Chapter 21
Wildlife Management in Southern Pine Regeneration Systems

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Abstract

Wildlife resources can be integrated into timber management plans for southern pine forests. However, joint production of timber and wildlife resources to meet landowner objectives requires an understanding of forestry-wildlife relationships, wildlife habitat needs, and economic trade-offs. Forest-wildlife management strategies may favor particular species, species richness, or a combination of the two; regardless, habitat diversity among stands and within stands is important. The diversity, abundance, and distribution of forest wildlife depend upon natural site characteristics and manipulation of individual stands within a managed forest. Pine silviculture can provide habitats suitable for most animal species that occur naturally in the southern pine region. Costs associated with forest wildlife management, at the expense of timber production, can be offset by income from fee hunting, which may provide an incentive to integrate wildlife into forest plans. In some instances, joint production of pine timber and wildlife can yield higher revenues than timber production alone.

21.1 Introduction

Wildlife is a forest resource, just as timber, water, fish, and opportunities for livestock grazing and outdoor recreation are forest resources. Managing forests for any one of these resources affects the others to some degree. Silvicultural manipulations to increase southern pine *(Pinus* spp.) yields greatly impact wildlife throughout the South. Thus, timber management is wildlife management, but the extent to which it is good for wildlife depends upon the considerations given to wildlife in the development and implementation of a forest plan [212].

In the past, relatively few species, principally game animals and some endangered species, have been considered in forest planning. And even today, except on special areas or refuges, wildlife and fish are seldom fully integrated into timber management programs largely because timber production is still the primary interest of most forestland owners. The traditional focus on game species is still present, but landowner concerns and public attitudes towards forestry and wildlife are changing. Interest in all wildlife species is increasing, and their distribution and abundance as "by-products" of timber management are not as acceptable as they once were. Forest management on some public and private forestlands is currently moving towards integrating a greater variety of wildlife species, both game and nongame, into forest plans.

Forest resources, especially wildlife, are important to people in the South. In 1980, approximately 12% of the South's population (> 16 years old) hunted game species and 41% enjoyed viewing wildlife [216], especially songbirds [190]. However, to maintain or enhance the forest wildlife we all enjoy requires an understanding of complex forestry-wildlife relationships. Timber and wildlife management are seen as generally compatible, but only if the needs of wildlife are recognized and considered along with those for timber management [212]. The purpose of this chapter is to promote a basic understanding of wildlife habitats in managed southern pine forests so that forestland owners and managers can achieve the wildlife objectives they desire. For others' perspectives on forest wildlife management and for additional information on specific pine ecosystems — e.g., slash *(Pinus elliottii* Engelm.), longleaf *(P. palustris* Mill.), loblolly *(P. taeda* L.), shortleaf *(P. echinata* Mill.) — I recommend papers by Johnson et al. [113], Harris et al. [86], Dickson [43], Buckner [18, 19], Owen [174], Wigley [226], and Johnson [110].

21.2 Forestry and Wildlife Objectives

Approximately 90% of southern forestlands are privately owned [65], primarily for timber production [166, 175]. Wildlife is typically rated as the second most important use, with most owners having multiple-use goals. The relative importance of timber production in the South is evident: pine plantations account for roughly 1 out of 3 ha of the pine forest type, and more than 162,000 ha of harvested

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timberland/year are being regenerated to pine plantations [117, 118]. Both opportunity and need exist to include wildlife in multiple-use forest management programs.

Forests can be managed for a mix of products or uses desired by their owners. The desired mix will change through time, however, according to landowner interests, public demand, economics, and capability of the land. Unmanaged pine stands are generally considered to be poor wildlife habitat through much of a rotation. The level of wildlife management depends upon the interests and goals of the landowner. Careful planning and implementation of silvicultural practices can provide good wildlife habitat, usually requiring trade-offs with other forest products at some cost to the landowner. However, income opportunities through the sale of hunting privileges can be used to offset some of those costs of wildlife management (see 21.5).

All landowners should identify and evaluate their particular interests, needs, and objectives related to their forestland. They should first determine what is possible on the land, and at what gain or cost, then analyze the trade-offs, establish reasonable priorities, make decisions, and develop a management plan for the desired mix of products and uses. Throughout this process, landowners without the necessary background and skills should seek technical assistance available from several sources (e.g., county extension service, public forestry and wildlife agencies, private consultants) and in the literature. Understanding the forest-habitat preferences and behavior of particular wildlife species allows landowners to make knowledgeable, cost-effective decisions in developing and implementing a forest plan.

21.3 Forestry-Wildlife Relationships

The four requirements of wildlife populations are food, water, cover, and space. The first three can be manipulated by forest management, and their diversity, amount, and quality determine the diversity and abundance of the forest wildlife community.

At least 90% of vertebrates in the U.S. are associated with forests, largely because forests are a 3-dimensional environment with considerably more height than other terrestrial habitats [189, 224]. Forests provide more different kinds of food and cover for more species of wildlife than any other habitat type. Approximately 400 species of vertebrates (perhaps 50 mammals, 250 birds, and 100 reptiles and amphibians) may be found in a large tract (4,000 ha) of southern forest during a year [86]. Compared to numbers of species in North America in general, those of breeding birds and mammals are relatively low in the southeastern states, but those of overwintering species and individuals are relatively high. Reptiles and amphibians are particularly abundant in the Southeast; for example, Florida has more species of reptiles and amphibians than resident breeding birds and mammals.

Timber management activities affect forest structure, vegetation communities, and successional patterns, and thereby determine the type of wildlife habitat present. However, the effect of any management activity can vary depending upon factors such as land form, plant community, season of the year, wildlife species, and even age and sex of individual animals. Forest wildlife management generally follows two basic philosophies: managing for species richness [55] or managing for featured species [235].

The goal of managing for species richness is to maintain as many resident wildlife species as possible by providing a diversity of habitats (stands of different timber type, age, and size) intermingled in a forest mosaic. The various stages of plant communities should be present through time to support a relatively stable, diverse wildlife population. This approach towards ecosystem management is most appropriate for larger ownerships. On smaller land bases, options are more limited; managing for habitat diversity within stands is as important as that between stands if species richness is to be achieved on small areas.

However, because many landowners prefer particular animal species, especially game, the more frequently used approach is managing for featured species. The goal is to optimize food, cover, and water for the species of interest. Other animals with habitat requirements similar to those of the featured species will also fare well. If several species with different habitat needs are featured, then managing for featured species can diversify habitat and thereby also favor species richness.

The two philosophies can be used together to insure species richness while favoring selected species in specific locations for particular purposes [212]. Information in the following discussions of stand succession, habitats, and species management can be applied to achieve one or both of these wildlife-management approaches.

21.3.1 Stand Succession

Succession is the natural progression of a forest stand through a series of plant growth stages. For example, after logging and regeneration, a pine plantation generally goes through the following stages: seedling-grass-forb, sapling-brush, poletimber, and sawtimber (Fig. 21.1). The timing of successional stages and the composition of associated plant communities in managed pine stands vary considerably, depending upon natural site characteristics, climate, and silvicultural techniques.

In loblolly pine plantations, the early successional stages are characterized by a high level of plant-species richness in the ground stratum [59]. The seedling-grass-forb stage (the first two growing seasons) is dominated by tall annuals and grasses the first year and lower perennial forbs, grasses, and woody plants the second year. Horseweed [*Conyza canadensis* (L.) Cronq.], ragweed (*Ambrosia artemisiifolia* L.), dog fennels (*Eupatorium* spp.), fireweed [*Erechtites hieracifolia* (L.) Raf.], purple aster (*Aster patens* Ait.), crabgrasses (*Digitaria* spp.), panicums

a

b

c

Figure 21.1. Examples of successional stages of loblolly pine plantations:

Seedling-grass-forb stage — trees approximately 1 m tall, after two growing seasons in the field.

Sapling-brush stage — trees approximately 3 m tall, after four growing seasons in the field.

Poletimber stage – trees approximately 10 to 12 m tall, and 15 to 20 cm dbh (diameter at breast height, 1.39 m above ground).

Sawtimber stage — trees approximately 18 to 20 m tall, and 25 to 35 cm dbh.

d

(*Panicum* spp.), and pokeweed (*Phytolacca americana* L.) may be conspicuously abundant in this stage. Seed and fruit production from blackberries (*Rubus* spp.), sumacs (*Rhus* spp.), pokeweed, grasses, legumes, and other herbaceous species can be abundant the second year. Habitat during this stage favors meadowlarks (*Sturnella magna* L.), mourning doves (*Zenaida macroura* L.), bobwhite quail (*Colinas virginianus* L.), grasshopper sparrows (*Ammodramus savannarum* Gmelin), white-footed mice (*Peromyscus leucopus* Rafinesque), and other ground-feeding animals. Wild turkeys (*Meleagris gallopavo* L.) use these areas for feeding, nesting, and brood rearing, white-tailed deer (*Odocoileus virginianus* Zimmerman) feed in them, and hawks and owls prey upon the small birds and mammals.

The sapling-brush stage extends from the third growing season until crown closure, usually (depending mostly upon pine density) at about the seventh growing season [2]. The ground cover in the third and fourth years is dominated by perennial grasses, frequently broomsedge (*Andropogon virginicus* L.), with vines and woody sprouts developing rapidly. Legumes, asters, goldenrods (*Solidago* spp.), and coneflowers (*Rudbeckia* spp.) may be locally abundant. By the middle of this stage, pines, hardwood sprouts, and blackberry vines are shading much of the understory; by the end of it, the pine canopy is suppressing an understory of hardwoods and scattered vines. Habitat during this stage favors the cotton rat (*Sigmodon hispidus* Say & Ord), cottontail rabbit (*Sylvilagus floridanus* J. A. Allen), bobwhite quail, indigo bunting (*Passerina cyanea* L.), yellowthroat (*Geothlypis trichas* L.), yellow-breasted chat (*Icteria virens* L.), and cardinal (*Cardinalis cardinalis* L.), along with predators such as bobcats (*Lynx rufits* Schreber), red and gray foxes (*Vulpes vulpes* L., *Urocyon cinereoargenteus* Schreber), and coyotes (*Canis latrans* Say). Deer and turkeys continue to use these areas. If snags are left during site preparation, the sapling-brush and seedling-grass-forb stages will be used by insect-eating and cavity-nesting birds such as woodpeckers, bluebirds (*Sialia sialis* L.), flycatchers, and chickadees (*Parus* spp.).

The poletimber stage, from crown closure to about midrotation age (15 to 20 years), is characterized by further development of the overstory. The pine overstory and hardwood midstory shade out most of the understory. The ground stratum, once dominated by grasses, forbs, and vines, is replaced by a layer of pine needles, although grasses, blackberry thickets, and some shrubs remain in scattered openings or along stand edges. Without thinning and burning, this stage has little value for wildlife other than providing cover for animals using adjacent habitats.

As the stand enters the sawtimber stage, the pine canopy maintains dominance over midstory hardwoods. Without thinning, this stage also has little value for wildlife. In most instances, though, the stand will be thinned for income and to promote diameter growth of the remaining crop trees.

Intermediate silvicultural treatments such as thinning for stocking control or merchantable timber, prescribed burning, and possibly pruning are usually conducted during the poletimber and sawtimber stages, with timing dependent upon landowner objectives. Such treatments create openings in the canopy which stimulate understory development. Ground-level vegetation reverts to earlier successional stages, and some of their wildlife values can be maintained throughout the rotation, depending upon frequency and extent of the treatments. In addition to deer, turkey, and other wildlife associated with earlier successional plant communities, poletimber and sawtimber stands are used by a group of insect-eating birds such as the yellow-billed cuckoo *(Coccyzus americanus* L.), rufous-sided towhee *(Pipilo erythrophthalmus* L.), pine warbler *(Dendroica pinus* Wilson), wood pewee *(Canopus virens* L.), and summer tanager *(Piranga rubra* L.). Wildlife diversity is in fact good in older stands treated to produce low basal areas and open canopies; indeed, without thinning and burning, a pine stand can become what some refer to as a "biological desert" or "pine barren," a dense canopy of pine and suppressed hardwoods over a ground cover of pine straw.

Stand succession is affected by many factors: regeneration method (natural or planted); the type, intensity, and season of site preparation and intermediate silvicultural treatments; the species, density, early mortality, growth, and form of pine trees; site quality; previous history of land use; soils; drainage; general climate and specific weather events; and native flora and fauna [43, 86, 113]. For example the slash pine flatwoods of Georgia have poor site quality that limits their potential for many wildlife species [113]. Many of the plants present during the early stages of slash pine plantations have low wildlife value, but the successional changes are less dramatic. Usually planted at wider spacing, with more open canopies, and regularly burned, slash pine plantations are more favorable for wildlife after the first 6 years. In contrast, loblolly pine plantations in the Georgia Piedmont support much higher numbers of wildlife in the early stages, but receive little use after canopy closure at about 7 years.

21.3.2 Special Habitats and Their Components

21.3.2.1 Edge and diversity

The size, shape, and distribution of forest stands largely determine the amount of edge habitat in a managed forest. An edge is the place where different plant communities or successional stages come together (Fig. 21.2). The transition area where these communities or stages influence each other is called an ecotone. Edges and their ecotones are usually richer in wildlife than their adjoining plant communities or successional stages; in these areas, the wildlife species are a mix of those in each plant community in addition to those adapted to the ecotone itself. In east Texas, numbers of bird species and individuals were about 3 times higher near the edge of a pine-hardwood stand than in the interior of that stand or in an adjacent pine plantation [207].

The amount of edge or ecotone in an area is determined by the length of the edge, the width of the ecotone, and their shape (linear vs. sinuous). The richness of edge habitats is influenced by the types of habitats converging. Richness is associated with the degree of contrast in vegetation structure along the edge [87, 138, 213]. The greater the contrast, the more likely the adjoining habitats are to be different in vegetation structure and in the wildlife they support. This usually increases species richness of the

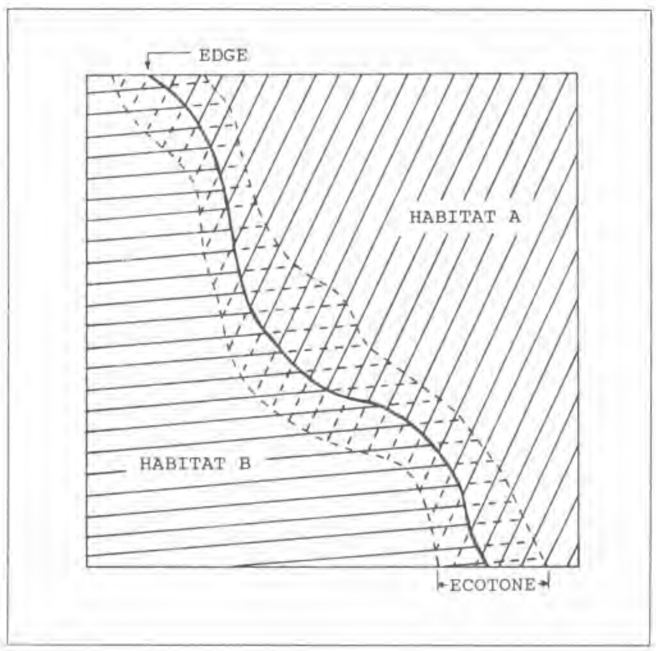

Figure 21.2. An edge is formed where two habitats come together; the influence of both habitats extends over the edge. An ecotone, the transition area between edge and adjoining community, is made up of plants and animals of the habitats forming the edge plus species adapted to the ecotone itself.

ecotone. For example, the four stages of pine plantation development (seedling-grass-forb, sapling-brush, poletimber, sawtimber) can be formed into six different edge combinations by joining two stages. The edge between an early successional stage and a late stage has greater species richness than the edge between two late stages.

The number of species present in a forest habitat is related to the size of the stand. Generally, the larger the habitat blocks, the greater the number of wildlife species associated with them, and the richer the species diversity along the edge. For example, bird-species richness in "islands" or blocks of forest habitat generally increases as average stand size increases [1, 66, 87]. Working with birds in New Jersey, Galli et al. [66] found that the number of species present was optimized in stands of about 24 to 45 ha. In Florida hardwoods, stands up to 30 ha supported only 64% of the local upland breeding bird species [83]. Thomas et al. [213] estimate that wildlife species richness attributable to stand size alone should be highest if the average stand size is about 34 ha. Anderson and Robbins [1] suggest that even 100 to 1,300 ha is too small to support a full complement of birds in hardwood forests of western Maryland, where, as stand size increased (to 10,000+ ha), the frequency of detection of neotropical (long-distance) migrants increased but that of edge species decreased. The principle involved here is that species with large home ranges and preferences for interior forest habitats can meet their needs only in larger stands. Therefore, it is important to understand the habitat preferences of wildlife species of interest to optimize habitat size and distribution.

Forest fragmentation — or the breakup of large forested areas by roads, agriculture, urbanization, or small forest stands — negatively impacts fauna that require large tract size or interior forest habitats [84]. Reduction in patch size and isolation of forest fragments affect species richness, species composition, and inbreeding and gene flow [85, 94]. Habitat fragmentation and associated impacts generally reduce the presence and abundance of large-bodied species (especially wide-ranging carnivores), specialists, and area-sensitive species (requiring large or interior forest habitats) while increasing those of middle-sized omnivores, generalists, and edge species. When working with large forested landscapes, it is important not only to consider the distribution and size of forested patches required by some species but also to enhance the connectivity among patches with corridors of similar habitat. Where large areas of older natural forest are a management goal, selective logging or extensive use of small clearcuts with natural regeneration may be appropriate. Streamside management zones provide a unique opportunity to connect stands or patches throughout a managed forest (see 21.3.2.3).

The general simplification of stand structure and decrease in forest diversity associated with intensive pine silviculture can be offset somewhat with careful management of the forest landscape. A patchy mosaic of irregularly shaped pine stands of various ages and sizes, interspersed with natural stands containing hardwoods, provides a diversity of habitats to support many of the native wildlife species. Management objectives for forest diversity among stands will not be the same on 100 ha as on 1,000 ha, or on 10,000 ha [94]. Stand size should vary depending upon total size of ownership and landowner objectives. Stands of 40 ha or less can be managed to meet most habitat-diversity objectives for species richness or featured species. Stands of 100 ha and more are used by many species of wildlife, including deer and wild turkeys [156, 227]. Natural forest or mature timber stands larger than 100 ha, or even 1,000 ha, provide habitat for interior forest species or those with large ranges, such as pileated woodpeckers (*Dryocopus pileatus* L.) or black bears (*Ursus americanus* Pallas).

To enhance diversity between stands, managers should maintain natural edges and design harvest units with elongated irregular boundaries to increase the length of edge habitat. Harvest units or silvicultural treatments should be distributed in a mosaic pattern to create more edge and the greatest contrast in vegetation structure over the long term. Size of ownership, soils, topography, and rotation length should be considered when planning stand size, shape, and distribution.

To enhance diversity within stands, especially on smaller ownerships, managers should maintain different plant communities and vegetation structure to provide habitats for species with small ranges that need access to more than one habitat type. Diversity within stands can be enriched through maintaining natural forest types on steep slopes, sand ridges, cypress domes, riparian zones, and other wet areas; mast-producing hardwoods and snags in clumps or scattered throughout stands; windrows not burned or planted; managed openings or food plots on temporary logging roads, skid trails, or log decks; varied planting density or thinning regimes; and patchy prescribed bums. It is important to recognize opportunities for managing the natural diversity inherent with each piece of land and to integrate it into the managed pine forest.

21.3.2.2 Snags and den trees

Snags and den trees, frequently produced by lightning, fire, disease, flooding, drought, and logging injuries, are important habitat components of forest communities (Fig. 21.3). A snag is a dying, partially dead, or standing dead tree suitable as a nest site for cavity-using wildlife. A den tree can be a dying tree or a relatively healthy live tree with natural dens near its base or up in its crown where dead branches or other injuries promote wood decay.

In the Southeast, approximately 60 species of birds and mammals use dens and cavities in trees for nesting, roosting, resting, or protection. Of 146 forest bird species in Louisiana, 70 nest there, and 30 of those (43%) nest in cavities [170]. Woodpeckers and other small birds feed on insects found in the decaying wood of snags, flycatchers and birds of prey use snags as perches while hunting, and

Figure 21.3. (a) Dead hardwood snag showing old cavities and evidence of woodpecker feeding activity; and (b) live hardwood trees with basal dens (the den tree on the left also had a cavity entrance up in the crown).

many songbirds perch on snags while singing. Woodpeckers frequently use resonant portions of snags as drumming sites to announce territories.

Primary cavity nesters, such as woodpeckers, usually excavate their own holes in snags. Secondary cavity nesters, such as owls, flycatchers, wrens, and bluebirds, often use woodpecker cavities or natural dens. Squirrels, mice, bats, skunks, raccoons *(Procyon lotor* L.), opossums *(Didelphis virginiana* Kerr), and other mammals use cavities in snags or hollow trees for winter and summer dens. Even bees, spiders, skinks, and tree frogs (*Hyla* spp.) use cavities for shelter and as feeding sites.

The hardness of a snag is an important characteristic in determining its value for nesting and feeding. Primary cavity nesters cannot excavate a cavity in just any tree, but depend upon trees infected with fungal heart rot [28] whose softened heartwood is easier to excavate. Potential nest trees for primary cavity nesters can be identified by the following signs: fungal conks of species known to cause heart rots, dead branch stubs, old wounds or scars, insect damage, butt rot, discolored or soft decayed wood, or obvious dead portions [25].

The presence of trees with cavities varies with forest type and stand history. Cavities are more abundant in hardwoods than in pines. In South Carolina and Florida, the density of den trees averaged 0.4/ha in pine plantation, 2.8/ha in natural pine, 12.9/ha in pine-hardwood, and 32.5/ha in hardwood forest types [145]. Snag densities in coastal South Carolina averaged 3.8/ha in pine stands (> 50% pine) and 10.4/ha in other stands [81]; the number of snags required to support average cavity-nesting bird populations in coastal South Carolina was estimated to be 7.7/ha.

Management for pine timber clearly does not favor animals that use cavities; however, snags and den trees can be integrated into managed pine forests (Fig. 21.4). Snags present in young pine plantations increase bird abundance and species richness for the cavity-user group [44, 45, 222]. Dickson et al. [45] indicated that at least 5 snags/ha seemed adequate for nesting, but recommended leaving substantial numbers of hardwoods during harvest and then killing a few trees every 5 to 10 years to create future snags.

Some other cavity-management options include: maintaining snags and den trees in designated natural stands, riparian (streamside) zones, inoperable sites, or other special areas; discontinuing the removal of dead or

Figure 21.4. Where pine management is intensive, snags and den trees can be (a) scattered out in plantations, or retained in (b) clumps in plantations and (c) streamside management zones.

dying trees in stands where cavities are limited; extending rotation lengths to 75 to 150 years; leaving large snags and den trees instead of small ones; creating snags by frill girdling and cavities by boring holes; or providing nest boxes. When managing for individual species of cavity users, managers should be aware of specific nesting habitat preferences, such as tree species, diameter, cavity or den size and location, and forest type (see Conner [25] for cavity-nest site characteristics). Nest boxes are expensive, and providing snags and dens for a full complement of cavity-using wildlife will be prohibitively costly where pine timber is the primary objective. Yet some level of management for cavities can be integrated into any forest plan.

Firewood cutters pose a serious threat to maintaining snags and live hardwood den trees in accessible locations (Fig. 21.5). Increased demand for dead wood as fuel has reduced the number of snags available in some areas of the U.S. [183]. In 1978, an estimated 800,000 snags were used as firewood in the Front Range of the Rocky Mountains from Denver north to the Wyoming border. During 1977 and 1978, the U.S.D.A. Forest Service placed signs on 110 snags in two areas of Colorado designating them as wildlife trees, yet all but three snags had been removed by woodcutters by fall 1979.

21.3.2.3 Riparian zones and wetlands

Riparian zones are areas bordering free-flowing or standing water, such as rivers, streams, lakes, or ponds, and are dominated by vegetation that requires unbound water or moist soil conditions. The riparian zones most common to forest managers occur along streams and vary in size and vegetative condition, depending upon stream class, gradient, water quality, topography, soils, and plant community. They form natural edges, transitional between aquatic and terrestrial habitats, usually with high species diversity.

Riparian zones frequently supply food, water, and cover for wildlife which use these zones disproportionately more than other habitat types. The elongated shape of riparian zones, particularly their meandering nature along streams, maximizes the development of edge. These zones serve as travel corridors throughout a managed forest, connecting

Figure 21.5. Though signs inform the public of reasons for maintaining streamside management zones, firewood cutting is still a problem in accessible locations.

stands adjacent to water courses, and also stabilize stream channels and adjacent floodplains, maintaining good water quality and productive aquatic habitats.

Managing riparian zones along streams as natural forest stands (frequently referred to as streamside management zones) assures a critical source of edge and diversity in a managed pine forest. Riparian zones which are dominated by hardwoods, as is normally the case, provide cavities and a source for hard mast [155]. Riparian woodlands in Iowa supported higher densities of breeding birds than upland woodlands, and bird-species richness increased with the width of riparian woodlands [197]. In loblolly pine plantations, riparian zones 40 to 141 m wide supported gray and fox squirrels *(Sciurus carolinensis* Gmelin, *S. niger L.)* in Mississippi [220], and zones 55 to 93 m wide supported squirrels as permanent residents in East Texas [46]. Riparian zones 50 to 100 m wide were recommended for gray squirrels in slash pine plantations of east Texas [148]. However, except for squirrels, little information is available on wildlife use of streamside management zones in the South. Very narrow streamside corridors may even be "ecological traps," where losses of desirable species to predation may exceed benefits [177].

Riparian zones with natural stand characteristics should be integrated into the management of southern pine forests. However, the width of streamside zones to be retained and logging activities within them are determined by site characteristics and individual landowner objectives. The narrower the zone, the more easily it is impacted, so trade-offs between wildlife and timber production must be considered. If logging is planned in riparian areas, single-tree and group-selection methods may be more favorable for wildlife than clearcutting, shelterwood, or seedtree cuts. With selective logging, it is possible to remove some timber and still retain much of the habitat intact for wildlife. Trees should be felled away from streams, skidders kept out of the zone, and logs winched out as much as possible. Trees that stabilize stream banks and adjacent slopes or that would fall in or across streams should not be cut. Some logging debris can be removed from the riparian zone, but the watercourse should not be overcleaned. Naturally occurring debris and fallen trees in or along a stream, which provide cover and resting areas for many aquatic and semi-aquatic wildlife species, should be left undisturbed. Because logging-road construction within riparian areas reduces the value of the area for wildlife, streams should be crossed at a few carefully selected places (those with gentle approaches, stable banks, and a firm stream bottom), and the most direct route used.

Management of riparian zones should address several considerations: timber, fish, wildlife, and water quality. Since forestry activities in these areas can affect aquatic and terrestrial habitats, consultation with both fishery and wildlife biologists may be helpful.

Freshwater wetlands — bayous, marshes, sloughs, swamps, bogs, seeps, or small shallow ponds intermittently or permanently flooded — have wildlife values similar to those of riparian zones. They too have an abundance and high diversity of plants and animals, some of them unique to specific habitat types. Many species of fish, amphibians, reptiles, waterfowl, and furbearers depend upon the aquatic-terrestrial habitats of wetlands and riparian areas in forests. Small temporary pools or intermittent ponds, often overlooked, are important breeding areas for some amphibians because of egg predation by fish in permanent waters [159]. The wildlife values of wetland habitats deserve special consideration in every multiple-use forest plan (see also chapter 9, this volume).

21.3.2.4 Mast

Mast is the fruit of woody plants considered as food for wildlife and livestock (Fig. 21.6). Hard mast includes the seeds of oak *(Quercus* spp.), hickory *(Carya* spp.), walnut *(Juglans* spp.), beech *(Fagus grandifolia* Ehrh.), ash *(Fraxinus* spp.), pine, and other species. Soft mast includes the fleshy fruits (the pomes, drupes, and berries) from plants such as blackberries, crabapples *(Malus* spp.), sumacs, grapes *(Vitis* spp.), palmettos *(Sabal* spp.), dogwoods *(Cornus* spp.), honeysuckle *(Lonicera* spp.), and hollies *(Ilex* spp.).

Extensive studies of wildlife feeding habits have demonstrated animals' preference for mast whenever it is available. Shaw [188] cited studies where acorns alone accounted for one-half to three-quarters of the seasonal diets of deer, turkey, squirrel, grouse *(Bonasa umbellus* L.), and quail. According to Martin et al. [144], approximately 300 species of birds and mammals nationwide consume mast of one form or another. Consumption is closely related to fruit maturity and is proportional to availability. A diversity of mast-bearing species assures sufficient forage in most years, though fluctuations occur. The yield and quality of mast crops, principally acorns, have been shown to affect the growth, condition, productivity, and survival of game animals such as deer, squirrel, and bear [80, 169, 178, 186].

In a diverse southern forest, mast is available for wildlife throughout the year [86, 131]. Hard mast is generally most abundant in late fall and winter. Fruits, nuts, and seeds are consumed as soon as they are ripe, and those that persist are eaten year-round. Annual yields of mast (dry weight) from woody species in the Arkansas Ozarks averaged 136 kg/ha in upland hardwoods and 84 kg/ha in pine-hardwoods over 8 years, with acorns making up about 90% [184]. In an east Texas pine-hardwood stand, annual mast production from woody plants averaged 11 kg/ha over a 15-year period, with acorns making up only 55% [77]. Annual acorn crops in pine-hardwood forests of Louisiana averaged 12 kg/ha over a 10-year period [10]. In east Texas, 34 mast-bearing species were found at a rate of 341 plants/ha in pines and 408 plants/ha in pine-hardwoods; aggregate fruit production by understory vegetation may exceed acorn production per square meter of basal area [130, 132]. Standing crops of mast (annual, fresh weight), principally fleshy fruits, in Georgia slash pine plantations averaged 46

Figure 21.6. Wildlife feed heavily upon the mast of woody species including seeds such as (a) acorns and (b) sumac heads, and fleshy fruits such as (c) pokeberries and (d) greenbrier berries.

kg/ha during the first 10 years after plantation establishment and 39 kg/ha during the second and third growing seasons after prescribed burning in older plantations [112].

Nutritional quality of mast is quite variable. In general, mast is a concentrated source of energy that is most available when herbage and browse are of limited quality and quantity. Acorns, pecans [from *Carya illinoensis* (Wang.) K. Koch], beechnuts, and chestnuts (from *Castanea* spp.) are low in protein and minerals but high in crude fat, an index of potential energy. Hickories, walnuts, and hazelnuts (from *Corylus* spp.) have exceptionally high nutrient content; they are highly digestible, have very high fat content, and are high in protein and minerals. The energy content of hickory and walnut kernels is nearly twice that of acorns and other nuts. Fleshy fruits contain predominantly carbohydrates; like acorns, they have moderate nutritional value and digestibility, and serve mainly as energy sources. Mast from spicebush [*Lindera benzoin* (L.) Blume], grape (*Vitis aestivalis* Michx.), and flowering dogwood (*Cornus florida* L.) has better than average nutritional value. Dried fruits and other seeds are of limited value to wildlife because of relatively high fiber content and low digestibility. Exceptions are the seeds of sweetgum (*Liquidambar styraciflua* L.), black locust (*Rohinia pseudo-acacia* L.), boxelder (*Ater negundo* L.), and many pines, which have high protein and crude fat content.

Timber management activities have various effects on mast production. The most direct influence is a change in the vegetative composition of a stand — that is, the loss of hardwoods. Managing mixed stands on a long rotation increases the flexibility to also manage for mast production over a long and continuous period. Conversely, managing dense pine plantations on short rotations precludes significant production of soft mast (except during early successional stages) or hard mast. On short rotations, hardwoods cannot reach fruit-bearing age by the time of pine harvest, and understory vegetation does not compete well in a fully stocked stand. Unless hardwoods of fruit-bearing age are retained at the beginning of a short rotation, little mast will be produced. Planning for hard-mast production in designated areas such as riparian zones or good upland hardwood sites reduces conflicts with pine timber production in other areas. Estimates of acorn requirements of wildlife and yield tables needed to calculate the oak component to produce the acorns are available in the literature [71, 188, 215].

Fruit production by understory vegetation is inversely related to timber stand density. Thinning stimulates growth of understory mast-producing species; however, too much thinning in older pine stands will allow formation of a midstory canopy that can inhibit mast production by shading out the understory [9, 182].

Prescribed burning is generally detrimental to hardwoods because repeated burns eventually remove hardwoods from the stand [191]. Fires reduce understory fruit production in pine and pine-hardwood stands for a year or two, depending upon the temperature and timing of the burn [112, 128]. Cool winter burns at 3- to 4-year intervals are optimal for understory production of mast for wildlife, and a longer interval will favor species that produce hard mast and other fruit but that do not reach mast-producing and fire-resistant size with frequent fires [112, 191].

21.3.2.5 Planted and natural openings

Managing selected areas as planted or natural openings can increase habitat diversity and is most beneficial where there is little forest habitat in early successional stages. Planted openings can provide supplemental food when natural forages are deficient, edge habitat, and nesting and brood-rearing sites. Natural openings can also increase the visibility of wildlife using them and affect their distribution, both of which may influence management strategies for game harvest. Clearings have traditionally been managed for quail, turkey, and deer, but other wildlife species have also benefited.

A variety of forage types — cultivated agricultural crops and native and introduced wild plant species [22] — can be planted in clearings, including clovers (*Trifolium* spp.), vetches (*Vicia* spp.), ryegrass (*Lolium multiflorum* Lam.), alfalfa (*Medicago sativa* **L.)**, brome grasses (*Bromus* spp.), oatgrass [*Arrhenatherum elatius* (L.) Presl.], lespedezas (*Lespedeza* spp.), orchard grass (*Dactylis glomerata* **L.)**, chufa (*Cyperus esculentus* **L.)**, peanut (*Arachis hypogaea* **L.)**, cowpeas (*Vigna* spp.), millets (*Panicum* spp.), sorghum (*Sorghum vulgare* Pers.), wheat (*Triticum aestivum* L.), corn (*Zea mays* L.), oats (*Avena sativa* **L.)**, rye (*Secale cereale* L.), partridge peas (*Cassia* spp.), and rice (*Oryza sativa* **L.)**.

Because of wide variation in site characteristics, local extension agents and wildlife biologists are usually the best sources of information for advice concerning mixtures of plant species, fertilizer needs, planting procedures, and planting dates. Selection of plant species for clearings should take into account seasonal availability and nutritional quality of native forage so that food planted in the clearing supplements the diets of wildlife when native forage is limiting.

An alternative to planting herbaceous species is to establish clumps of evergreen browse species or mast-producing trees, shrubs, or vines. For example, Japanese honeysuckle (*Lonicera japonica* Thunb.) is a valuable forage plant in clearings and in the forest understory [31, 79, 185]. Honeysuckle is a shade-tolerant, evergreen perennial that grows well in southern pine plantations and contributes to the diets of deer, turkey, quail, rabbits, and other wildlife. Nutrient content of the leaves is consistently high throughout the year.

Openings with natural vegetation can be maintained by regular burning or disking to promote grass-forb and low shrub habitats. Temporary logging roads, skid trails, landings, old fields, frost pockets, areas with shallow soils, poorly or excessively drained areas, seeps, and swampy areas can be converted to or maintained as natural openings. Small natural openings in pine plantations can significantly improve edge habitat diversity. For example, a 7-year-old loblolly pine plantation in Louisiana, with many small wet areas dominated by sedges (*Carex* spp.) and waxmyrtle (*Myrica cerifera* **L.)**, supported approximately 24 breeding birds/ha, an unusually high density [170]. Other odd areas that can be managed as openings to enhance habitat diversity include old house sites, fruit or nut orchards, field borders, fence rows, ditch banks, small fields, stock ponds, and decadent wolf trees. The edges of forest stands along clearings can be thinned to enhance the transition from forest interior to the open, essentially increasing the width of the forest ecotone. Scattered snags or mast-producing trees can also be retained in openings.

There are almost unlimited opportunities for managing planted and natural openings, although site characteristics will influence location, size, shape, and costs in many instances. Average sizes of clearings are generally 1/4 to 3 ha, most commonly about 1 ha [125]. However, larger openings, such as fields 4 to 16 ha or more, are attractive to turkeys [135]. Landowners should evaluate costs and perceived benefits — planting and maintaining openings for wildlife use can be quite costly, and actual benefits to wildlife vary and have not been well quantified [125, 126]. Although agricultural-type operations are expensive, maintaining openings with natural vegetation on poor pine sites is a low-cost alternative. Forage plantings on areas impacted by logging activities (e.g., landings, logging roads) can reduce erosion potential in addition to providing wildlife food.

21.3.3 Southern Pine Management and Wildlife Habitat

21.3.3.1 Harvest-regeneration system

The forest management sequence of timber harvest and stand regeneration, in most instances, has more direct and immediate impacts on forest wildlife and habitat than other types of forest manipulation. The harvest-regeneration sequence also affects wildlife habitat values throughout the life of the regenerated stand and, frequently, of adjacent stands or areas. To meet wildlife management objectives, the development and implementation of a forest plan should address specific logging and regeneration methods, as well as related factors such as stand succession and the size, shape, and distribution of stands.

The harvest-regeneration system selected by a landowner is normally determined by timber production objectives and related economic considerations. In order of increasing impact to wildlife, these systems generally consist of single-stem and group selection, shelterwood, seedtree, and clearcut and plant (see also chapter 3, this volume, for detailed comparison of regeneration methods). The effects on wildlife depend largely upon the amount of canopy opening and degree of simplification of stand structure. For example, forest bird communities are related to habitat complexity characteristics such as spatial heterogeneity or patchiness [142, 180], vertical layering of canopy foliage [115, 141], and plant-species richness.

Selection cutting and natural regeneration are favored by some [43, 86] as the best system for most wildlife species. Selection cutting, with regular intervals of stand entry that produce an uneven-aged forest, provides the greatest opportunity to manage for within-stand patchiness, canopy layering, and mixed species composition. Snags and den trees can easily be maintained in this system, and regular openings in the canopy allow development of ground-level and other understory vegetation.

Shelterwood and seedtree systems retain some canopy layering because of the extended regeneration phase. Ground-level vegetation is also abundant during regeneration. The unpredictable nature of natural seeding with regard to germination, survival, stocking density, and growth creates a heterogeneous environment suitable for diverse wildlife populations [86]. These ultimately even-aged systems also provide opportunities to manage for habitat diversity among stands.

Pine plantations, established by clearcutting and then planting seedlings, alter habitat and wildlife communities most drastically. A mature pine-hardwood stand, providing habitats suitable for canopy-feeding birds and cavity-nesting animals, can rapidly be changed to an early successional pine plantation, favoring ground-feeding wildlife such as deer, rabbits, quail, and several small mammal and "brush" bird species. Clearcutting reduces structural diversity within the stand and availability of cavities — losses that require increased attention when managing for special habitat features such as openings, snags, den trees, hard mast, and riparian zones to maintain diverse, productive wildlife populations.

Site preparation and planting practices associated with plantation establishment vary in their impacts to wildlife habitats (see chapters 12 through 15, this volume). In general, more intensive site preparation favors the early grass-forb stage and accelerates pine canopy development, whereas less intensive site preparation favors the brush stage [20, 113, 134]. Chemical site preparation yields an abundance of snags [45, 222]. Fruit production from woody plants in young plantations is greatest with the least soil disturbance; a site-preparation burn fosters more fruits than do mechanical treatments that destroy or injure most plants [204, 206]. On longleaf pine sites, legumes declined after chopping but increased after burning, whereas composites increased after chopping and burning [20]. Site-preparation practices increase the diversity and abundance of desirable forage for deer in young plantations over those of uncut forest [103, 134, 203], and burning usually enhances forage nutrient content [202]. Planting pines on a wide spacing (e.g., 3.6 x 3.6 m) [43] can delay pine canopy closure and extend the favorable seedling-grass-forb and sapling-brush successional stages.

No single harvest-regeneration system is recommended for all southern pine types, sites, landowners, or wildlife. However, when properly applied, each system can be managed to integrate wildlife objectives with timber-production goals within existing site and economic constraints.

21.3.3.2 Vegetation control

Herbicides are frequently used to control forest vegetation that competes with commercial crop trees for water, nutrients, and sunlight. In the South, herbicide treatments are prescribed for selected stands to control weeds during plantation establishment or to release pines from hardwood competition in later years (see chapter 19, this volume). But herbicides also have the potential to affect wildlife through toxicity and by altering habitat [146, 160].

The presence of herbicides in the forest environment does not necessarily imply that they are injuring wildlife. Herbicide residues are short lived, generally degrading within days or weeks [171]. The half-life of most herbicides in vegetation ranges up to 30 days [168]. After an extensive review, Morrison and Meslow [160] concluded that both acute and chronic toxic doses for wildlife are well above levels found in the forest following normal herbicide applications. They also determined that chronic doses are difficult to realize because of the low persistence of forest herbicides.

Deer readily consume vegetation treated with herbicides [23, 210]. In the Pacific Northwest, black-tailed deer (*Odocoileus hemionus columbianus* Richardson) did not leave stands treated with 2,4,5-T, atrazine, 2,4-D, silvex, dalapon, or glyphosate [14, 167, 209]. However, most animals simply cannot eat enough herbicide-treated food to accumulate appreciable levels of herbicides at normal application rates. Moreover, herbicide residues in animal diets are excreted rapidly [181]. For example, more than 90% of phenoxy herbicides ingested is excreted in urine within 72 hours [171]; black-tailed deer did not accumulate atrazine, 2,4-D, or 2,4,5-T after continuous exposure to them in the field [167]. Thus, if forest herbicides are applied at recommended rates, the potential hazards of toxicity to wildlife are not significant [168, 218].

By altering forest vegetation, herbicides may influence animal communities. However, individual herbicides or application rates may affect only selected vegetation (e.g., grasses, broadleaved plants), and wildlife response to herbicide-induced habitat change depends upon the preferences of individual species, not of the animal community as a whole. In the West, use of herbicides to reduce woody brush in Jeffrey pine *(Pins jeffreyi* Grey. & Balf.) and Douglas-fir *[Pseudotsuga menziesii* (Mirb.) Franco] plantations had little or no effect on overall density and diversity of bird communities, but there were shifts in abundance or foraging activities of selected bird species [4, 161, 162, 172]. A herbicide treatment to release spruce *(Picea* spp.) seedlings in Nova Scotia noticeably changed the structure and plant-species composition of vegetation, but had little effect on the abundance and species composition of breeding birds and small mammals [64].

Chemical site preparation with mist-blown 2,4,5-T and injected 2,4-D to establish shortleaf and loblolly pines in east-central Mississippi resulted in young plantations (1 to 6 years old) with greater bird diversity and abundance than in other plantations established with mechanical site preparation [36]. The abundance of snags in herbicide-treated plantations provided preferred habitats for cavity nesters which were absent or not as common in the mechanically prepared plantations. By stand age 7 years, however, differences in bird diversity due to site-preparation method were negligible.

Preferred deer forage can be increased or reduced by herbicide treatments in pine plantations, but overall effects of treatments are temporary. Use of hexazinone (0.6 to 1.1 kg/ha) for herbaceous weed control during the first growing season after planting loblolly pine reduced abundance of deer forage; however, after the second growing season, deer forage in treated plantations recovered and was similar to or more abundant than that in untreated plantations [13, 30]. Several important wildlife plants were resistant to hexazinone at 1.1 kg/ha: deer forage species included blackberry, honeysuckle, and greenbrier *(Smilax* spp.); seed or fruit producers included woolly croton *(Croton capitatus* Michx.), pokeweed, and legumes such as partridge peas and lespedezas [13].

Use of several phenoxy herbicides to control brush in 4- and 5-year-old loblolly pine plantations in Mississippi also reduced abundance of game food plants during the first growing season after application, with vegetative recovery the second growing season [51]. In similar plantations in Mississippi and Alabama, two growing seasons after aerial applications of hexazinone (2.2 kg/ha) for pine release, deer forage was more abundant in treated than untreated plots [105]. Pine release with imazapyr in 2-, 4-, and 5-year-old plantations increased deer forage on treated relative to untreated areas [99]. Generally, grasses and woody plants decreased and (orbs and vines increased after imazapyr treatment. Panicums, honeysuckle, dewberry, blackberry, lespedezas, and winged elm *(Ulmus alata* Michx.) were variably resistant to imazapyr at rates of 0.6 to 1.1 kg/ha.

In sum, herbicide use at recommended rates appears to pose no significant toxic hazard to forest wildlife [146, 160]; residues are short lived and occur in low concentrations. Though herbicides directly affect forest-habitat conditions and therefore may indirectly influence animal communities, most impacts are short term, with vegetation recovering within one or two growing seasons in most instances.

21.3.3.3 Prescribed burning

Fire is both a natural feature and management tool in southern pine forests (see chapter 12, this volume). Prescribed burning is used to reduce wildfire hazard, prepare sites for planting or seeding, control competing understory hardwoods, improve the quantity and quality of range forage, control certain tree diseases, and manage wildlife habitats. Approximately 1 million ha of forestland in the South are prescribe-burned each year [158]. Fire sets back vegetative succession (Fig. 21.7); it influences the amount, composition, and size of vegetation in the understory and, to some extent, the overstory. Specific responses to fire vary with the frequency and season of burn, weather, fuels, and stand condition, including previous fire history. Native plants and animals evolved with periodic fire. Indeed, many plants have characteristics that enhance the flammability of their communities [165], and some animals that benefit from fire may also exhibit characteristics that perpetuate their habitats [140]. For example, herbivores appear to alter fuels in forest understories and openings by eating and thereby suppressing fire-sensitive plants and releasing the more flammable species, which influences burning.

Though some animals may be killed by fire [119], the consensus is that vertebrates rarely are [5, 49, 140, 200]. Wildlife mortality was low **(1** mud turtle) during an aerial-ignition prescribed burn of 90 ha of slash pine plantation and natural forest in South Carolina, although 33 deer, 1 turkey, 9 squirrels, 1 rabbit, 9 quail, 2 mice, 2 mud turtles *(Kinosternon subrubrum* Lacepede), and 2 feral hogs *(Sus scrofa* **L.)** were seen either leaving the burn area, entering it, or using it during or immediately after the fire [62]. During a winter prescribed burn in Alabama, radio-tagged deer used streambeds and moist sites as refuges from fire and at no time were observed running in response to the fire [106].

Species richness of small-mammal populations (rabbit size and smaller) before and after fires is notably stable [5], although fire may increase populations of some species, decrease those of others, and have no measurable effect on

Figure 21.7. Prescribed fire affects vegetative composition in the understory:
(a) A prescribed fire backed through a pine plantation in late winter will top-kill much of the small-diameter, woody vegetation in the understory.
(b) An open understory is common after a prescribed burn.
(c) During the first growing season after a burn, the understory is dominated by herbaceous vegetation; woody vines and shrubs recover and dominate the understory in subsequent years.
(d) Grasses and forbs are abundant during the first couple of years after a burn; many seed-producing legumes, such as the vetch flowering here, increase after fire.

still others [211]. Small mammals avoid fire by going into underground burrows or leaving the area, and post-fire populations depend upon regrowth of ground cover. Short-term impacts of fire on small mammals include loss of food and cover, and increased exposure to predation; the long-term response of many small mammal species is increased numbers, largely due to the post-fire abundance of herbaceous and seed-producing plants [176]. Similarly, few reptiles and amphibians are killed by fire, and prescribed burning is probably beneficial to most herpetofauna of southern pine forests [154]. Regularly burned forested sandhill communities and slash pine plantations within the ranges of the eastern indigo snake *(Drymarchon corais* Boie) and gopher tortoise *(Gopherus polyphemus* Daudin), both endangered species, supported higher densities of these reptiles than adjacent natural areas where most longleaf pine had been harvested and fire seldom used [123, 196]. Thirty other vertebrate species were observed to use the burrows of gopher tortoises.

Fire alters bird habitats and the guild composition of bird communities [42]. However, species richness again remains notably stable after burns [5]. Slight shifts in bird species composition after burning usually reflect a decrease in foragers of the tree trunk and canopy and an increase in ground feeders. Bird counts in a burned slash pine stand in Florida during the first few months after burning were essentially no different from counts in an adjacent unburned stand [52], which may be attributed to home range attachments of individual resident birds, the relatively brief duration of severe habitat disruptions, and the frequency of forest fires as a normal feature of slash pine ecology.

Results of some of the studies discussed above reflect the effects of a single fire in a frequently burned habitat. They do not indicate that bird and mammal populations in regularly burned habitats are not different from those in habitats rarely subjected to fire.

Hot fires may destroy snags and cavity trees that are important to cavity-nester foraging and reproduction [26]. Though fires may temporarily increase the number of snags, they can depress the total number available in the long run. Protecting snags and cavity trees by raking fuels away from tree bases and using cool backing fires will minimize the loss of existing snags and den trees. A small but constant supply of nesting and foraging trees may be provided by prescribed backing fires every 7 to 10 years.

Exceptions to the normally low wildlife mortality after fire are pocosin wildfires, characterized by rapidly moving head fires followed by severe ground fires in deep organic soils. In coastal North Carolina, pocosin wildfires killed 4.3 deer/km^2 in 1981 and 1.0 deer/km^2 in 1985 [173]; after the 1985 fire, researchers estimated that 20% of the deer in the burned area died and 20% of the survivors were severely burned (burned feet and legs with secondary infection and malnutrition).

Fires reduce populations of soil and surface invertebrates, but surface insects are protected somewhat by their ability to fly and seek refuge. Many insects are attracted to forest fires by smoke and heat [56]. Invertebrates that can be controlled by fire are usually the species that lay eggs or have immature stages in the forest floor [140]. In a study of tick parasitism on turkey poults, 35% of poults exposed to unburned plots were infested by lone star ticks (*Amblyomma americanuni* L.), whereas only one tick was recovered from poults exposed to burned plots [109]. Frequent burning alters groundstory vegetation, resulting in increases in some invertebrates, especially those important in the diets of bobwhite quail and wild turkey.

Vegetation recovers rapidly on burned sites. Herbaceous plants dominate the understory during the first and possibly second seasons after a burn; vines, shrubs, and hardwood sprouts abound in 3- to 5-year roughs. However, the effects of fire on wildlife habitat and forage cannot be generalized. Prescribed burning can be used to initiate or maintain early successional stages of understory vegetation whose nutritional quality after burning varies depending upon season, frequency, and type of fire, fuels, and weather. The initial regrowth after burning is typically more palatable and nutritious than that before burning, similar in quality to plants in initial growth stages [72]. Fire can be used to maintain or improve the palatability, quality, and availability of grasses, forbs, vines, and other desirable plants for range cattle (*Bos taurus* L.) and wildlife and is most effective in thinned or open stands where abundant sunlight reaches the ground. Thus, many game and furbearing animals (e.g., deer, coyote, bear, turkey, quail, ruffed grouse) dependent on early successional stages tend to increase after fire [140], whereas species dependent upon late stages tend to be displaced.

A 40-year study of prescribed burning in loblolly pine stands of coastal South Carolina provides the most comprehensive information about changes to southern pine ecosystems caused by regular burning over a long period [124, 217]. Annual summer burning nearly eliminated understory woody vegetation, and ground cover consisted almost entirely of grasses and forbs. Biennial summer and annual winter burning produced an abundance of woody sprouts and ground cover dominated by grasses, forbs, and shrubs. Summer burning led to greater coverage by grasses. Periodic (3- to 7-year intervals) winter and summer burning promoted a moderate level of hardwood sprouts and an abundance of shrub stems, and ground cover consisted largely of shrubs, hardwoods, and vines. The low-intensity fires in that study did not adversely affect the chemical or physical properties of sand and silt loam soils.

Using the 20th-year measurements from the above-mentioned South Carolina prescribed burning study, Lewis and Harshbarger [133] evaluated the effects on quail, turkey, deer, and cattle. Annual winter fires produced the best quail habitat because of the abundance of forbs, especially legumes; periodic winter burning produced the best deer and turkey habitat; and annual winter and biennial summer burns produced the best cattle forage. This study indicates that species diversity and abundance of understory plants can be partially controlled by burning, and that habitat conditions for selected animals can be achieved by the planned use of fire.

Most prescribed burning has been done in winter. However, recently there has been considerable interest in and greatly increased use of warm-season burning on wildlife lands. The assumption is that late spring is the "natural" fire season (lightning) to which the biota are adapted, and responses then differ from those during winter.

Under various conditions, fire can increase abundance of legumes and other important wildlife food plants [20, 33, 103, 195], increase seed production [34, 35], temporarily improve nutritional quality of forage plants [41, 129, 205], increase insect abundance and therefore the opportunity to feed on insects in post-burn habitats [6, 95-97], create favorable nesting and brood-rearing habitats for important game birds [48, 58, 192], and affect mast production [112, 128, 191]. Frequent, light fires over a long period can very slowly effect change, but ultimately, a very drastic change. The impacts of repeated fires are cumulative and may shift from positive to negative, or vice versa, over the long term. Fire plays an important role in the dynamics of southern forests by affecting vegetative succession. Prescribed burning can be a valuable tool in managing forestlands, but proper use to achieve long-term objectives requires planning, judicious implementation (accounting for site-specific conditions), and evaluation of results. Specific prescribed-burning recommendations for selected game animals and songbirds are included later in this chapter (see 21.4).

21.3.3.4 Thinning

Pine plantations and natural stands may be thinned to increase tree survival in densely stocked stands, to harvest a portion of the timber, to increase diameter growth of

Figure 21.8. Unthinned pine stands (a, poletimber; b, sawtimber) are characterized by dense pine overstory, sparse understory, and ground cover largely of pine needles; they have little wildlife value. Thinning opens up the canopy and stimulates understory development (c and d); ground-level vegetation reverts to earlier successional stages, with associated wildlife benefits.

residual crop trees, or to manage for specific stand characteristics relative to a mix of age, size, and species composition. Landowner objectives should include both timber stand improvement and wildlife stand improvement.

Thinnings, including partial harvests such as single-tree or group selection, create openings in the canopy. And increased sunlight reaching the ground enhances opportunities to manage the understory. Response of ground-level vegetation to fertilization, prescribed burning, disking, or mowing is greater in thinned or open stands. Forage can even be planted in the larger openings created by group selection or row thinning. For example, underplantings or interplantings of subclover *(Trifolium subterraneum* L.) or bahia grass *(Paspalum notatum* Flugge) in widely spaced or thinned plantations are management practices for turkey. Regular thinning of pine plantations and natural pine stands will maintain light penetration through the canopy and promote diverse understory development with increased cover, forage plants, and mast production (Fig. 21.8).

Precommercial thinning of 7-year-old loblolly pine plantations in Alabama (stocking reduced from 1,468 to 1,119 trees/ha) resulted in average deer forage production during the 3 years after thinning that was 1.8 to 2.6 times higher than that in unthinned plantations and 4.7 to 8.4 times higher than that in natural pine-hardwood stands [101]. Prescribe-burned and precommercially thinned plots (stocking reduced from 1,431 to 865 trees/ha) in a 7-year-old loblolly pine plantation in Mississippi produced deer forage that averaged 2.0 times higher than that in untreated plots in winter and 3.9 times higher than that in untreated plots in summer during the first 2 years after treatment [100]. In a direct-seeded slash pine plantation precommercially thinned to densities ranging from 1,235 to 13,091 trees/ha at age 3, herbage yields at stand age 12 years were inversely related to stand basal area, varying from 628 kg/ha (tree basal area of 28.7 m^2/ha) to 2,500 kg/ha (tree basal area of 12.4 m^2/ha) [73]. Where tree densities were equal in the slash pine plantation, herbage yields were similar in plots selectively and strip thinned.

Summer deer forage in 12- to 14-year-old pine plantations, burned and commercially thinned at age 13 (stocking reduced to about 700 trees/ha), averaged 26 kg/ha before treatment, 326 kg/ha one growing season after treatment, and 429 kg/ha two growing seasons after treatment [104]. Winter deer forage averaged 4.5 kg/ha before treatment, 31 kg/ha one season after treatment, and 52 kg/ha two seasons after treatment.

In older plantations and natural stands that have been thinned, deer forage production and understory development are related to stand age, basal area, tree height, midstory development, and other stand characteristics [7, 8, 12, 60, 77, 100]. Heavy thinning of pine can lead to development of a multilayered hardwood midstory which competes with the understory [11]. Thus, a pine canopy can be managed to enhance habitats for ground-dwelling mammals and birds or for species associated with midstory hardwoods.

Other wildlife management objectives to consider when thinning pine plantations or natural stands are mast production [9] and snags and den trees for cavity-dependent animals [25, 54]. For example, thinning may be detrimental to woodpeckers if all decaying trees are removed [27]; timber stand improvement activities that include herbicide injection of large oaks can reduce acorn production over the long term while temporarily increasing snag abundance and ground cover [208].

21.3.3.5 Rotation length

The replacement of mature pine and hardwood forests with intensively managed pine stands typically eliminates den and cavity availability, hardwood mast yields, and hardwood foliage in the canopy, unless these habitat characteristics are maintained through management. Rotation length is important in such management.

Rotation lengths for intensively managed pine species are generally 20 to 40 years, depending upon timber production goals for pulpwood or sawtimber. Longer rotations (40 to 100 years or more) offer greater flexibility for producing adequate amounts of deer forage over a long and continuing period, maintaining hardwood mast yields, and providing a diversity of plant species and vegetative conditions within forest stands [70]. Acorn yields are negligible for oaks < 20 years old and greatest for oaks 40 to 100 years old [71, 215]. Shaw [188] recommended an 80-year rotation for even-aged oak silviculture. Optimum mast production for oak, hickory, walnut, pecan, and beech falls within a broad range of 25 to 200 years at diameters of 10 to 75 cm [215].

Under an even-aged management system, most stands will be too young to provide snags of adequate diameter for many cavity nesters (e.g., 15 to 65 cm dbh for woodpeckers) [54]. However, at least some portion of each owner's forestlands can be scheduled for longer rotations. Increasing rotation length to a minimum of 100 years is recommended for most cavity-nesting birds and to 150 years for the pileated woodpecker [25, 53]. Owen [174] recommended rotations of 60 to 80 years to manage for snags and cavities in selectively harvested stands. The red-cockaded woodpecker *(Picoides borealis* Viellot), an endangered species, prefers live pines with heart rot for cavity excavation; most of their cavities are in pines 60 to 150 years old [92]. Stands managed to provide cavities for birds will also meet the den and cavity needs of most other vertebrates.

Maintaining pine stands in earlier successional stages by short rotations (< 35 years) eliminates the mature pine and hardwood forests preferred by many breeding bird species [157], such as the pileated woodpecker, Carolina chickadee *(Parus carolinensis* Audubon), tufted titmouse *(P. bicolor* L.), brown-headed nuthatch *(Sitta pusilla* Latham), wood thrush *(Hylocichla mustelina* Gmelin), red-eyed vireo *(Virio olivaceous* L.), ovenbird *(Seiurus aurocapillus* L.), and Kentucky warbler *(Oporornis formosus* Wilson). Short-rotation pine stands frequently lack suitable cavities for nests, an understory nesting stratum (with no thinning), high-energy fruits and hardwood mast, and deciduous foliage necessary for many songbirds [113, 157]. Long rotations (60 to 80 years) for pine stands > 40 ha could provide habitat for some interior-forest species [157].

Rotation length for pines has traditionally been determined by timber management objectives. However, if full complements of wildlife species are desired in managed pine forests, rotation lengths can be extended to provide favorable understory and overstory characteristics (pine and hardwood), good yields and diversity of hardwood mast, and adequate numbers of snags, cavities, and den trees. Long rotations may be appropriate for natural pine and pine-hardwood stands, for selected pine plantations, and for special areas within the managed forest (e.g., streamside zones).

21.4 Species-Management Recommendations

Species management is discussed for selected game animals and songbirds, but many other wildlife species may interest landowners. Only about 20% of resident mammals and 10% of resident birds are game species [86]. For additional information on species discussed below and for those not included, I suggest the following publications:

American Wildlife & Plants — A Guide to Wildlife Food Habits [144]
Integrating Timber and Wildlife Management in Southern Forests [24]
Wildlife Habitat Management Handbook [215]
Prescribed Fire and Wildlife in Southern Forests [230]
Managing Southern Forests for Wildlife and Fish [47]

21.4.1 White-tailed Deer

White-tailed deer are the most common, widespread big-game animal in the United States, with more than 10 subspecies in the Southeast. Average home ranges of southern whitetails have varied from approximately 60 to 520 ha in several habitat types and physiographic provinces [143]. Deer occupy forest and nonforest habitats and are most active at dawn and dusk, spending more time feeding than in any other activity. Silvicultural operations and other disturbances (e.g., logging, site preparation, fire) that promote a flush of vegetation at ground level generally benefit deer.

Deer diets are quite varied [215]. In spring and summer, deer foods consist primarily of leaves and new twigs of deciduous woody plants, herbaceous plants, succulent fruits and berries, and fungi; in fall and winter, foods include hard and soft mast, evergreen browse, herbaceous plants, and fungi. Whitetails also feed in pastures, fields of planted agricultural crops, and wildlife forage plantings wherever they occur near deer cover.

Important deer food plants, by physiographic province, are summarized by the U.S.D.A. Forest Service [215] and Harlow and Guynn [82]. Plants frequently browsed by white-tailed deer in the South include greenbriers, yellow jessamine *[Gelsemium sempervirens* (L.) Ait. F.], blackberry, trumpetcreeper *[Campsis radicans* (L.) Seem.], Virginia creeper *[Parthenocissus quinquefolia* (L.) Panchon], blueberry *(Vaccinium* spp.), huckleberry *(Gaylussacia* spp.), chinaberry (*Melia azedarach* L.), yaupon *(Ilex vomitoria* Ait.), hawthorn *(Crataegus* spp.), dogwood, blackgum *(Nyssa sylvatica* Marsh.), gallberry [I. *coriacea* (Pursh) Chapman], willow *(Salix* spp.), sumac, red maple *(Ater rubrum* L.), grape, American beautyberry *(Callicarpa americana* L.), waxmyrtle, bay *(Magnolia virginiana* L.), and titi *(Cyrilla racemiflora* L.). Warren and Hurst [221] rated deer use of 521 species of plants growing in Mississippi pine plantations, and more than half of them were moderately or heavily browsed.

Pine management can be compatible with white-tailed deer management [43, 75, 103, 113]. Deer herd response will vary according to the frequency and intensity of silvicultural activities. Site preparation, vegetation control, prescribed fire, thinning, fertilization, pruning, and rotation length affect the quality or quantity of deer forage in the understory. Activities which directly affect canopy development, such as wide planting density and regular thinning to maintain an open stand, will have longer term effects. Regularly scheduled, well-distributed silvicultural activities, coupled with maintenance of mast-producing hardwoods, will provide the habitats and foods used by deer. The U.S.D.A. Forest Service [215] recommends retaining about 20% of the land base in mast-producing hardwoods for deer management.

Deer forage production during the first 2 years after an 8-year-old pine plantation in Mississippi was burned and precommercially thinned (40% reduction in stand density) averaged 554 kg/ha in summer and 53 kg/ha in winter; untreated plots averaged 141 kg/ha in summer and 26 kg/ha in winter [100]. In uneven-aged pine stands (50 to 60 years old) in Louisiana subjected to 3-year rotational burns and thinning at several levels, total forage measured in November for 5 years after thinning ranged from 889 to 3,021 kg/ha in plots thinned to 6.9 and 13.8 m^2/ha and from 420 to 1,578 kg/ha in plots thinned to 20.7 and 27.6 m^2/ha [229]; herbage and browse production was affected by residual pine basal area, site index, and burning. Winter burns on 3- to 5-year rotations in open pine stands will maintain or enhance understory forage for deer [75, 133, 205, 231]. Where hardwood mast production is a long-term goal, the use of regular fires should be avoided.

On infertile forestlands where deer populations rely heavily upon mast, especially acorns, manipulating understory condition through pine silviculture may only increase an already abundant supply of low-quality roughage and may be of little beneft to deer [111]. Forage can be planted to provide deer food in areas and during seasons when native forage is low in quality or abundance. Species frequently planted for deer in openings, along roads, and on abandoned logging access include winter wheat, honeysuckle, clover, vetch, fescue, ryegrass, alfalfa, lespedezas, and several agricultural crops [32].

Suggested reading for those interested in white-tailed deer is the Wildlife Management Institute's book *White-tailed Deer Ecology and Management* [76]. Additional information is available in the proceedings (abstracts) of annual meetings of the Southeast Deer Study Group, and in publications by Halls [74, 75], Blair and Brunett [10], Hurst and Warren [103], and Harlow and Guynn [82].

21.4.2 Wild Turkey

The wild turkey is the largest and premier game bird of southern forests. There are two subspecies in the South, the eastern turkey (*Meleagris gallopavo silvestris* Viellot) and the Florida turkey (*M. g. osceola* Scott). Like the white-tailed deer, the wild turkey has made a dramatic comeback since the 1930s and 1940s. Trapping and relocation of wild birds during the past 4 decades have resulted in abundant, widespread turkey populations throughout much of the South. Estimates of wild turkeys in 14 southeastern states have increased from 244,000 in 1958 [163] to 1,048,000 in 1979 [3]. And approximately 60% of the total wild turkey harvest in the U.S. occurs in the South, having increased from 39,000 in 1958 to 132,000 during the 1978-79 season. Turkey populations and the popularity of turkey hunting have continued to grow through the 1980s. For example, the Mississippi turkey harvest has increased from 20,000 in 1978-79 to approximately 58,000 in 1986-87.

In a review of turkey home ranges, Brown [17] discussed average annual ranges of 140 to 553 ha for birds in the South. However, more recent studies indicate that average annual ranges of 1,500 to 3,500 ha are not uncommon [57, 58, 228]. Shortly after daybreak, turkeys descend from the roost and normally feed in the morning and afternoon, with midday wandering, loafing, light feeding, preening, and dusting. Turkeys are opportunistic omnivores, consuming what is seasonally abundant and palatable. Their diets consist of about 90% plant material and 10% animal material [120]. During the first 2 months after hatching, poults feed heavily on insects and fruits, increasing the amounts of green vegetation in their diet as they age. Diets of older birds, which vary seasonally and according to habitats occupied, include mast, insects, green herbage, seeds, and cultivated grains. Turkeys feed on acorns whenever they are available; indeed, acorns can make up a significant portion of their fall and winter diets. Other mast frequently eaten includes beechnuts, drupes from dogwood and blackgum, grapes, cherries *(Prunus* spp.), blackberries, dewberries, huckleberries, blueberries, and the seeds of pine, sweetgum, and magnolia. Leaves and seeds of grasses, sedges, and other herbaceous species are also important. Grasses frequently eaten by turkeys are crabgrass, bluegrass *(Poa* spp.), carpet grass *(Axonopus* spp.), paspalum, and panic grass. Invertebrates such as grasshoppers, katydids, walkingsticks, caterpillars, beetles, dragonflies, stinkbugs, and fly larvae are eaten by turkeys, as are cultivated crops such as corn, soybeans *[Glycine max* (L.) Merr.], and small grains.

There has been considerable skepticism about the compatibility of wild turkeys and intensive pine management such as clearcutting, forest-type conversion to pine, and short pine rotations. However, many biologists have noted the remarkable adaptability and tolerance of turkeys to changing land-use practices and modified habitats [137, 187, 234]. Recent research has demonstrated that turkeys will use pine plantation habitats and that poletimber stage and older plantations, especially those thinned and burned, may be heavily used year-round [58, 91, 193, 194, 227]. Pine plantations provide roosting, foraging, nesting, and brood-rearing habitats. Winter burning of pine stands on a varying 2- to 5-year rotation benefits turkeys [98, 133]; the predominantly herbaceous ground cover during the first year or two after fire produces palatable green forage and seeds, supports good invertebrate populations, and provides brood-rearing habitats. Woody shrubs and vines abundant in 3- to 5-year-old roughs can yield ample soft mast and create brushy habitats suitable for nesting.

Though turkeys will use young pine plantations, care should be taken that young stands do not predominate and that stands being thinned and burned are well distributed throughout the managed forest. Turkeys in the Ouachita Mountains of Arkansas frequently used poletimber stands with basal areas of 11 to 20 m^2/ha and sawtimber stands with 20 to 24 m^2/ha [227]. Wild turkeys in east Texas most often used sawtimber stands with 16 to 19 m^2/ha [93].

Long sawtimber rotations are most favorable for turkeys because of the length of time that stands can be in the open timber stages with regular thinning and burning. The U.S.D.A. Forest Service [215] recommends retaining about 20% of an ownership in mast-producing hardwoods with about half the basal area in appropriate species. These hardwoods can be retained or developed in pine-hardwood stands, in streamside management zones, or in other designated areas, and should be well distributed. Food plots may also be important for turkeys, especially where forest openings are limited or where mast production is low. Plantings of corn, winter wheat, rye, chufas, many grasses, clovers, and other legumes can provide green forage, seeds, and insects. Natural openings can be maintained by burning, mowing, or disking

Suggested readings on wild turkeys and their management include the proceedings of National Wild Turkey symposia, Hewitt [88], and Bromley and Carlton [16].

21.4.3 Bobwhite Quail

The bobwhite is a bird of open forests, forest edges and openings, fields, and fence rows. Like the wild turkey, there are two subspecies of bobwhite quail in the Southeast, the eastern bobwhite *(Colinus virginianus virginianus* L.) and the Florida bobwhite (C. *v. floridanus* Coues). Winter home ranges may cover up to 30 to 35 ha but generally average 3 to 7 ha [179]. Movements during summer are < 1 km for most bobwhites [139, 164]. Bobwhites are active during daylight, normally feeding in the morning and afternoon and loafing during midday. They roost on the ground in a circle, tails together and heads outward. Good quail populations are associated with well-drained, moderately fertile soils that support good plant growth and seed production.

Bobwhites are mostly seed eaters, probably eating more seeds of legumes than of any other plant family [78, 122, 199]. Plants make up about 85% and insects about 15% of their annual diets. During late fall through early spring, acorns and the seeds of pines, legumes, and other plants are eaten most frequently; during the warm season, soft mast, insects, and the seeds of grasses and other herbaceous plants make up most of their diet. Green plant leaves are favored in spring. Bobwhite chicks feed heavily on insects during their first few weeks of life, gradually shifting to adult foods by the time they are two months old. Many of the seeds, insects, and mast species eaten by bobwhites are the same as those eaten by wild turkeys. Some wild legumes highly preferred by quail include wildbeans *(Strophostyles* spp.), beggarweeds *(Desmodium* spp.), sesbania *(Sesbania macrocarpa* Muhl. ex Raf.), partridge peas, lespedezas, milk peas *(Galactic* spp.), and butterfly peas *[Centrosema virginianum* (L.) Benth.]. When acorns are abundant, quail may feed on them to the exclusion of other foods.

Drought can greatly affect seed production by legumes and other herbaceous plants, and when poor mast crops coincide with drought, foot plots can become very important. Plot sizes of 500 to 1,500 m^2 are recommended at a rate of 1 plot/4 to 8 ha [122]. Good locations are field-forest edges, forest openings, and rights-of-way. Cultivated crops such as corn, small grains, sunflowers *(Helianthus* spp.), soybeans, peanuts, and cowpeas, as well as clovers, vetches, sesbania, beggarweeds, woolly croton, partridge peas, and lespedezas make good plantings. Promoting the growth of vines and woody brush species around the edges of food plots provides escape cover and mast.

Pine management can be compatible with quail. Without special management, quail numbers are frequently high in young pine plantations before canopy closure, especially where fire is used during site preparation. Maintaining quail in older pine stands requires thinning to produce openings in the canopy and regular fire to promote ground vegetation used by quail. Landers and Mueller [122] suggested thinning pine stands to a basal area less than or equivalent to 75% of site index (tree height in meters at age 50), minus 5.7:

Target basal area (0.75 x site index) —5.7.

For example, if site index is 25 m, then trees should be thinned to a basal area of approximately 13 m^2/ha or less for quail management. Rosene [179] recommended long rotations, uneven-aged stands, and overstory thinning to allow about 60% sunlight on the ground for maximum quail populations.

Small stand sizes create more edge within home ranges of individual coveys of quail. The objective is to manage for food and cover close together. Burning, disking, and mowing in open forest, fields, pastures, forest openings, and edges promote a ground cover of seed-producing annual plants and fruit-producing woody species. Annual winter burning provides foods (herbaceous forage, seeds, insects), brood habitat, and control of some parasites; however, fire should be excluded from some areas for 2 to 3 years to provide nesting habitat and fruit production [121]. Patchy annual burns (about 70% coverage) are recommended because the scattered unburned brushy areas are preferred nesting sites, and the brush conceals coveys from predators during the day and while roosting at night [122].

Suggested readings on bobwhite quail ecology and management include hooks by Stoddard [199] and Rosene [179], proceedings of National Bobwhite Quail symposia, and a handbook by Landers and Mueller [122].

21.4.4 Squirrels

There are four species of tree squirrels in southern woodlands; of these, the fox and gray squirrels are most frequently observed and sought after as game species. Flying squirrels (*Glaucomys* spp.), nocturnal animals that are seldom seen, are not discussed here. The fox squirrel, larger than the gray, spends much time foraging on the ground and prefers open forests with clearings. The gray squirrel is primarily arboreal, seldom venturing far from trees, and prefers denser forests. Home ranges are up to about 16 ha for fox squirrels and about 1 to 3 ha for grays [61].

Both fox and gray squirrels depend upon forests with hardwoods of mast-bearing age for food and shelter. They feed heavily on hard mast: acorns, hickory nuts, beechnuts, and pecans. The yield and quality of mast, especially acorns, affect fecundity, survival, and dispersion of squirrels and hunter success the following year [169]. Other foods regularly eaten include blackberries, mulberries (*Mores rubra* L.), and other soft fruits, dogwood and blackgum drupes, maple seeds, fungi, the cambium layer beneath tree bark, and many buds, flowers, and seeds [144]. Squirrels den in cavities and use leaf nests, but reproduction is more successful in cavities.

Intensive pine management reduces or eliminates squirrel populations. Management options for both fox and gray squirrels exist in hardwood and pine-hardwood stands and in streamside management zones, and for fox squirrels in slash and longleaf pine stands. Sawtimber rotations provide hardwood mast after about 25 years and den trees at about 40 years. The U.S.D.A. Forest Service [215] recommends even-aged management, 80-year rotations, retaining at least one-third of squirrel management areas in stands at least 50 years old, and maintaining about half the stand basal area in oak, hickory, and beech. Stands should be thinned to release mast-producing hardwoods and increase understory fruit production, and den trees retained. Prescribed fire is seldom used as a management practice for squirrels [116]; nevertheless, it is beneficial, possibly necessary, for fox squirrels in southern pine forests. Prescribed fire maintains fox squirrel foraging habitat at ground level and soft mast production in the understory. Fire may be excluded to promote hardwood regeneration.

Pine plantation management is not necessarily incompatible with squirrels. Good squirrel populations have been maintained in streamside management zones in Mississippi (4.1 squirrels/ha) [220] and east Texas (2.2 squirrels/ha) [46, 148]. Streamside zones 50 to 100 m wide should provide adequate habitat for squirrels if managed through selective harvests to maintain desirable species composition and den-tree availability. A diversity of mast-bearing species will yield sufficient food during most years.

21.4.5 Rabbits

There are six rabbit and hare (*Lepus* spp.) species whose distributions overlap the southern pine range; of these, the eastern cottontail, swamp rabbit (*Sylvilagus aquaticus* Bachman), and marsh rabbit (*S. palustris* Bachman) are more common. Rabbits are chiefly nocturnal, active from early evening to late morning, and generally spend the day under cover. Home ranges of rabbits are normally < 8 ha, but males may range up to 40 ha. Swamp rabbit ranges are typically < 16 ha.

The eastern cottontail is associated with heavy brush, briar patches, open forest with a brushy understory, forest edges and openings, and fence rows. Swamp and marsh rabbits inhabit wet bottomlands, swamps, marshes, hammocks, and cane thickets, and both are good swimmers. Cottontails eat green vegetation in summer, and bark, buds, and twigs in winter; swamp rabbits rely on sedges and grasses; and marsh rabbits feed on tubers and bulbs in addition to green vegetation and bark.

Though swamp and marsh rabbits may be found in wetlands within managed pine stands, the cottontail is the most abundant rabbit species on upland pine sites. Intensive pine management is favorable for cottontail populations. Young brushy pine plantations are good rabbit habitat, and opening of the canopy through regular thinning maintains a productive understory for cottontails. Unburned windrows and residual slash provide protective cover in plantations. Hill [90] recommends prescribed burning on 1- or 2-year intervals to maintain the understory at optimum productivity for rabbits. Patchy annual burns or some burning each year on alternate small blocks provides brushy cover and an adequate mix of herbaceous plants, vines, and woody species to meet seasonal food needs.

21.4.6 Birds

Many species of birds use southern forests as residents, breeding birds, wintering birds, or transients. On a large scale (500 x 500 km), breeding land birds may number approximately 70 to 120 species and wintering land birds about 90 to 115 [67]. Bird species diversity is correlated with canopy layering, plant species diversity [141], and patchiness [180]. Bird density and species richness generally increase with stand age and, in older stands, with increasing hardwood composition [53, 157]. Thus, mature (> 45 years old) pine and mixed pine-hardwood stands tend to have the highest density and richness of birds in managed pine forests.

A discussion of Louisiana avifauna by Noble et al. [170] demonstrates these principles of bird abundance and diversity. There are 337 bird species in Louisiana, of which 146 (43%) depend upon forest habitats. The maximum numbers of bird species likely to occur are 51 (pine forests) and 133 (pine-hardwoods) by forest type and 16 (early regeneration), 20 (seedlings and saplings), 20 (poletimber), 31 (sawtimber), and 127 (mature and overmature forests) by successional stage. Generally, between 17 and 23 bird species breed in loblolly pine stands of the mid-South, depending upon stand age and habitat diversity. But, merely by developing a vegetative stratum other than the pine overstory (e.g., brushy understory or hardwood midstory), the number of individual birds using the stands can be doubled.

Birds feed largely on nuts, seeds, fruits, insects, and small animals, and readily eat agricultural crops. Silvicultural practices that reduce understory vegetation and eliminate dead trees, promoting a pure pine overstory with a bare forest floor, are deleterious to bird communities [232]. Thus, a goal for managing bird communities is to maintain structural complexity in the forest to provide a variety of habitat components. Rotations of 80 to 100 years or more are recommended so that cavity nesters can have adequate nesting sites [25, 53, 215]. Stand sizes of 40 ha or less are suggested for nongame birds, but clearcuts exceeding 40 ha will provide habitat for interior forest species if rotations are long [157, 215]. Small stands with irregular boundaries are good for species that prefer edge habitat.

Thinning and burning promote understory development, mast production, and maintenance of cavity trees. Tree species composition, stocking level, age class, and spatial distribution are easily manipulated during thinnings or partial harvests. Heavy thinning of pine leads to increases in hardwood density and basal area in pine plantations [7], benefiting the many birds associated with hardwoods in the canopy. Existing and potential snags should be retained when thinning and during site preparation, as should cull hardwoods, residual slash, and unburned windrows. Snags in clearcuts increased the abundance and species diversity of wintering and breeding bird communities in east Texas [44, 45]. Nest boxes can be used to replace natural cavities in intensively managed forests, but costs may be prohibitive [147]. Frequent burning and hot fires should be avoided, as they can reduce the long-term availability of snags [25]. However, periodic winter burns at 3- to 6-year intervals in open pine stands can maintain understory vegetation, mast production, and patchy cover for birds [42, 170]. Some of the natural diversity of each site (e.g., openings, glades, wetlands, seeps, hammocks, savannahs, clumps of hardwoods or snags) should be preserved for songbirds within pine plantations.

Plantings for birds frequently are woody species — trees, shrubs, and vines — that provide mast and cover [68, 215]. Vegetation that can be retained as natural thickets or planted for birds includes oaks, hawthorns, dogwood, wild plum, crabapple [*Malus ioensis* (Wood) Britt.], wild cherry (*Prunus serotina* Ehrh.), eastern redcedar (*Juniperus virginiana* L.), mulberry, Russian olive (*Elaeagnus angustifolia* L.), briars and brambles, holly, blackgum, grape, persimmon (*Diospyros virginiana* L.), hackberries (*Celtic* spp.), blueberries, sumacs, and elderberry (*Sambucus canadensis* L.).

In addition to managing for a diversity of bird species, some landowners may need to feature selected species (e.g., endangered species) on their forestlands. However, the particular habitat requirements of featured species must be determined before implementing a management plan. Technical assistance for special plans may be available from state wildlife agency and cooperative extension personnel.

Suggested readings are proceedings of a workshop on management of southern forests for nongame birds [40] and a symposium on snag habitat management [38].

21.5 Economics of Wildlife in Managed Pine Forests

A good understanding of the costs and benefits of producing forest wildlife in lieu of timber [15] or livestock [69, 198] is necessary to meet landowner goals within self-imposed financial constraints. As the number of "forest products" considered increases, complexity in understanding the trade-offs grows until it defies comprehension [15].

Costs and benefits are not well defined for site-specific implementation of individual wildlife-management or silvicultural practices. Likewise, many forestry-wildlife relationships are not well defined, and benefits vary depending upon individuals' values and priorities. Costs can be opportunity costs (value of product forgone), direct expenses (out-of-pocket expenses for materials or labor), or expenditures of personal time. Benefits can be hunting fees, packages of meat, outdoor recreation, frequency of observations, or self-satisfaction in good land stewardship. Because many benefits are not tied directly to dollar prices, to understand the values associated with particular management decisions we must look at opportunity costs - "the dollars that you could have made but did not because you wanted something else."

The following discussion is a testimony to the difficulties that I have with forestry-wildlife economics and the lack of a standardized "measuring stick" for evaluating wildlife-management costs and benefits. The studies discussed frequently relate perceived benefits of undetermined values to opportunity costs and direct expenses such as $/ha, $/ha/yr, $/day, $/nest box, $/harvested deer, timber volume or basal area forgone, $/woodpecker clan, % of the value of a product, and $/kg of forage. Results may be presented as capitalized present net values, present day values, present day costs, objective function values, annual equivalents, or capitalized values forgone. "Present" and "current" are defined as at the time the study was done; values are not adjusted to the value of the dollar today. Moreover, most of the studies were models, rather than case studies of actual programs.

21_5.1 Costs of Wildlife Management

Wide spacing of planted pine seedlings (e.g., 3.1 x 3.1 m, 3.6 x 3.6 m) has been recommended to delay the time until pine canopy closure and extend the period of dense vegetative growth at ground level to benefit wildlife. Total wood production and basal area of slash, loblolly, and longleaf pine after 14 growing seasons, with a sanitation cut at age 12 years where necessary, were compared for various planting densities [219]. Relative to a 1.8- x 1 8-m initial spacing, slash pine at spacings of 2.9 x 2.9 m and 3.7 x 3.7 m, respectively, produced 49 and 56% less wood; wood production was 36 and 42% lower, at those respective spacings, for loblolly pine and 27 and 46% lower for longleaf pine. For the 1.8- x 1.8-m, 2.9- x 2.9-m, and 3.7- x 3.7-m spacings, respectively, basal areas of these stands after 14 growing seasons were 34.3, 20.7, and 17.0 m^2/ha for slash pine, 30.8, 20.9, and 19.6 m^2/ha for loblolly pine, and 12.0, 9.0, and 6.2 m^2/ha for longleaf pine. Basal areas of stands planted at 2.9 x 2.9 m were 60 to 75% lower, and those of stands planted at 3.7 x 3.7 m were 50 to 63% lower, than basal areas of stands planted at 1.8- x 1.8-m spacings. Though wood production and basal area are considerably reduced at wider spacings, differences in planting costs and precommercial thinning requirements should also be considered, depending upon timber production goals.

Forage plantings can be costly if materials, labor, and overhead (e.g, depreciation, maintenance, and operation of equipment) are considered. Estimates of creating openings on National Forest lands during 1935-65 ranged from $37/ha to rejuvenate an old field site to $2,470/ha to create a clearing in rugged wooded mountain terrain [126]. Normal costs for a new clearing were $37 to $247/ha in the Coastal Plain and Piedmont and $494 to $988/ha in the mountains. Expense of annual maintenance depended upon management intensity. Mowing and top dressing cost $37 to $111/ha, complete renovation $124 to $222/ha.

In 1954, the cost of clearing openings in ti,; Missouri Ozarks averaged $89/ha, and seedbed preparation, lime, fertilizer, seed, and labor an additional $124 to $148/ha [136]. And in 1959, the cost of creating forage plantings for deer and turkey in South Carolina was $74 to $88/ha, with 5-year maintenance and re-establishment costs of $42 to $267/ha [223]. The average cost of producing 100 kg of forage (dry weight) in South Carolina ranged from $1.17 for white Dutch clover *(Trifolium repens* L.) to $7.58 for perennial ryegrass *(Lolium perenne* L.). Insect numbers were highest on clovers and lowest on rescue grass *(Bromus catharticus* Vahl) and oats. The cost of labor during the South Carolina study was $1/hour.

Artificial cavities, or nest boxes, can be used to replace natural cavities in intensively managed forests, but at considerable expense. At $25/installed nest box, it would cost $1,050/ha to replace 42 natural cavities after an intensive improvement cut in an uneven-aged pine-hardwood forest undisturbed for at least 40 years in Louisiana [170]; at 25% occupancy, this translates to about $100/nest box used. In addition, nest boxes have other problems. They do not support woodpeckers that need to excavate cavities as part of their courtship behavior, they attract predators and hold parasites, they may increase mortality of winter residents, and they do not provide for other wildlife uses of snags such as roosting, feeding, and perching [89].

Hicks [89] used an example developed by Wick and Canutt [225] to illustrate the economic impacts of retaining snags on wood production in a ponderosa pine *(Pinus ponderosa* Dougl. ex Laws.) stand in the Northwest. The present-day value of timber forgone to provide snag habitat at a 60% level on a 150-year rotation was $295/ha, approximately a third of the market value of the forestland. Or, with a different management technique, present-day costs to maintain secondary cavity-nesting species at the 60% level on 40.5 ha with 130 nest boxes was $6,786, or $168/ha.

Marginal costs of preserving existing colonies and extending rotations to develop recruitment stands to achieve a population goal for the endangered red-cockaded woodpecker were analyzed for the Croatan National Forest in coastal North Carolina [114]. Depending upon tree species, site index, and areal coverage, the costs to preserve currently occupied colony sites in perpetuity ranged from $255 to $56,529/site and totaled $528,459 for 52 colonies. The goal for the Croatan was 191 red-cockaded woodpecker clans (a clan is a group of woodpeckers occupying a colony site). Marginal costs to extend rotation length for recruitment stands ranged from $11,824 to $118,349/clan.

Using 1980-86 stumpage prices, McKee [149] assessed opportunity costs associated with a 6.5-ha streamside zone, precommercial thinning, and prescribed burning at 3-year.

rather than 5-year, intervals for wildlife management in a 65-ha loblolly pine plantation. The timber revenue forgone (annual equivalent of present net worth) to include wildlife in the regime ranged from $8.70 to $12.23/ha annually, depending upon stumpage values. When stumpage values were low ($12/cord; $116/thousand bd ft Scribner), a timber-management profit was turned into a loss by including wildlife management.

Costs of deer management to the timberland owner have been determined in different ways. On Virginia timberlands with healthy deer herds in the 1960s, Davis [39] estimated that adjustments to timber management for deer were justified when a harvested deer brought a return of $13 to $37 on poor timberland and $37 to $190 on good timberland. In 1983, McKee et al. [153] determined opportunity costs associated with several levels of deer management on a 7,255-ha pine-hardwood forest in Mississippi. Constraints on wood flow and regeneration requirements, streamside management zones, and cutting of adjacent plantations and natural stands were imposed at various levels to provide deer habitat of increasing quality. Annual equivalents of capitalized value forgone to move from poor habitat diversity (1 deer/24 ha) to higher levels were $2.08/ha for good (1 deer/12 ha) and $8.01/ha for excellent (1 deer/6 ha) habitat diversity. McKee [151] estimated these costs to improve habitat diversity could amount to 14 to 58% of the stumpage value of a timber crop.

At a turkey-habitat symposium in 1981, McKee [150] estimated that pine plantation management yields 74% more wood and 119% more annual income than uneven-aged management. And, on a 790-ha tract of pine-hardwood timber to be converted to loblolly pine plantations over 20 years, annual opportunity costs (per-hectare annual equivalents of capitalized present net value) associated with restrictions on cutting adjacent stands in a 5-year period and retaining wide (121-m) streamside management zones on perennial streams were $2.84/ha and $2.20/ha, respectively [150, 152]. The annual cost of streamside management zones, on the basis of their area alone (53.4 ha), was $32.52/ha.

The expense of integrating wildlife in southern pine forests varies with ownership size and with the intensity of timber- and wildlife-management practices, and may be unacceptably high when timber production goals are primary. For example, costs of installing nest boxes, retaining snags, or extending rotation length to manage for cavity nesters are high, especially over large areas. However, many wildlife-management activities have acceptable costs or may not conflict with less intense timber production. Each tract of forestland presents unique opportunities to integrate wildlife and timber management. The challenge is to recognize and develop these at a profit, or at acceptable cost.

21.5.2 Income From Wildlife Management

The increased abundance or quality of wildlife, especially game animals, resulting from forest wildlife management offers opportunities for income from fee hunting programs and other wildlife-oriented activities (e.g., photography, birdwatching). This revenue may offset or exceed the timber value forgone to accommodate the wildlife. Fee hunting programs common on private lands in the Southeast include leasing of hunting rights, permit hunts by the day or season, selling memberships to hunters for exclusive use of properties, guided hunts, and lands in fee permit wildlife management areas in cooperation with state wildlife agencies.

Leasing of hunting rights is the most common form of fee hunting on private lands in the Southeast (Fig. 21.9). Lassiter [127] conducted landowner surveys covering 8.0 million ha in four southeastern states in 1983 to evaluate public access to wildlife on large private forestland holdings. Fee hunting occurred on 60.5% of the survey lands: 16.5% in fee permit wildlife management areas in cooperation with state wildlife agencies, 11.0% in fee permit programs operated by landowners, and 33.0% in leased lands. Annual lease fees on 2.6 million ha ranged from $0.62 to $19.77/ha, averaging $3.41/ha; annual fees on 78% of leased lands were less than $4.94/ha. During the interviews, foresters noted that annual income of $7.41 to $12.35/ha from wildlife will cause some adjustment in forest management practices to favor wildlife.

In a mail survey of consulting foresters, timber companies, state-agency biologists, and hunt-club presidents, Busch [21] assessed the status of lease hunting in 11 southeastern states in 1984. Annual lease fees paid through consultants for 2.1 million ha ranged from $0.74 to $29.65/ha, averaging $4.77/ha. Timber companies reported annual lease fees of $2.47 to $26.88/ha, which varied by location, timber type, and game species. Mean annual lease fees for industry timberlands ranged from $2.67 to $4.69/ha for individual states. In general, fees were higher for hardwood stands than for mixed natural stands, and both were higher than for pine plantations. Consultants reported differential fees for species-specific leases, averaging

Figure 21.9. The most common fee hunting arrangement on private forestlands in the Southeast is a hunting club that leases the right to control hunter access.

$4.52/ha for deer, $5.14/ha for quail, $4.94/ha for turkey, and $3.71/ha for dove. State-agency biologists reported mean annual lease fees of $0.59/ha for private lands in cooperative wildlife management areas, with fees in individual states ranging from none to $4.08/ha. Most hunt-club presidents (81%) felt that current lease fees were fair; deer-club respondents in South Carolina thought annual lease prices should be $2.49/ha and $3.61/ha for dog and still hunting, respectively, whereas those in Mississippi thought prices should be $5.04/ha and $6.80/ha, respectively.

In 1984, annual hunting lease fees on private forestlands in Arkansas ranged from $0.62/ha to $12.35/ha, with $2.47/ha the most common fee [175]; those on 0.9 million ha of nonindustrial private forestlands in North Carolina averaged $3.09/ha but ranged up to $8.65/ha [63]. Lease fees for timberlands near major urban areas are generally higher; for example, forestlands near New Orleans and Baton Rouge generally lease for $12.35 to $24.71/ha annually [29]. In the lower Mississippi Delta, annual hunting leases for deer and turkey on large hardwood tracts (> 405 ha) commonly yield $37.06/ha and occasionally yield in excess of $74.13/ha [214]. Lease fees are normally lower on forest industry lands than on nonindustrial private lands. Mean annual fees in Arkansas in 1984, when < 10% of large private forestlands were leased, were $3.01/ha on industry lands and $3.36/ha on other private lands [175]. Lassiter's [127] surveys found that annual fees on industry lands averaged $3.09/ha whereas those on other private lands averaged $6.45/ha. Across the South, the "local market" affects fees on industry and other lands.

Annual fees for permit programs in the southeastern states surveyed by Lassiter [127] ranged from $2 to $35, with 88% less than $15. Timber companies responding to Busch's [21] survey of southeastern states reported average permit fees of $12.60/day, $61.71/season, and $37.31/year.

Special areas can bring higher permit fees. International Paper Company managed a 1,619-ha tract in 1986 specifically for archery hunting of deer in Louisiana, with 100 season permits available at $200/hunter, and 3-day permits available for $100 [37]. Facilities included an archery range, a headquarters building with meeting room and check station, and 28 campsites with water and electricity. The deer herd was estimated at 1 deer/6 ha.

Seasonal memberships to private hunting clubs on Gulf States Paper Corporation lands in Alabama were $200 to $250/hunter for spring turkey hunting or fall deer and small-game hunting in 1973 [201]. However, in 1988, annual membership fees started at about $1,000/person for hunting on large ownerships or hunting plantations in the South [107]. Currently, commercial hunting facilities on private lands commonly charge $150 to $325/day for deer hunting and about $200/day for quail hunting. Standard fees for package hunts of wild boar or turkey are $200 to $300, and those for trophy white-tailed deer begin at about $1,000. The hunts at commercial facilities frequently include lodging, meals, guides, stands, and other amenities.

Dutrow and Devine [50] analyzed net revenues from joint production of timber and turkeys in the physiographic provinces of Virginia. Using a value of $10.80/day for wild turkey hunting and the results of a telephone survey of wildlife researchers, they estimated that annual revenues for turkey hunting could amount to $9.88/ha for owners of 810 ha or more (40 hunters at $200 each). With cost adjustments to accommodate turkey habitat, net revenues from joint timber and turkey production exceeded revenues from timber alone. In comparison with timber production only, annual equivalent income from timber and turkey production was $24.71/ha higher in the mountains, $14.83/ha higher in the Piedmont, and $88.95/ha higher in the Coastal Plain. Much of the gain in the Coastal Plain was attributable to increasing the timber rotation length, which permitted a significant hike in opportunities to market sawtimber and peeler logs at much higher per-unit prices. The authors noted that the opportunity for annual income is an incentive for including turkeys in forest management plans.

In McKee's [149] example discussed earlier, a 65-ha loblolly pine plantation was managed for joint timber-wildlife production with annual opportunity costs of $8.70 to $12.23/ha. However, when annual hunting lease income of $12.35/ha was added to the economic analysis, revenue gains over timber management only were $0.99 to $4.52/ha. Revenue was enhanced most when stumpage price was low. Thus, there is a strong incentive to manage for annual income from hunting when timber values are down.

Busch [21] determined that an annual hunting lease fee of $4.94/ha increased the net present value of a typical loblolly pine plantation 73% and that of a less intensively managed natural loblolly stand 8%. The net present value of each $2.47/ha of annual hunt lease payment was $28.79/ha for a plantation and $24.26/ha for a natural stand. Thus, in these examples, $28.79 and $24.26 respectively could be forgone in per-hectare timber revenue without reducing the investment-return ratio.

Fee hunting provides annual income which compensates for reduced timber revenues because of wildlife management practices. However, each forest ownership requires an economic assessment to understand site-specific trade-offs. A cash-flow analysis for a timber-wildlife plan, taking into account marketing, contracts, liability and insurance, and game harvest strategies, will indicate the feasibility of achieving success. Assistance in evaluating existing or proposed fee hunting programs may be available from consulting wildlife biologists, cooperative extension agents, or state-agency biologists. Several state wildlife agencies in the Southeast have cooperative deer-management programs to assist in deer herd management on private lands. Where ownerships are too small, cooperatives can be formed with adjacent landowners to manage and market forest and wildlife resources on a collectively larger land base [233].

A few enterprising landowners with fee hunting programs also offer nonconsumptive wildlife-oriented activities on a fee basis. A landowner on Little St. Simons Island off the Georgia coast offers birdwatching at $325/day, including a place to stay and a professional naturalist staff [1081. Birdwatching there is a bigger business than deer hunting. St. Simons has diverse natural habitats and an abundance of birds; a visitor can see over 100 species on a good day during the spring migration. Similarly, in Texas, some ranchers provide lodging, meals, and blinds to view and photograph big game (native and exotic) and other wildlife. These types of nontraditional fee activites are increasing as landowners seek to increase revenues when hunting seasons are closed.

21.6 Summary Remarks

Wildlife can be integrated into the managed forest at some cost, with opportunities for income from fee hunting or other activities. Almost unlimited options are available, and trade-offs must be evaluated. Forest plans should be drafted and then reviewed and revised regularly because priorities may change. The decisions of the landowner or forest manager can be made in a relatively short time, but the effects of implementing them will be apparent in the woods for a considerably longer time. A good plan can maintain many options for the future.

The key to assuring productive wildlife habitats in managed pine forests is landscape diversity, among and within stands:

> "To maintain a full and natural complement of wildlife species, a full and natural complement of plant communities (habitats) must be retained in the landscape" [531.

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References

I. Anderson, S. H., and C. S. Robbins. 1981. Habitat size and bird community management. Trans. North Am. Wildl. and Nat. Resour. Conf. 46:511-520.
2. Atkeson, T. D., and A. S. Johnson. 1979. Succession of small mammals on pine plantations in the Georgia Piedmont. Am. Midl. Nat. 101:385-392.
3. Bailey, R. W. 1980. The wild turkey status and outlook in 1979. Natl. Wild Turkey Symp. 4:1-9.
4. Beaver, D. L. 1976. Avian populations in herbicide treated brush fields. Auk 93:543-553.
5. Bendel], J. F. 1974. Effects of fire on birds and mammals. Pages 73-138 *In* Fire and Ecosystems (T. T. Kozlowski and C. E. Ahlgren, eds.). Academic Press, New York.
6. Blackford, J. 1955. Woodpecker concentration in a burned forest. Condor 57:28-30.
7. Blair, R. M. 1960. Deer forage increased by thinnings in a Louisiana loblolly pine plantation. J. Wildl. Manage. 24:401-405.
8. Blair, R. M. 1967. Deer forage in a loblolly pine plantation. J. Wildl. Manage. 31:432-437.
9. Blair, R. M. 1969. Timber stand density influences food and cover. Pages 74-76 *In* White-tailed Deer in the Southern Forest Habitat, Proc. of a Symposium (L. K. Halls, ed.). U.S.D.A. Forest Serv., South. Forest Exp. Sta., Nacogdoches, Tex.
10. Blair, R. M., and L. E. Brunett. 1977. Deer habitat potential of pine-hardwood forests in Louisiana. U.S.D.A. Forest Serv., South.Forest Exp. Sta., New Orleans, La. Res. Pap. SO-136. 11 p.
11. Blair, R. M., and H. G. Enghardt. 1976. Deer forage and overstory dynamics in a loblolly pine plantation. J. Range Manage. 9:104-108.
12. Blair, R. M., and D. P. Feduccia. 1977. Midstory hardwoods inhibit deer forage in loblolly pine plantations. J. Wildl. Manage. 41:677-684.
13. Blake, P. M., G. A. Hurst, and T. A. Terry. 1987. Responses of vegetation and deer forage following application of hexazinone. South. J. Appl. Forestry 11:176-180.
14. Borrecco, J. E., H. C. Black, and E. F. Hooven. 1972. Response of black-tailed deer to herbicide-induced habitat changes. Proc. Annu. Conf. West. Assoc. State Game and Fish Comm. 52:437-451.
15. Boyce, S. G. 1982. Planning for joint production of multiple forest benefits. Proc. Annu. Cony. Soc. Am. Foresters (1981):204-208.
16. Bromley, P. T., and R. L. Carlton (eds.). 1981. Habitat requirements and habitat management for the wild turkey in the Southeast. Proc. of the Symposium, Virginia Wild Turkey Federation, Elliston. 180 p.
17. Brown, E. K. 1980. Home range and movements of wild turkeys - a review. Natl. Wild Turkey Symp. 4:251-261.
18. Buckner, J. L. 1982. Integration of forestry and wildlife management in the loblolly pine type. Pages 297-305 *In* Symposium on the Loblolly Pine Ecosystem (East Region). School of Forest Resources, North Carolina State Univ., Raleigh.
19. Buckner, J. L. 1983. Wildlife concerns in the managed slash pine ecosystem. Pages 369-374 *In* Proceedings of the Symposium on the Managed Slash Pine Ecosystem (E. L. Stone, ed.). School of Forest Resources and Conservation, Univ. of Florida, Gainesville.
20. Buckner, J. L., J. L. Landers, J. A. Barker, and C. J. Perkins. 1979. Wildlife food plants following preparation of longleaf pine sites in southwest Georgia. South. J. Appl. Forestry 3:56-59.
21. Busch, F. A., III. 1987. Lease hunting in the southern United States. M.S. thesis, Clemson Univ., Clemson, S.C. 78 p.
22. Callahan, R. L., J. S. Parkman, D. W. Sanders, and J. A. Wolfe. 1984. Mississippi planting guide. U.S.D.A. Soil Conserv. Serv., Jackson, Miss. 41 p.
23. Campbell, D. L., J. Evans, G. D. Lindsey, and W. E. Dusenberry. 1981. Acceptance by black-tailed deer of foliage treated with herbicides. U.S.D.A. Forest Serv., Pacific Northwest Forest and Range Exp. Sta., Portland, Oreg. Res. Pap. PNW-290. 31 p.
24. Chabreck, R. H., and R. H. Mills (eds.). 1980. Integrating timber and wildlife management in southern forests.

Annual Forestry Symposium 29, Louisiana State Univ., Baton Rouge, La. 119 p.
25. Conner, R. N. 1978. Snag management for cavity nesting birds. Pages 120-128 *In* Proc. of the Workshop, Management of Southern Forests for Nongame Birds (R. M. DeGraaf, tech. coord.). U.S.D.A. Forest Serv., Southeast. Forest Exp. Sta., Asheville, N.C. Gen. Tech. Rep. SE-14.
26. Conner, R. N. 1981. Fire and cavity nesters. Pages 61-65 *In* Prescribed Fire and Wildlife in Southern Forests (G. W. Wood, ed.). Belle W. Baruch Forest Sci. Institute, Clemson Univ., Georgetown, S.C.
27. Conner, R. N., R. G. Hooper, H. S. Crawford, and H. S. Mosby. 1975. Woodpecker nesting habitation in cut and uncut woodlands in Virginia. J. Wildl. Manage. 39:144-150.
28. Conner, R. N., 0. K. Miller, Jr., and C. S. Adkisson. 1976. Woodpecker dependence on trees infected by fungal heart rots. Wilson Bull. 88:575-581.
29. Conrad, J. 1985. Hunting for forest income. Am. Forests 91(9):45-46, 73-75.
30. Copeland, J. D., and G. A. Hurst. 1986. Deer forage on pine plantations after intensive mechanical and chemical site preparation. Proc. South. Weed Sci. Soc. 39:237.
31. Craft, B. R., and J. L. Haygood. 1972. Production, nutritive quality, and rootstock survival of Japanese honeysuckle. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 26:69-81.
32. Crawford, H. S. 1984. Habitat management. Pages 629-646 *In* White-tailed Deer Ecology and Management (L. K. Halls, ed.). Stackpole Books, Harrisburg, Pa.
33. Cushwa, C. T., E. V. Brender, and R. W. Cooper. 1966. The response of herbaceous vegetation to prescribed burning. U.S.D.A. Forest Serv., Southeast. Forest Exp. Sta., Asheville, N.C. Res. Note SE-53. 2 p.
34. Cushwa, C. T., E. Czuhai, R. W. Cooper, and W. H. Julian. 1969. Burning clearcut openings in loblolly pine to improve wildlife habitat. Georgia Forest Resources Council, Macon. Pap. 61.5 p.
35. Cushwa, C. T., and J. B. Redd. 1966. One prescribed burn and its effects on habitat of the Powhatan Game Management Area. U.S.D.A. Forest Serv., Southeast. Forest Exp. Sta., Asheville, N.C. Res. Note SE-61. 2 p.
36. Darden, T. L., Jr. 1980. Bird communities in managed loblolly-shortleaf pine stands in east central Mississippi. M.S. thesis, Mississippi State Univ., Mississippi State. 117 p.
37. Davis, D. 1986. San Patricio means meeting a deer on its own terms. Forests & People 36(3):8-10, 12, 35.
38. Davis, J. W., G. A. Goodwin, and R. A. Ockenfels (tech. coords.). 1983. Snag habitat management: proceedings of the symposium. U.S.D.A. Forest Serv., Rocky Mountain Forest and Range Exp. Sta., Fort Collins, Colo. Gen. Tech. Rep. RM-99. 226 p.
39. Davis, L. S. 1967. Dynamic programming for deer management planning. J. Wildl. Manage. 31:667-679.
40. DeGraaf, R. M. (tech. coord.). 1978. Proceedings of the workshop management of southern forests for nongame birds. U.S.D.A. Forest Serv., Southeast. Forest Exp. Sta., Asheville, N.C. Gen. Tech. Rep. SE-14. 176 p.
41. DeWitt, J. B., and J. V. Derby, Jr. 1955. Changes in nutritive value of browse plants following forest fires. J. Wildl. Manage. 19:65-70.
42. Dickson, *J.* G. 1981. Effects of forest burning on songbirds. Pages 67-72 *In* Prescribed Fire and Wildlife in Southern Forests (G. W. Wood, ed.). Belle W. Baruch Forest Sci. Institute, Clemson Univ., Georgetown, S.C.
43. Dickson, J. G. 1982. Impact of forestry practices on wildlife in southern pine forests. Proc. Annu. Cony. Soc. Am. Foresters (1981):224-230.
1. Dickson, J. G., and R. N. Conner. 1982. Winter birds and snags in an east Texas clearcut. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 36:638-642.
2. Dickson, J. G., R. N. Conner, and J. H. Williamson. 1983. Snag retention increases bird use of a clear-cut. J. Wildl. Manage. 47:799-804.
3. Dickson, J. G., and J. C. Huntley. 1987. Riparian zones and wildlife in southern forests: the problem and squirrel relationships. Pages 37-39 *In* Managing Southern Forests for Wildlife and Fish - a Proc. (J. G. Dickson and 0. E. Maughan, eds.). U.S.D.A. Forest Serv., South. Forest Exp. Sta., New Orleans, La. Gen. Tech. Rep. SO-65.
4. Dickson, J. G., and 0. E. Maughan (eds.). 1987. Managing southern forests for wildlife and fish - a proceedings U.S.D.A. Forest Serv., South. Forest Exp. Sta., New Orleans, La. Gen. Tech. Rep. SO-65. 85 p.
5. Dimmick, R. W. 1971. The influence of controlled burning on nesting patterns of bobwhite in west Tennessee. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 25:149-155.
6. Doerr, P. D., L. B. Keith, and D. H. Rusch. 1970. Effects of fire on a ruffed grouse population. Proc. Tall Timbers Fire Ecol. Conf. 10:25-46.
7. Dutrow, G. F., and H. A. Devine. 1981. Economics of forest management for multiple outputs: timber and turkey. Pages 114-121 *In* Habitat Requirements and Habitat Management for the Wild Turkey in the Southeast, Proc. of the Symposium (P. T. Bromley and R. L. Carlton, eds.). Virginia Wild Turkey Federation, Elliston.
8. Easley, J. M. 1977. Effects of chemical brush control on vegetation in pine plantations. M.S. thesis, Mississippi State Univ., Mississippi State. 45 p.
9. Emlen, J. T. 1970. Habitat selection by birds following a forest fire. Ecology 51:343-345.
10. Evans, K. E. 1978. Oak-pine and oak-hickory forest bird communities and management options. Pages 76-89 *In* Proc. of the Workshop, Management of Southern Forests for Nongame Birds (R. M. DeGraaf, tech. coord.). U.S.D.A. Forest Serv., Southeast. Forest Exp. Sta., Asheville, N.C. Gen. Tech. Rep. SE-14.
11. Evans, K. E., and R. N. Conner. 1979. Snag management. Pages 214-225 *In* Management of North Central and Northeastern Forests for Nongame Birds, Workshop Proc. (R. M. DeGraaf and K. E. Evans, eds.). U.S.D.A. Forest Serv., North Central Forest Exp. Sta., St. Paul, Minn. Gen. Tech. Rep. NC-51.
12. Evans, R. D. 1974. Wildlife habitat management program: a concept of diversity for the public forests of Missouri. Pages 73-83 *In* Timber-Wildlife Management Symposium (J. P. Slusher and T. M. Hinkley, eds.). Missouri Academy of Sci., Columbia. Occas. Pap. 3. As cited in Thomas 1979 [212, this list].
13. Evans, W. G. 1971. The attraction of insects to forest fires. Proc. Tall Timbers Conf. on Ecol. Animal Control by Habitat Manipulation 2:115-127.
14. Everett, D. D., D. W. Speake, and W. K. Maddox. 1979. Wild turkey ranges in Alabama mountain habitat. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 33:233-238.
15. Exurn, J. H., J. A. McGlincy, D. W. Speake, J. L. Buckner, and F. M. Stanley. 1987. Ecology of the eastern wild turkey in an intensively managed pine forest in southern Alabama. Tall Timbers Res. Sta., Tallahassee, Fla. Bull. 23.70 p.
16. Felix, A. C., III, T. L. Sharik, B. S. McGinnes, and W. C. Johnson. 1983. Succession in loblolly pine plantations converted from second-growth forest in the central Piedmont of Virginia. Am. Midl. Nat. 110:365-380.
60. Fenwood, J. D., D. F. Urbston, and R. F. Harlow. 1984. Determining deer habitat capability in Ouachita National

Forest pine stands. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 38:13-22.
61. Flyger, V., and J. E. Gates. 1982. Fox and gray squirrels. Pages 209-229 *In* Wild Mammals of North America (J. A. Chapman and G. A. Feldhamer, eds.). Johns Hopkins Univ. Press, Baltimore.
62. Folk, R. H., III, and C. W. Bales. 1982. An evaluation of wildlife mortality resulting from aerial ignition prescribed burning. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 36:643-646.
63. Franklin, C., and J. A. Allen. 1985. Hunting leases on private nonindustrial forest land in North Carolina. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 39:3/1 1 350.
64. Freedman, B., A. M. Poirier, R. Morash, and F. Scott. 1988. Effects of the herbicide 2,4,5-T on the habitat and abundance of breeding birds and small mammals of a conifer clearcut in Nova Scotia. Can. Field-Naturalist 102:6-11.
65. Frey, H. T. 1982. Major uses of land in the United States: 1978. U.S.D.A. Economic Res. Serv., Washington, D.C. Agric. Econ. Rep. 487.22 p.
66. Galli, A. E., C. F. Leck, and R. T. T. Forman. 1976. Avian distribution patterns in forest islands of different sizes in central New Jersey. Auk 93:356-364.
67. Gauthreaux, S. A., Jr. 1978. The structure and organization of avian communities in forests. Pages 17-37 *In* Proc. of the Workshop, Management of Southern Forests for Nongame Birds (R. M. DeGraaf, tech. coord.). U.S.D.A. Forest Serv., Southeast. Forest Exp. Sta., Asheville, N.C. Gen. Tech. Rep. SE-14.
68. Gill, J. D., and W. M. Healy (eds.). 1974. Shrubs and vines for northeastern wildlife. U.S.D.A. Forest Serv., Northeast. Forest Exp. Sta., Upper Darby, Pa. Gen. Tech. Rep. NE-9. 180 p.
69. Glover, M. K., and J. R. Conner. 1988. A model for selecting optimal combinations of livestock and deer lease-hunting enterprises. Wildl. Soc. Bull. 16:158-163.
70. Goodrum, P. D. 1969. Short and long rotations in relation to deer management in southern forests. Pages 71-73 *In* White-tailed Deer in the Southern Forest Habitat, Proc. of a Symposium (L. K. Halls, ed.). U.S.D.A. Forest Serv., South. Forest Exp. Sta., Nacogdoches, Tex.
71. Goodrum, P. D., V. H. Reid, and C. E. Boyd. 1971. Acorn yields, characteristics, and management criteria of oaks for wildlife. J. Wildl. Manage. 35:520-532.
72. Grelen, H. E., and C. E. Lewis. 1981. Value of range data on fire effects to the wildlife manager. Pages 155-162 *In* Prescribed Fire and Wildlife in Southern Forests (G. W. Wood, ed.). Belle W. Baruch Forest Sci. Institute, Clemson Univ., Georgetown, S.C.
73. Grelen, H. E., L. B. Whitaker, and R. E. Lohrey. 1972. Herbage response to precommercial thinning in direct-seeded slash pine. J. Range Manage. 25:435-437.
74. Halls, L. K. (ed.) 1969. White-tailed deer in the southern forest habitat, proceedings of a symposium. U.S.D.A. Forest Serv., South. Forest Exp. Sta., Nacogdoches, Tex. 130 p.
75. Halls, L. K. 1973. Managing deer habitat in loblolly-shortleaf pine forest. J. Forestry *71:7 52-7 57*.
76. Halls, L. K. (ed.) 1984. White-tailed Deer Ecology and Management. Stackpole Books, Harrisburg, Pa. 870 p.
77. Halls, L. K., and C. E. Boyd. 1982. Influence of managed pine stands and mixed pine/hardwood stands on well being of deer. U.S.D.A. Forest Serv., South. Forest Exp. Sta., New Orleans, La. Gen. Tech. Rep. SO-183. 18 p.
78. Handley, C. 0. 1931. The food and feeding habits of bobwhites. Pages 113-165 *In* The Bobwhite Quail - Its Habits, Preservation and Increase (H. L. Stoddard, ed.). C. Scribner's Sons, New York.
79. Handley, C. 0. 1945. Japanese honeysuckle in wildlife management. J. Wild!. Manage. 9:261-264.
80. Harlow, R. F. 1972. Reproductive rates in white-tailed deer of Florida. Q. J. Fla. Acad. Sci. 24:19-38.
81. Harlow, R. F., and D. C. Guynn, Jr. 1983. Snag densities in managed stands of the South Carolina Coastal Plain. South. J. Appl. Forestry 7:224-229.
82. Harlow, R. F., and D. C. Guynn, Jr. 1987. Foods, food habits and food habits analysis studies of white-tailed deer. Dep. of Forestry, Clemson Univ., Clemson, S.C. 179 p.
83. Harris, L. D. 1980. Forest and wildlife dynamics in the Southeast. Trans. North Am. Wildl. and Nat. Resour. Conf. 45:307-322.
84. Harris, L. D. 1984. The Fragmented Forest. Univ. of Chicago Press, Chicago, Ill. 211 p.
85. Harris, L. D. 1989. The faunal significance of fragmentation of southeastern bottomland forests. Pages 126-134 *In* The Forested Wetlands of the Southern United States (D. D. Hook and R. Lea, eds.). U.S.D.A. Forest Serv., Southeast. Forest Exp. Sta., Asheville, N.C. Gen. Tech. Rep. SE-50.
86. Harris, L. D., D. H. Hirth, and W. R. Marion. 1979. The development of silvicultural systems for wildlife. Louisiana State Univ. Annu. Forestry Symp. 28:65-81.
87. Harris, L. D., and J. D. McElveen. 1981. Effect of forest edges on north Florida breeding birds. School of Forest Resources and Conserv., Univ. of Florida, Gainesville. IMPAC Rep. 6(4). 24 p.
88. Hewitt, 0. H. (ed.) 1967. The Wild Turkey and its Management. The Wildlife Society, Washington, D.C. 589 p.
89. Hicks, L. L. 1983. Snag management: options and incentives for private landowners. Pages 60-63 *In* Snag Habitat Management: Proc. of the Symposium (J. W. Davis, G. A. Goodwin, and R. A. Ockenfels, tech. coords.). U.S.D.A. Forest Serv., Rocky Mountain Forest and Range Exp. Sta., Fort Collins, Colo. Gen. Tech. Rep. RM-99.
90. Hill, E. P. 1981. Prescribed fire and rabbits in southern forests. Pages 103-108 *In* Prescribed Fire and Wildlife in Southern Forests (G. W. Wood, ed.). Belle W. Baruch Forest Sci. Institute, Clemson Univ., Georgetown, S.C.
91. Holbrook, H. T., M. R. Vaughan, and P. T. Bromley. 1985. Wild turkey management on domesticated pine forests. Natl. Wild Turkey Symp. 5:253-258.
92. Hooper, R. G., A. F. Robinson, Jr., and J. A. Jackson. 1980. The red-cockaded woodpecker: notes on life history and management. U.S.D.A. Forest Serv., Southeast. Area, State and Private Forestry, Atlanta, Ga. Gen. Rep. SA-GR 9.8 p.
93. Hopkins, C. R. 1981. Dispersal, reproduction, mortality, and habitat utilization of restocked eastern turkeys in East Texas. Ph.D. diss., Texas A & M Univ., College Station. 117 p.
94. Hunter, M. L., Jr. 1987. Managing forests for spatial heterogeneity to maintain biological diversity. Trans. North Am. Wildl. and Nat. Resour. Conf. 52:60-69.
95. Hurst, G. A. 1971. The effects of controlled burning on arthropod density and biomass in relation to bobwhite quail brood habitat on a right-of-way. Proc. Tall Timbers Conf. on Ecol. Animal Control by Habitat Manipulation 2:173-183.
96. Hurst, G. A. 1972. Insects and bobwhite quail brood habitat management. Natl. Bobwhite Quail Symp. 1:65-82.
97. Hurst, G. A. 1978. Effects of controlled burning on wild turkey poult food habits. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 32:30-37.
98. Hurst, G. A. 1981. Effects of prescribed burning on the

eastern wild turkey. Pages 81-88 *In* Prescribed Fire and Wildlife in Southern Forests (G. W. Wood, ed.). Belle W. Baruch Forest Sci. Institute, Clemson Univ., Georgetown, S.C.

99. Hurst, G. A. 1987. Vegetative responses to imazapyr for pine release. Proc. South. Weed Sci. Soc. 40:247.

100. Hurst, G. A., J. J. Campo, and M. B. Brooks. 1980. Deer forage in a burned and burned-thinned pine plantation. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 34:476-481.

101. Hurst, G. A., J. J. Campo, and M. B. Brooks. 1981. Deer forage in precommercially thinned pine plantations. Southeast Deer Study Group 4:5. (Abstr.)

102. Hurst, G. A., D. C. Guynn, and B. D. Leopold. 1980. Correlation of forest characteristics with white-tailed deer forage. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 33:48-55.

103. Hurst, G. A., and R. C. Warren. 1980. Intensive pine plantation management and white-tailed deer habitat. Lousiana State Univ. Annu. Forestry Symp. 29:90-102.

104. Hurst, G. A., and R. C. Warren. 1982. Deer forage in 13-year-old commercially thinned and burned loblolly pine plantations. Proc. Annu. Conf. Southeast. Assoc. Fish and Wild!. Agencies 36:420-426.

105. Hurst, G. A., and R. C. Warren. 1986. Deer forage on pine plantations after a herbicide application for pine release. Proc. South. Weed Sci. Soc. 39:238.

106. Ivey, T. L. 1983. Behavioral response of white-tailed deer to prescribed fire. Southeast Deer Study Group 6:18. (Abstr.)

107. Jackson, J. 1988. Wildlife enterprises for the southern forest farmer. Forest Farmer 47(8):9-11.

108. Jackson, J. 1989. Birdwatching: a nonconsumptive wildlife enterprise. Forest Farmer 48 (8):9.

109. Jacobson, H. A., and G. A. Hurst. 1979. Prevalence of parasitism by *Amblyomma americanum* on wild turkey poults as influenced by prescribed burning. J. Wildl. Dis. 15:43-47.

110. Johnson, A. S. 1987. Pine plantations as wildlife habitat: a perspective. Pages 12-18 *In* Managing Southern Forests for Wildlife and Fish - A Proc. (J. G. Dickson and O. E. Maughan, eds.). U.S.D.A. Forest Serv., South. Forest Exp. Sta., New Orleans, La. Gen. Tech. Rep. SO-65.

111. Johnson, A. S., P. E. Hale, and J. M. Wentworth. 1986. Are we really managing deer populations? Southeast Deer Study Group 9:9-10. (Abstr.)

112. Johnson, A. S., and J. L. Landers. 1978. Fruit production in slash pine plantations in Georgia. J. Wildl. Manage. 42:606-613.

113. Johnson, A. S., J. L. Landers, and T. D. Atkeson. 1975. Wildlife in young pine plantations. Pages 147-159 *In* Symposium on Management of Young Pines (W. E. Balmer, ed.). U.S.D.A. Forest Serv., Southeast. Area, State and Private Forestry, Atlanta, Ga.

114. Judge, R. P., R. Strait, and W. F. Hyde. 1984. Economics of endangered species management: the red-cockaded woodpecker. Trans. North Am. Wildl. and Nat. Resour. Conf. 49:375-381.

115. Karr, J. R., and R. R. Roth. 1971. Vegetation structure and avian diversity in several new world areas. Am. Nat. 105:423-435.

116. Kirkpatrick, R. L., and H. S. Mosby. 1981. Effect of prescribed burning on tree squirrels. Pages 99-101 *In* Prescribed Fire and Wildlife in Southern Forests (G. W. Wood, ed.). Belle W. Baruch Forest Sci. Institute, Clemson Univ., Georgetown, S.C.

117. Knight, H. A. 1984. Southern U.S. timber supplies. Proc. North Am. Int. Inst. Appl. Systems Anal. Network Meet. 3:27-37.

118. Knight, H. A. 1985. An overview of the timber resource in the Southeast. American Pulpwood Assoc., Williamsburg, Va. Tech. Pap. 85-P-6.9 p.

119. Komarek, E. V. 1969. Fire and animal behavior. Proc. Tall Timbers Fire Ecol. Conf. 9:161-207.

120. Korschgen, L. J. 1967. Feeding habits and foods. Page 137-198 *In* The Wild Turkey and its Management (O. H. Hewitt, ed.). The Wildlife Society, Washington, D.C.

121. Landers, J. L. 1981. The role of fire in bobwhite quail management. Pages 73-80 *In* Prescribed Fire and Wildlife in Southern Forests (G. W. Wood, ed.). Belle W. Baruch Forest Sci. Institute, Clemson Univ., Georgetown, S.C.

122. Landers, J. L., and B. S. Mueller. 1986. Bobwhite quail management: a habitat approach. Tall Timbers Res. Sta., Tallahassee, Fla. Misc. Publ. No. 6.39 p.

123. Landers, J. L., and D. W. Speake. 1980. Management needs of sandhills reptiles in southern Georgia. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 34:515-529.

124. Langdon, O. G. 1981. Some effects of prescribed fire on understory vegetation in loblolly pine stands. Pages 143-153 *In* Prescribed Fire and Wildlife in Southern Forests (G. W. Wood, ed.). Belle W. Baruch Forest Sci. Institute, Clemson Univ., Georgetown, S.C.

125. Larson, J. S. 1967. Forests, wildlife, and habitat management - a critical examination of practice and need. U.S.D.A. Forest Serv., Southeast. Forest Exp. Sta., Asheville, N.C. Res. Pap. SE-30. 28 p.

126. Larson, J. S. 1969. Agricultural clearings as sources of supplemental food and habitat diversity for white-tailed deer. Pages 46-50 *In* White-tailed Deer in the Southern Forest Habitat, Proc. of a Symposium (L. K. Halls, ed.). U.S.D.A. Forest Serv., South. Forest Exp. Sta., Nacogdoches, Tex.

127. Lassiter, R. L., Jr. 1985. Access to and management of the wildlife resources on large private timberland holdings in the southeastern United States. Coll. of Business Admin., Tennessee Tech. Univ., Cookeville. 253 p.

128. Lay, D. W. 1956. Effects of prescribed burning on forage and mast production in southern pine forests. J. Forestry 54:582-584.

129. Lay, D. W. 1957. Browse quality and the effects of prescribed burning in southern pine forests. J. Forestry 55:342-347.

130. Lay, D. W. 1961. Fruit production of some understory hardwoods. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 15:30-37.

131. Lay, D. W. 1965. Fruit utilization by deer in southern forests. J. Wildl. Manage. 29:370-375.

132. Lay, D. W. 1969. Foods and feeding habits of white-tailed deer. Pages 8-13 *In* White-tailed Deer in the Southern Forest Habitat. Proc. of a Symposium (L. K. Halls, ed.). U.S.D.A. Forest Serv., South. Forest Exp. Sta., Nacogdoches, Tex.

133. Lewis, C. E., and T. J. Harshbarger. 1976. Shrub and herbaceous vegetation after 20 years of prescribed burning in the South Carolina Coastal Plain. J. Range Manage. 29:13-18.

134. Lewis, C. E., B. F. Swindel, L. F. Conde, and J. E. Smith. 1984. Forage yields improved by site preparation in pine flatwoods of north Florida. South. J. Appl. Forestry 8:181-185.

135. Lewis, J. C. 1964. Populations of wild turkeys in relation to fields. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 18:49-56.

136. Lewis, J. C. 1967. Management of the eastern wild turkey in the Ozarks and bottomland hardwoods. Pages 371-407 *In* The Wild Turkey and its Management (0. H. Hewitt, ed.). The Wildlife Society, Washington, D.C.

137. Lindzey, J. S., and D. W. Wanless. 1973. Problems in wild

turkey management and research. Natl. Wild Turkey Symp. 2:229-232.
138. Logan, W., E. R. Brown, D. Longrie, G. Herb, and R. A. Corthell. 1985. Edges. Pages 115-127 *In* Management of Wildlife and Fish Habitats in Forests of Western Oregon and Washington (Part 1 - Chapter Narratives) (E. R. Brown, ed.). U.S.D.A. Forest Serv., Pacific Northwest Region, Portland, Oreg. Publ. No. R6-F&WL-192-1985.
139. Loveless, C. M. 1958. The mobility and composition of bobwhite quail populations in south Florida. Florida Game and Fresh Water Fish Comm. Tech. Bull. 4.64 p. As cited in Rosene 1969 [179, this list].
140. Lyon, L. J., H. S. Crawford, E. Czuhai, R. L. Fredriksen, R. F. Harlow, L. J. Metz, and H. A. Pearson. 1978. Effects of fire on fauna. U.S.D.A. Forest Serv., Washington, D.C. Gen. Tech. Rep. WO-6.22 p.
141. MacArthur, R. H., and J. W. MacArthur. 1961. On bird species diversity. Ecology 42:594-598.
142. MacArthur, R. H., J. W. MacArthur, and J. Preer. 1962. On bird species diversity, II. Prediction of bird census from habitat measurements. Am. Nat. 96:167-174.
143. Marchinton, R. L., and D. H. Hirth. 1984. Behavior. Pages 129-168 *In* White-tailed Deer Ecology and Management (L. K. Halls, ed.). Stackpole Books, Harrisburg, Pa.
144. Martin, A. C., H. S. Zim, and A. L. Nelson. 1951. American Wildlife & Plants - A Guide to Wildlife Food Habits. McGraw-Hill Book Co., New York. 500 p.
145. McComb, W. C., S. A. Bonney, R. M. Sheffield, and N. D. Cost. 1986. Den tree characteristics and abundance in Florida and South Carolina. J. Wildl. Manage. 50:584-591.
146. McComb, W. C., and G. A. Hurst. 1987. Herbicides and wildlife in southern forests. Pages 28-36 *In* Managing Southern Forests for Wildlife and Fish - A Proc. (J. G. Dickson and 0. E. Maughan, eds.). U.S.D.A. Forest Serv., South. Forest Exp. Sta., New Orleans, La. Gen. Tech. Rep. SO-65.
147. McComb, W. C., and R. E. Noble. 1981. Nest-box and natural-cavity use in three mid-south forest habitats. J. Wildl. Manage. 45:93-101.
148. McElfresh, R. W., J. M. Inglis, and B. A. Brown. 1980. Gray squirrel usage of hardwood ravines within pine plantations. Louisiana State Univ. Annu. Forestry Symp. 29:79-89.
149. McKee, B. 1986. Economic tradeoffs: timber and game. Forest Farmer 46(2):18-19.
150. McKee, C. W. 1981. The economics of forest management for softwood sawlogs. Pages 95-103 *In* Habitat Requirements and Habitat Management for the Wild Turkey in the Southeast, Proc. of the Symposium (P. T. Bromley and R. L. Carlton, eds.). Virginia Wild Turkey Federation, Elliston.
151. McKee, C. W. 1986. Economics of accommodating wildlife. Proc. Soc. Am. Foresters Natl. Cony. (1986):133-137.
152. McKee, C. W. 1982. Personal communication, Auburn Univ. Auburn, Ala.
153. McKee, C. W., W. E. Killcreas, and J. E. Waldrop. 1983. Methodology for assessing timber and white-tailed deer habitat trade-offs. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 37:103-117.
154. Means, D. B., and H. W. Campbell. 1981. Effects of prescribed burning on amphibians and reptiles. Pages 89-97 *In* Prescribed Fire and Wildlife in Southern Forests (G. W. Wood, ed.). Belle W. Baruch Forest Sci. Institute, Clemson Univ., Georgetown, S.C.
155. Melchiors, M. A., and C. Cicero. 1987. Streamside and adjacent upland forest habitats in the Ouachita Mountains. Proc. Annu. Conf. Southeast. Assoc. Fish and Wild!. Agencies 41:385-393.
156. Melchiors, M. A., T. H. Silker, and J. E. Reeb. 1985. Deer use of young pine plantations in southeastern Oklahoma. J. Wildl. Manage. 49:958-962.
157. Meyers, J. NI., and A. S. Johnson. 1978. Bird communities associated with succession and management of loblolly-shortleaf pine forests. Pages 50-65 *In* Proc. of the Workshop, Management of Southern Forests for Nongame Birds (R. M. DeGraaf, tech. coord.). U.S.D.A. Forest Serv., Southeast. Forest Exp. Sta., Asheville, N.C. Gen. Tech. Rep. SE-14.
158. Mobley, H. E., and W. E. Balmer. 1981. Current purposes, extent, and environmental effects of prescribed fire in the South. Pages 15-21 *In* Prescribed Fire and Wildlife in Southern Forests (G. W. Wood, ed.). Belle W. Baruch Forest Sci. Institute, Clemson Univ., Georgetown, S.C.
159. Moler, P. E. 1987. Wildlife values of small, isolated wetlands in the southeastern Coastal Plain. Southeast. Nongame Endangered Wildl. Symp. 3:234-241.
160. Morrison, M. L., and E. C. Meslow. 1983. Impacts of forest herbicides on wildlife: toxicity and habitat alteration. Trans. North. Am. Wildl. and Nat. Resour. Conf. 48:175-185.
161. Morrison, M. L., and E. C. Meslow. 1984. Effects of the herbicide glyphosate on bird community structure, western Oregon. Forest Sci. 30:95-106.
162. Morrison, M. L., and E. C. Meslow. 1984. Response of avian communities to herbicide-induced vegetation changes. J. Wild!. Manage. 48:14-22.
163. Mosby, H. S. 1959. General status of the wild turkey and its management in the United States, 1958. Natl. Wild Turkey Symp. 1:1-11.
164. Murphy, D. A., and T. S. Baskett. 1952. Bobwhite mobility in central Missouri. J. Wildl. Manage. 16:498-510.
165. Mutch, R. W. 1970. Wildland fires and ecosystems - a hypothesis. Ecology 51:1046-1051.
166. Nabi, D. H., D. C. Guynn, Jr., T. B. Wigley, and S. P. Mott. 1983. Behaviors of Mississippi nonindustrial private forest landowners toward hunting. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 37:1-7.
167. Newton, M., and L. A. Norris. 1968. Herbicide residues in blacktail deer from forests treated with 2,4,5-T and atrazine. Proc. West. Soc. Weed Sci. 22:32-34.
168. Newton, M., and L. A. Norris. 1976. Evaluating short- and long-term effects of herbicides on nontarget forest and range biota. Down to Earth 32:18-26.
169. Nixon, C. M., M. W. McClain, and R. W. Donohoe. 1975. Effects of hunting and mast crops on a squirrel population. J. Wildl. Manage. 39:1-25.
170. Noble, R. E., R. B. Hamilton, and W. C. McComb. 1980. Some effects of forestry on nongame birds. Louisiana State Univ. Annu. Forestry Symp. 9:65-78.
171. Norris, L. A. 1981. The movement, persistence, and fate of the phenoxy herbicides and TCDD in the forest. Residue Rev. 80:65-135.
172. Osaki, S. K. 1979. An assessment of wildlife populations and habitat in herbicide-treated Jeffrey pine plantations. M.S. thesis, Univ. of California, Berkeley. 83 p.
173. Osborne, J. S., R. D. McClanahan, E. B. Gillis, V. F. Nettles, and 0. Florschultz. 1986. Effects of wildfires in a North Carolina pocosin on deer populations, harvest, and habitat. Southeast Deer Study Group 9:5-6. (Abstr.)
174. Owen, C. N. i984. Integrating wildlife and loblolly pine management. Pages 233-245 *In* Symposium on the Loblolly Pine Ecosystem (West Region) (B. L. Karr, J. B. Baker, and T. Monaghan, eds.). School of Forest Resources, Mississippi State Univ., Mississippi State.
175. Owen, C. N., T. B. Wigley, and D. L. Adams. 1985. Public use of large private forests in Arkansas. Trans. North Am. Wildl. and Nat. Resour. Conf. 50:232-241.

176. Ream, C. H. 1981. The effects of fire and other disturbances on small mammals and their predators: an annotated bibliography. U.S.D.A. Forest Serv., Intermountain Forest and Range Exp. Sta., Ogden, Utah. Gen. Tech. Rep. INT-106. 55 p.
177. Reese, K. P., and J. T. Ratti. 1988. Edge effect: a concept under scrutiny. Trans. North Am. Wildl. and Nat. Resource Conf. 53:127-136.
178. Rogers, L. 1976. Effect of mast and berry crop failures on survival, growth, and reproductive success of black bears. Trans. North Am. Wildl. and Nat. Resour. Conf. 41:431-438.
179. Rosene, W. 1969. The Bobwhite Quail - Its Life and Management. Rutgers Univ. Press, New Brunswick, N.J. 418 p.
180. Roth, R. R. 1976. Spatial heterogeneity and bird species diversity. Ecology 57:773-782.
181. Sassman, J., R. Pienta, M. Jacobs, and J. Cioffi. 1984. Background statements. Volume I. Herbicides. U.S.D.A. Forest Serv., Washington, D.C. Agric. Handb. 633.
182. Schuster, J. L., and L. K. Halls. 1962. Timber overstory determines deer forage in shortleaf-loblolly pine-hardwood forests. Proc. Soc. Am. Foresters Meet. (1962):165-167.
183. Scott, V. E., J. A. Whelan, and P. L. Svoboda. 1980. Cavity-nesting birds and forest management. Pages 311-324 *In* Workshop Proc.: Management of Western Forests and Grasslands for Nongame Birds (R. M. DeGraaf and N. G. Tilghman, eds.). U.S.D.A. Forest Serv., Intermountain Forest and Range Exp. Sta., Salt Lake City, Utah. Gen. Tech. Rep. INT-86.
184. Segelquist, C. A., and W. E. Green. 1968. Deer food yields in four Ozark forest types. J. Wildl. Manage. 32:330-337.
185. Segelquist, C. A., M. Rogers, and F. D. Ward. 1971. Quantity and quality of Japanese honeysuckle on Arkansas Ozark food plots. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 25:47-53.
186. Segelquist, C. A., F. D. Ward, and R. G. Leonard. 1969. Habitat-deer relations in two Ozark enclosures. J. Wildl. Manage. 33:511-520.
187. Shaffer, C. H., and J. V. Gwynn. 1967. Management of the eastern wild turkey in oak-pine and pine forests of Virginia and the Southeast. Pages 303-342 *In* The Wild Turkey and its Management (0. H. Hewitt, ed.). The Wildlife Society, Washington, D.C.
188. Shaw, S. P. 1971. Wildlife and oak management. Pages 84-89 *In* Oak Symposium Proc. U.S.D.A. Forest Serv., Northeast. Forest Exp. Sta., Upper Darby, Pa.
189. Shaw, S. P. 1981. Wildlife management on private nonindustrial forestlands. Pages 36-42 *In* Wildlife Management on Private Lands (R. T. Dumke, G. V. Burger, and J. R. March, eds.). La Crosse Printing Co., La Crosse, Wis.
190. Shaw, W. W., and W. R. Mangun. 1984. Nonconsumptive use of wildlife in the United States. U.S.D.I. Fish and Wildl. Serv., Washington, D.C. Resour. Publ. 154.20 p.
191. Shrauder, P. A., and H. A. Miller. 1969. The effects of prescribed burning on deerfood and cover. Pages 81-84 *In* White-tailed Deer in the Southern Forest Habitat, Proc. of a Symposium (L. K. Halls, ed.). U.S.D.A. Forest Serv., South. Forest Exp. Sta., Nacogdoches, Tex.
192. Simpson, R. C. 1972. Relationship of post-burn intervals to the incidence and success of bobwhite nesting in southwest Georgia. Natl. Bobwhite Quail Symp. 1:150-158.
193. Smith, D. R. 1988. Use of midrotation-aged loblolly pine plantations by wild turkeys. M.S. thesis, Mississippi State Univ., Mississippi State. 48 p.
194. Smith, W. P., and R. D. Teitelbaum. 1986. Habitat use by eastern wild turkey hens in southeastern Louisiana. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 40:405-415.
195. Speake, D. W. 1966. Effects of controlled burning on bobwhite quail populations and habitat of an experimental area in the Alabama Piedmont. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 20:19-32.
196. Speake, D. W., J. A. McGlincy, and T. R. Colvin. 1978. Ecology and management of the eastern indigo snake in Georgia: a progress report. Pages 64-69 *In* Proc. of the Rare and Endangered Wildlife Symposium (R. R. Odom and L. Landers, eds.). Georgia Dep. of Natural Resources, Game and Fish Div., Athens. Tech. Bull. WL-4.
197. Stauffer, D. F., and L. B. Best. 1980. Habitat selection by birds of riparian communities: evaluating effects of habitat alterations. J. Wildl. Manage. 44:1-15.
198. Steinbach, D. W., J. R. Conner, M. K. Glover, and J. M. Inglis. 1987. Economic and operational characteristics of recreational leasing in the Edwards Plateau and Rio Grande Plains of Texas. Trans. North Am. Wildl. and Nat. Resour. Conf. 52:496-515.
199. Stoddard, H. L. 1931. The Bobwhite Quail - Its Habits, Preservation and Increase. C. Scribner's Sons, New York. 559 p.
200. Stoddard, H. L., Sr. 1963. Bird habitat and fire. Proc. Tall Timbers Fire Ecol. Conf. 2:163-175.
201. Stout, G. G. 1974. Effects of fee hunting on a private land wildlife management program. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 28:668-675.
202. Stransky, J. J., and L. K. Halls, 1976. Browse quality affected by pine site preparation in east Texas. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 30:507-512.
203. Stransky, J. J., and L. K. Halls. 1978. Forage yield increased by clearcutting and site preparation. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 32:38-41.
204. Stransky, J. J., and L. K. Halls. 1980. Fruiting of woody plants affected by site preparation and prior land use. J. Wildl. Manage. 44:258-263.
205. Stransky, J. J., and R. F. Harlow. 1981. Effects of fire on deer habitat in the Southeast. Pages 135-142 *In* Prescribed Fire and Wildlife in Southern Forests (G. W. Wood, ed.). Belle W. Baruch Forest Sci. Institute, Clemson Univ., Georgetown, S.C.
206. Stransky, J. J., and D. Richardson. 1977. Fruiting of browse plants affected by pine site preparation in east Texas. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 31:5-7.
207. Strelke, W. K., and J. G. Dickson. 1980. Effect of forest clear-cut edge on breeding birds in east Texas. *J.* Wildl. Manage. 44:559-567.
208. Strode, D. D. 1957. .A preliminary report of the effects of the TSI program on the wildlife habitat in the Ocala National Forest. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 19:59-68.
209. Sullivan, T. P. 1985. Effects of glyphosate on selected species of wildlife. Pages 186-199 *In* The Herbicide Glyphosate (E. Grossbard and D. Atkinson, eds.). Butterworths, London.
210. Sullivan, T. P., and D. S. Sullivan. 1979. The effects of glyphosate herbicide on food preference and consumption in black-tailed deer. Can. J. Zool. 57:1406-1412.
211. Taylor, D. L. 1981. Effects of prescribed fire on small mammals in the southeastern United States. Pages 109-120 *In* Prescribed Fire and Wildlife in Southern Forests (G. W. Wood, ed.). Belle W. Baruch Forest Sci. Institute, Clemson Univ., Georgetown, S.C.
212. Thomas, J. W. 1979. Introduction. Pages 10-21 *In* Wildlife

Habitats in Managed Forests - The Blue Mountains of Oregon and Washington (J. W. Thomas, ed.). U.S.D.A. Forest Serv., Washington, D.C. Agric. Handb. 553.

213. Thomas, J. W., C. Maser, and J. E. Rodiek. 1979. Edges. Pages 48-59 *In* Wildlife Habitats in Managed Forests - The Blue Mountains of Oregon and Washington (J. W. Thomas, ed.). U.S.D.A. Forest Serv., Washington, D.C. Agric. Handb. 553.

214. Tomlinson, B. H. 1985. Economic values of wildlife: opportunities and pitfalls. Trans. North Am. Wildl. and Nat. Resour. Conf. 50:262-270.

215. U.S.D.A. Forest Service. 1980. Wildlife habitat management handbook. South. Region, Atlanta, Ga. FSH 2609.23R.

216. U.S.D.I. Fish and Wildlife Service and U.S.D.C. Bureau of the Census. 1982. The 1980 national survey of fishing, hunting and wildlife-associated recreation. U.S.D.I. Fish and Wildl. Serv., Washington, D.C. 136 p.

217. Waldrop, T. A., D. H. Van Lear, F. T. Lloyd, and W. R. Harms. 1987. Long term studies of prescribed burning in loblolly pine forests of the southeastern Coastal Plain. U.S.D.A. Forest Serv., Southeast. Forest Exp. Sta., Asheville, N.C. Gen. Tech. Rep. SE-45. 23 p.

218. Ware, G. W. 1980. Effects of pesticides on nontarget organisms. Residue Rev. 76:173-201.

219. Ware, L. M., and R. Stahel in. 1948. Growth of southern pine plantations at various spacings. J. Forestry 46:267-274.

220. Warren, R. C., and G. A. Hurst. 1980. Squirrel densities in pine-hardwood forests and streamside management zones. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 34:492-498.

221. Warren, R. C., and G. A. Hurst. 1981. Ratings of plants in pine plantations as white-tailed deer food. Mississippi Agric. and Forest Exp. Sta., Mississippi State Univ., Mississippi State. Info. Bull. 18.14 p.

222. Warren, R. C., G. A. Hurst, and T. L. Darden. 1984. Relative abundance of cavity nesting birds on pine plantations site prepared by herbicides. Pages 197-205 *In* Proc. of the Workshop on Management of Nongame Species and Ecological Communities (W. C. McComb, ed.). Dep. of Forestry, Univ. of Kentucky, Lexington.

223. Webb, L. G. 1963. Utilization of domestic forage crops by deer and wild turkeys with notes on insects inhabiting the crops. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 17:92-100.

224. Webb, W. L. 1973. Timber and wildlife. Pages 468-489 *In* Report of the President's Advisory Panel on Timber and Environment. (Appendix N.) As cited in Shaw 1981 [189, this list].

225. Wick, H. L., and P. R. Canutt. 1979. Impacts on wood production. Pages 148-161 *In* Wildlife Habitats in Managed Forests - The Blue Mountains of Oregon and Washington (J. W. Thomas, ed.). U.S.D.A. Forest Serv., Washington, D.C. Agric. Handb. 553.

226. Wigley, T. B. 1986. Wildlife and shortleaf pine management. Pages 222-234 *In* Symposium on the Shortleaf Pine Ecosystem (P. A. Murphy, ed.). Arkansas Cooperative Extension Serv., Little Rock.

227. Wigley, T. B., J. M. Sweeney, M. E. Garner, and M. A. Melchiors. 1985. Forest habitat use by wild turkeys in the Ouachita Mountains. Natl. Wild Turkey Symp. 5:183-197.

228. Wigley, T. B., J. M. Sweeney, M. E. Garner, and M. A. Melchiors. 1986. Wild turkey home ranges in the Ouachita Mountains. J. Wildl. Manage. 50:540-544.

229. Wolters, G. L., A. Martin, and H. A. Pearson. 1982. Forage response to overstory reduction on loblolly-shortleaf pine-hardwood forest range. J. Range Manage. 35:443-446.

230. Wood, G. W. (ed.). 1981. Prescribed fire and wildlife in southern forests. Belle W. Baruch Forest Sci. Institute, Clemson Univ., Georgetown, S.C. 170 p.

231. Wood, G. W. 1988. Effects of prescribed fire on deer forage and nutrients. Wildl. Soc. Bull. 16:180-186.

232. Wood, G. W., and L. J. Niles. 1978. Effects of management practices on nongame bird habitat in longleaf-slash pine forests. Pages 40-49 *In* Proc. of the Workshop, Management of Southern Forests for Nongame Birds (R. M. DeGraaf, tech. coord.). U.S.D.A. Forest Serv., Southeast. Forest Exp. Sta., Asheville, N.C. Gen. Tech. Rep. SE-14.

233. Yarrow, G. K., E. J. Jones, and J. F. Williamson. 1988. Landowner cooperatives for income and recreation from wildlife and forest resources. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 42 (in press).

234. Zeedyk, W. D., and J. G. Dickson. 1985. Fifth national wild turkey symposium summary. Natl. Wild Turkey Symp. 5:333-339.

235. Zeedyk, W. D., and R. B. Hazel. 1974. The southeastern featured species plan. Pages 58-62 *In* Timber-Wildlife Management Symposium (J. P. Slusher and T. M. Hinkley, eds.). Missouri Academy of Sci., Columbia. Occas. Pap. 3. As cited in Thomas 1979 [212, this list].