sigara* spp.)
- Predaceous diving beetle (*Agabus* spp., *Coptotomus* spp.)
- Water scavenger beetle (*Berosus* spp., *Tropisternus* spp.)
- Other beetles (Coleoptera)
- Midges (*Chironomus* spp., *Pentaneura* spp.)
- Crane flies (Tipulidae)
- Phantom midges (*Chaoborus* spp.)
- Mosquitoes (*Culex* spp., *Aedes* spp.)
- Deer and Horse flies (*Tabanus* spp., *Chrysops* spp.)
- Rat-tailed maggot (*Eristalis* spp.)
- Moths, Butterflies (Lepidoptera)

### ARTHROPODS (cont.)

Crustaceans
- Isopoda (*Asellus* spp.)
- Amphipods (*Crangonyx* spp., *Hyalella aztecta, Gammarus* spp.)

Crayfish (*Cambarus* spp., *Procambarus* spp.)

## VERTEBRATES

### FISH

Redfin pickerel (*Esox americanus americanus*)
Chain pickerel (*E. niger*)
Grass pickerel (*E. americanus*)
Bowfin (*Amia calva*)
Topminnow (*Fundulus* spp.)
Killifish (*Fundulus* spp.)
Yellow bullhead (*Ictalurus natalis*)
Warmouth (*Lepomis gulosus*)
Mosquitofish (*Gambusia affinis*)
Large-mouth bass (*Micropterus salmoides*)
Brown bullhead (*Ictalurus nebulosus*)
Bluegill (*Lupomis malrochirus*)
Banded pygmy sunfish (*Elassoma zonatum*)
Flier (*Centrarchus macropterus*)
Starhead topminnow (*Fundulus notti*)

### AMPHIBIANS

Congo eel (*Amphiuma means*)
Lesser Siren (*Siren intermedia*)
Marbled salamander (*Ambystoma opacum*)
Spotted salamander (*Ambystoma maculatum*)
Southern dusky salamander (*Desmognathus auriculatus*)
Many-lined salamander (*Stereochilus marginatus*)
Mud salamander (*Pseudotritor montanus*)
Dwarf salamander (*Eurycea quadridigitata*)
Spadefoot toad (*Scaphiopus* spp.)
Cricket frog (*Acris gryllus*)
Green tree frog (*Hyla cinerea*)
Common tree frog (*Hyla versicolor*)
River frog (*Rana heckscheri*)
Green frog (*Rana clamitans*)
Leopard frog (*Rana utricularia*)

### REPTILES

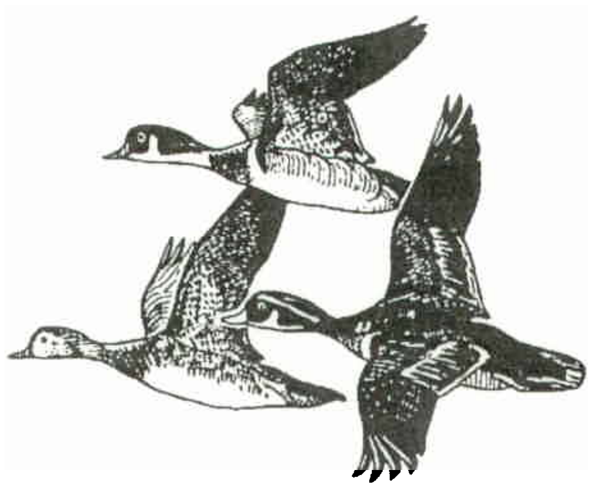
Eastern mud turtle (*Kinosternon subrubrum subrubrum*)
Box turtle (*Terrapene* spp.)
Anole (*Anolis carolinensis*)
Water snake (*Natrix* spp.)
Garter snake (*Thamnophis* spp.)
Black rat snake (*Elaphe obsoleta obsoleta*)
Gray rat snake (*Elaphe obsoleta spiloides*)
Copperhead (*Ancistrodon contortrix*)
Cottonmouth (*Ancistrodon piscivorus*)
Canebrake rattlesnake (*Crotalus horridus*)

## BIRDS

Prothonotary warbler (*Protonotaria citrea*)
Parula warbler (*Parula americana*)
Tufted titmouse (*Parus bicolor*)
Red-shouldered hawk (*Buteo lineatus*)
Red-winged blackbird (*Agelaius phoeniceus*)
Great blue heron (*Ardea herodias*)
Yellow-crowned night-heron (*Nycticorax violacea*)
Robin (*Turdus migratorius*)
Barred Owl (*Strix varia*)
Downy woodpecker (*Picoides Pubescens*)
Red-bellied woodpecker (*Centurus carolinus*)
Cardinal (*Cardinalis cardinalis*)
Yellowthroat (*Geothlypis trichas*)
Kentucky warbler (*Oporornix formosus*)
Pine warbler (*Dendroica pinus*)
Carolina wren (*Thryothorus luduvicianus*)
Wood thrush (*Hylocichlia mustelina*)
Wood pewee (*Contopus virens*)
Wild turkey (*Meleagris gallopavo*)
Summer tanager (*Piranga rubra*)
Common grackle (*Quiscalus quiscula*)
Mallard (*Anas platyrhynchos*)
Wood duck (*Aix sponsa*)
Hooded merganser (*Mergus culculatus*)
Canada goose (*Branta canadensis*)
Gadwall (*Anas strepera*)
Green-winged teal (*Anas crecca*)
Ring-necked duck (*Aythya collaris*)
Pintail (*Anas acuta*)
Black duck (*Anas rubripes*)

## MAMMALS

Beaver (*Castor canadensis*)
Mink (*Mustela vison*)
River otter (*Lutra canadensis*)
Raccoon (*Procyon lotor*)
Swamp rabbit (*Sylvilagus aquaticus*)
White-tailed deer (*Odocoileus virginianus*)
Cougar (*Felis concolor*)
Bobcat (*Lynx rufus*)
Gray fox (*Urocyon cinereoargenteus*)
Deer mouse (*Peromyscus maniculatus*)
Cotton mouse (*Peromyscus gossypinus*)
Golden mouse (*Peromyscus nuttalli*)
Short-tailed shrew (*Blarina brevicauda*)
Southeastern shrew (*Sorex longirostris*)
Gray squirrel (*Sciurus carolinensis*)
Fox squirrel (*Sciurus niger*)



# Index