Recovery Plan for the

Red-cockaded Woodpecker (*Picoides borealis*)

Second Revision

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U.S. Fish and Wildlife Service
Southeast Region
Atlanta, GA

Red-cockaded Woodpecker Recovery Team:

T. Beaty, U.S. Army
J. H. Carter, III, J. H. Carter III and Associates, Inc.
J. E. Cely, South Carolina Department of Natural Resources
R. N. Conner, U.S. Forest Service
R. Costa, Team Leader, U.S. Fish & Wildlife Service
S. J. Daniels, Primary Editor, U.S. Fish & Wildlife Service
R. S. DeLotelle, DeLotelle and Guthrie, Inc.
D. L. Krusac, U.S. Forest Service
J. A. Jackson, Florida Gulf Coast University
J. L. Hardesty, The Nature Conservancy
R. G. Hooper, U.S. Forest Service
J. A. Hovis, Florida Fish and Wildlife Conservation Commission
J. C. Ozier, Georgia Department of Natural Resources
C. J. Petrick, U.S. Air Force
D. M. Richardson, U.S. Fish & Wildlife Service
J. R. Walters, Virginia Polytechnic Institute and State University
T. B. Wigley, National Council for Air and Stream Improvement

Approved by: [signature]
Regional Director, Southeast Region
U.S. Fish & Wildlife Service

[signature]
Craig Manson, Assistant Secretary of the Interior for Fish, Wildlife and Parks

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DISCLAIMER

This Recovery Plan Revision outlines the actions that, to the best of current understanding, are necessary to recover red-cockaded woodpeckers. It does not represent the view or official position of any individuals or agencies involved in the development of the plan, other than the U.S. Fish and Wildlife Service. It represents official policy of the U.S. Fish and Wildlife Service only after the regional director has signed it as approved. This revision is subject to further modification as dictated by new findings, changes in species status, and completion of recovery tasks. Implementation of this plan is the responsibility of federal and state management agencies in the areas where the species occurs. Implementation is done through incorporation of management guidelines identified within this Recovery Plan Revision into agency decision documents. Decision documents, as defined by the National Environmental Policy Act (NEPA), are subject to the NEPA process for public review and alternatives selection.

LITERATURE CITATION SHOULD READ AS FOLLOWS:

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STANDARD ABBREVIATIONS

The following standard abbreviations for units of measurement are found throughout this document:

cm = centimeters	in = inches	m^2 = square meters
m = meters	ft = feet	ft^2 = square feet
km = kilometers	mi = miles	dbh = diameter at breast height
ha = hectares	ac = acres	
g = grams	oz = ounces	

ACKNOWLEDGMENTS

The process of revising the 1985 red-cockaded woodpecker recovery plan began in August 1995, when potential recovery team members were identified. In January 1996, 15 potential members were asked to participate on the team; all accepted. The first team meeting was held in March 1996; two additional meetings, each one week long, were held in April and December 1997. Between March 1996 and March 2000, team members individually spent hundreds of hours working on the revision, including participation in team meetings, writing, and reviewing. The U.S. Fish and Wildlife Service is very appreciative of the time and hard work put forth by team members during this process. Combined, the team has approximately 257 years of red-cockaded woodpecker experience in the private, state, and federal sectors. Their professional experiences with red-cockaded woodpeckers have included research, population and habitat management, and regulatory and policy responsibilities. They have unselfishly contributed their knowledge, time, and expertise to the many challenges of the recovery plan revision process. The U.S. Fish and Wildlife Service thanks each of them for their contributions and is grateful to have worked with such a team.

By April 1999, much of the Introduction had been drafted. However, several major tasks remained to be accomplished. These tasks included writing Recovery, Listing, Executive Summary, and other sections; compiling and editing the contributions of 15 other authors; and creating tables, Literature Cited, and Index. In April 1999, the U.S. Fish and Wildlife Service hired Ms. Susan Daniels as a wildlife biologist and recovery team member to take the lead on completing these tasks. The recovery team and U.S. Fish and Wildlife Service are proud to extend special thanks to “one of our own” for her continuous hard work during the past four years on this challenging project. Sue has done an outstanding job of assembling and completing this revision.

Ultimately, recovery of the red-cockaded woodpecker is and will be dependent upon the on-the-ground hard work of biologists, foresters, technicians, researchers, and land managers working on the private, state, and federal properties where the birds survive. During the past seven years, many of these individuals have been asked to supply information including population and habitat data, maps, and management costs. The U.S. Fish and Wildlife Service and the recovery team are particularly grateful to these many individuals for their timely and reliable responses to our requests. They have supplied a tremendous amount of information for this document.

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EXECUTIVE SUMMARY

CURRENT STATUS

The red-cockaded woodpecker (*Picoides borealis*) is a federally listed endangered species endemic to open, mature and old growth pine ecosystems in the southeastern United States. Currently, there are an estimated 14,068 red-cockaded woodpeckers living in 5,627 known active clusters across eleven states. This is less than 3 percent of estimated abundance at the time of European settlement. Red-cockaded woodpeckers were given federal protection with the passage of the Endangered Species Act in 1973. Despite this protection, all monitored populations (with one exception) declined in size throughout the 1970's and into the 1980's. In the 1990's, in response to intensive management based on a new understanding of population dynamics and new management tools, most populations were stabilized and many showed increases. Other populations remain in decline, and most have small population sizes. Our major challenge now is to bring about the widespread increases in population sizes necessary for recovery.

BASIC ECOLOGY AND POPULATION DYNAMICS

Red-cockaded woodpeckers are a cooperatively breeding species, living in family groups that typically consist of a breeding pair with or without one or two male helpers. Females may become helpers, but do so at a much lower rate than males. The ecological basis of cooperative breeding in this species is unusually high variation in habitat quality, due to the presence or absence of a critical resource. This critical resource is the cavities that red-cockaded woodpeckers excavate in live pines, a task that commonly takes several years to complete.

Red-cockaded woodpeckers exploit the ability of live pines to produce large amounts of resin, by causing the cavity tree to exude resin through wounds, known as resin wells, that the birds keep open. This resin creates an effective barrier against climbing snakes. Longleaf pine is a preferred tree species for cavity excavation because it produces more resin, and for a longer period of time, than other southern pines.

Group living has profound influence over population dynamics. In non-cooperatively breeding birds, breeders that die are replaced primarily by the young of the previous year. Thus, variation in reproduction and mortality can have strong, immediate impacts on the size of the breeding population. However, in red-cockaded woodpeckers and other cooperative breeders, a large pool of helpers is available to replace breeders. As a result, the size of the breeding population is not strongly affected by how many young are produced each year, or even on how many breeders may die. Because of this, we use the number of potential breeding groups rather than number of individuals as our measure of population size. A potential breeding group is an adult female and adult male that occupy the same cluster, with or without one or more helpers, whether or not they attempt to nest or successfully fledge young.

Because of the cooperative breeding system, red-cockaded woodpecker populations are unusually resistant to environmental and demographic variation, but highly sensitive to the spatial arrangement of habitat. The buffering effect of helpers against annual variation operates only when helpers can readily occupy breeding vacancies as they arise. Helpers do not disperse very far and typically occupy vacancies on their natal territory or a neighboring one. If groups are isolated in space, dispersal of helpers to neighboring territories is disrupted and the buffering effect of the helper class is lost. When this happens, populations become much less likely to persist through time. Also, the cooperative breeding system does not allow rapid natural growth of populations. Colonization of unoccupied habitat is an exceedingly slow process under natural conditions, because cavities take long periods of time to excavate and birds do not occupy habitat without cavities. As forests age and old pines become abundant, rates of natural cavity excavation and colonization may increase.

Understanding these three components of the population dynamics of red-cockaded woodpeckers provides us the foundation for recovery efforts: (1) population size and trend are determined by the number of potential breeding groups rather than annual variation in reproduction and survival; (2) the buffering capacity of the helper class must be maintained, by maintaining close aggregations of territories; and (3) colonization of unoccupied habitat will be very slow without management assistance.

HABITAT REQUIREMENTS AND LIMITING FACTORS

Red-cockaded woodpeckers require open pine woodlands and savannahs with large old pines for nesting and roosting habitat (clusters). Large old pines are required as cavity trees because the cavities are excavated completely within inactive heartwood, so that the cavity interior remains free from resin that can entrap the birds. Also, old pines are preferred as cavity trees, because of the higher incidence of the heartwood decay that greatly facilitates cavity excavation. Cavity trees must be in open stands with little or no hardwood midstory and few or no overstory hardwoods. Hardwood encroachment resulting from fire suppression is a well-known cause of cluster abandonment. Red-cockaded woodpeckers also require abundant foraging habitat. Suitable foraging habitat consists of mature pines with an open canopy, low densities of small pines, little or no hardwood or pine midstory, few or no overstory hardwoods, and abundant native bunchgrass and forb groundcovers.

Limiting factors are those that directly affect the number of potential breeding groups, because this is the primary determinant of population size and trend. Several factors currently impact the persistence of breeding groups. Foremost among these are the factors that limit suitable nesting habitat, namely fire suppression and lack of cavity trees. Fire suppression has resulted in loss of potential breeding groups throughout the range of red-cockaded woodpeckers, because the birds cannot tolerate the hardwood encroachment that results from lack of fire. This limitation is addressed through the use of prescribed burning. Lack of cavity trees, and potential cavity trees, limits the number of breeding groups in most populations. This limitation is addressed in the short-term through cavity management tools such as artificial cavities and restrictor plates, and over the long-term by growing large old trees in abundance.

Another factor directly limiting the number of potential breeding groups is habitat fragmentation and consequent isolation of groups, which results in disrupted dispersal of helpers and failure to replace breeders. This limitation is best addressed through the appropriate placement of clusters of artificial cavities, and implementation of silvicultural practices that minimize fragmentation.

There are several other threats to the existence and recovery of the species, not limiting most populations currently, but which will become more important as the current limitations are addressed. Chief among these are (1) degradation of foraging habitat through fire suppression and loss of mature trees, and (2) loss of valuable genetic resources because of small size and isolation of populations. As currently limiting factors such as lack of cavities are relieved, the continued growth and natural stability of red-cockaded woodpecker populations will depend on provision of abundant, good quality foraging habitat and careful conservation of genetic resources.

POPULATION AND SPECIES VIABILITY

Four types of threats to species and population viability have been identified: genetic stochasticity (consisting of both inbreeding and genetic drift), demographic stochasticity, environmental stochasticity, and catastrophes. We now have some knowledge of population sizes of red-cockaded woodpeckers necessary to withstand these extinction threats, primarily from research performed with a spatially explicit, individually based simulation model of population dynamics developed specifically for this species.

Red-cockaded woodpeckers exhibit inbreeding depression and inbreeding avoidance behaviors. Inbreeding is expected to affect population viability in populations of less than 40 potential breeding groups, and may be a significant factor affecting viability in isolated populations of 40 to 100 potential breeding groups as well. Immigration rates of 2 or more migrants per year can effectively reduce inbreeding in populations of any size, including very small ones.

Effects of demographic stochasticity on population viability vary with the spatial arrangement of groups. Populations as small as 25 potential breeding groups can be surprisingly resistant to random demographic events, if those groups are highly aggregated in space. Populations as large as 100 potential breeding groups can be impacted by demographic stochasticity, if groups are not aggregated and dispersal of helpers is disrupted. Demographic stochasticity is not expected to affect populations larger than 100 potential breeding groups. Similarly, effects of environmental stochasticity vary with the spatial arrangement of groups. Based on preliminary results of the model and estimates of environmental stochasticity derived from the North Carolina

Sandhills, 250 potential breeding groups will likely withstand effects of environmental stochasticity regardless of their spatial arrangement.

Loss of genetic variation through the process of genetic drift is an inevitable consequence of finite population size. New genetic variation arises through the process of mutation. In large populations, mutation can offset loss through drift and genetic variation is maintained. Just how large a population must be to maintain variation is a difficult question. Currently, researchers recognize that in general, only populations with actual sizes in the thousands, rather than hundreds, can maintain long-term viability and evolutionary potential in the absence of immigration. However, if populations are connected by immigration rates on the order of 1 to 10 migrants per generation (0.5 to 2.5 migrants per year), the genetic variation maintained by these populations is equal to that of one population as large as the sum of the connected populations. Thus, sufficient connectivity among populations can maintain genetic variation and long-term viability for the species.

RECOVERY GOAL

The ultimate recovery goal is species viability. This goal is represented by delisting. Once delisting criteria are met, the size, number, and distribution of populations will be sufficient to counteract threats of demographic, environmental, genetic, and catastrophic stochastic events, thereby maintaining long-term viability for the species as defined by current understanding of these processes. Regions and habitat types currently occupied by the species will be represented to the best of our ability, given habitat limitations.

RECOVERY CRITERIA

Recovery criteria have been formulated using eleven recovery units delineated according to ecoregions. Populations required for recovery are distributed among recovery units to ensure the representation of broad geographic and genetic variation in the species. Viable populations within each recovery unit, to the extent allowed by habitat limitations, are essential to the recovery of the species as a whole.

Population sizes identified in recovery criteria are measured in number of potential breeding groups. A potential breeding group is an adult female and adult male that occupy the same cluster, with or without one or more helpers, whether or not they attempt to nest or successfully fledge young. A traditional measure of population size has been number of active clusters. Potential breeding groups is used in recovery criteria in addition to active clusters, because number of active clusters can include varying proportions of solitary males and captured clusters. (A captured cluster is one that does not support its own group, but is kept active by a member or members of a neighboring group.) Increases in proportions of captured clusters and solitary males are early indicators of population decline. Estimates of all three parameters—number of active clusters, proportion of solitary males, and proportion of captured clusters—are required to derive estimates of potential breeding groups.

To facilitate use of potential breeding groups as a measure of population size, we have provided a range of numbers of active clusters considered the likely equivalents of the required number of potential breeding groups. Estimated number of active clusters is likely to be at least 1.1 times the number of potential breeding groups, but it is unlikely to be more than 1.4 times this number. Thus, an estimated 400 to 500 active clusters will be necessary to contain 350 potential breeding groups, depending on the proportions of solitary males and captured clusters and also on the estimated error of the sampling scheme. It is expected that all recovery populations will have sampling in place that is adequate to judge potential breeding groups. If this is not the case, only the highest number of active clusters in the range given can be substituted to meet the required population size.

Delisting

Delisting shall occur when each of the following criteria is met. Rationale for each criterion is given immediately following this list. See Tables 1, 2, and 3 for population designation. All properties identified as part or all of a recovery population (Tables 1, 2, and 3) should be managed for maximum size that the habitat designated for red-cockaded woodpeckers will allow. (Maximum size is generally based on 200 ac [81 ha] per group).

Criterion 1. There are 10 populations of red-cockaded woodpeckers that each contain at least 350 potential breeding groups (400 to 500 active clusters), and 1 population that contains at least 1000 potential breeding groups (1100 to 1400 active clusters), from among 13 designated primary core populations, and each of these 11 populations is not dependent on continuing installation of artificial cavities to remain at or above this population size. The 13 designated primary core populations, and the recovery units in which they are located, are listed in Table 1.

Criterion 2. There are 9 populations of red-cockaded woodpeckers that each contain at least 250 potential breeding groups (275 to 350 active clusters), from among 10 designated secondary core populations, and each of these 9 populations is not dependent on continuing installation of artificial cavities to remain at or above this population size. The 10 designated secondary core populations, and the recovery units in which they are located, are listed in Table 2.

Criterion 3. There are at least 250 potential breeding groups (275 to 350 active clusters) distributed among designated essential support populations in the South/Central Florida Recovery Unit, and six of these populations (including at least two of the following: Avon Park, Big Cypress, and Ocala) exhibit a minimum population size of 40 potential breeding groups that is independent of continuing artificial cavity installation.

Designated essential support populations in the South/Central Florida Recovery Unit are listed in Table 3.

Criterion 4. The following populations are stable or increasing and each contain at least 100 potential breeding groups (110 to 140 active clusters): (1) Northeast North Carolina/Southeast Virginia Essential Support Population of the Mid-Atlantic Coastal Plain Recovery Unit, (2) Talladega/Shoal Creek Essential Support Population of the Cumberlands/Ridge and Valley Recovery Unit, and (3) North Carolina Sandhills West Essential Support Population of the Sandhills Recovery Unit; and these populations are not dependent on continuing artificial cavity installation to remain at or above this population size. These populations are also listed in Table 3.

Criterion 5. For each of the populations meeting the above size criteria, responsible management agencies shall provide (1) a habitat management plan that is adequate to sustain the population and emphasizes frequent prescribed burning, and (2) a plan for continued population monitoring.

Rationale for Delisting Criteria

Criterion 1. A population size of 350 potential breeding groups is considered highly robust to threats from environmental stochasticity as well as inbreeding and demographic stochasticity. It is the lowest current estimate of the minimum size necessary to offset losses of genetic variation through genetic drift. One primary core population has the potential to harbor 1000 potential breeding groups within the near future; this criterion is included because such a large population may well be resistant to loss of genetic variation through drift. Eleven of 13 primary core populations are required for delisting because it is recognized that at any given time, one or two may be suffering hurricane impacts. Thirteen primary core populations are designated because of available habitat and because this number, together with 10 secondary core populations (below), may serve to facilitate natural dispersal among populations and maximize retention of genetic variability. Primary and secondary core populations provide for the conservation of the species within each major physiographic unit in which it currently exists, with the exception of South/Central Florida. This recovery unit is represented by several, smaller, essential support populations (below). Populations that depend on continuing artificial cavity installation to maintain stable or increasing trends are barred from meeting delisting criteria because this management technique is considered appropriate for short-term management only.

Criterion 2. A population size of 250 potential breeding groups is the minimum size considered robust to environmental stochasticity, and is well above the size necessary to withstand inbreeding and demographic stochasticity. Nine of 10 designated secondary core populations are required for delisting to allow for hurricane impacts.

Criterion 3. This unique habitat type is represented to the extent that available habitat allows. Unique genetic resources are conserved as much as reasonably possible.

Because of small size, some of these populations will remain vulnerable to extinction threats and may eventually be lost. The likelihood of extirpation of small populations is minimized by enhancing the spatial arrangement of territories so that they are highly aggregated.

Criterion 4. These unique or important habitats, and genetic resources contained within this population, will be represented at the time of delisting. This population size is midway in estimates of sizes necessary to withstand threats from inbreeding depression and is considered robust to demographic stochasticity if territories are moderately aggregated in space.

Criterion 5. Continued habitat management and population monitoring are necessary to ensure that the species does not again fall to threatened or endangered status.

Downlisting

Downlisting shall occur when each of the following criteria is met. Rationale for each criterion is presented immediately following this list.

Criterion 1. The Central Florida Panhandle Primary Core Population in the East Gulf Coastal Plain Recovery Unit is stable or increasing and contains at least 350 potential breeding groups (400 to 500 active clusters).

Criterion 2. There is at least one stable or increasing population containing at least 250 potential breeding groups (275 to 350 active clusters) in each of the following recovery units: Sandhills, Mid-Atlantic Coastal Plain, South Atlantic Coastal Plain, West Gulf Coastal Plain, Upper West Gulf Coastal Plain, and Upper East Gulf Coastal Plain.

Criterion 3. There is at least one stable or increasing population containing at least 100 potential breeding groups (110 to 140 active clusters) in each of the following recovery units: Mid-Atlantic Coastal Plain, Sandhills, South Atlantic Coastal Plain, and East Gulf Coastal Plain.

Criterion 4. There is at least one stable or increasing population containing at least 70 potential breeding groups (75 to 100 active clusters) in each of four recovery units, Cumberlands/Ridge and Valley, Ouachita Mountains, Piedmont, and Sandhills. In addition, the Northeast North Carolina/Southeast Virginia Essential Support Population is stable or increasing and contains at least 70 potential breeding groups (75 to 100 active clusters).

Criterion 5. There are at least four populations each containing at least 40 potential breeding groups (45 to 60 active clusters) on state and/or federal lands in the South/Central Florida Recovery Unit.

Criterion 6. There are habitat management plans in place in each of the above populations identifying management actions sufficient to increase the populations to recovery levels, with special emphasis on frequent prescribed burning during the growing season.

Rationale for Downlisting Criteria

Criterion 1. A population size of 350 potential breeding groups is considered highly robust to threats from environmental stochasticity as well as inbreeding and demographic stochasticity. It is the lowest current estimate of the minimum size necessary to offset losses of genetic variation through genetic drift.

Criterion 2. This population size, 250 potential breeding groups, is sufficient to withstand extinction threats from environmental uncertainty, demographic uncertainty, and inbreeding depression. These 6 populations, in combination with the single population identified in criterion (1), will represent each major recovery unit.

Criterion 3. A second population in these coastal recovery units will decrease the species' vulnerability to hurricanes. The West Gulf Coastal Plain is excluded because there are no candidate populations there. The lower size, 100 potential breeding groups, is considered sufficient to withstand threats from demographic uncertainty and inbreeding depression, and is much more quickly attained than 250 potential breeding groups thought necessary to withstand environmental stochasticity.

Criterion 4. These special habitats will be represented at the time of downlisting. This population size is midway in estimates of sizes necessary to withstand threats from inbreeding depression and is considered robust to demographic stochasticity if territories are moderately aggregated in space.

Criterion 5. This unique region will be represented at the time of downlisting. Forty potential breeding groups is at the lower end of estimates of sizes necessary to withstand inbreeding depression and are considered robust to demographic stochasticity if territories are highly aggregated in space.

Criterion 6. These habitat management plans are necessary to ensure progress toward delisting.

ACTIONS NEEDED

The primary actions needed to accomplish the ultimate (delisting) and interim (downlisting) recovery goals are (1) application of frequent fire to both clusters and foraging habitat, (2) protection and development of large, mature pines throughout the landscape, (3) protection of existing cavities and judicious provisioning of artificial cavities, (4) provision of sufficient recruitment clusters in locations chosen to enhance the spatial arrangement of groups, and (5) restoration of sufficient habitat quality and quantity to support the large populations necessary for recovery.

DATE OF RECOVERY

We estimate that, with full implementation of this recovery plan, red-cockaded woodpeckers will be downlisted by the year 2050 and delisted by 2075.

TABLE 1. Designated primary core populations (13) by recovery unit. Location (state) and individual properties comprising recovery populations are also listed. At delisting, the Central Florida Panhandle will contain 1000 or more potential breeding groups, and at least 11 of the remaining 12 primary core populations will contain 350 or more potential breeding groups. See 7 for more information, including definitions of recovery roles and recovery units. See map insert also.

Recovery Unit / **Population**	**Property Full Name**	**State**
East Gulf Coastal Plain		
(1) Central Florida Panhandle	Apalachicola Ranger District, Apalachicola National Forest	FL
	Ochlockonee River State Park	FL
	St. Marks National Wildlife Refuge	FL
	Tate's Hell State Forest	FL
	Wakulla Ranger District, Apalachicola National Forest	FL
(2) Chickasawhay	Chickasawhay Ranger District, DeSoto National Forest	MS
(3) Eglin	Eglin Air Force Base	FL
Mid-Atlantic Coastal Plain		
(4) Coastal North Carolina	Croatan National Forest	NC
	Holly Shelter Game Lands	NC
	Marine Corps Base Camp Lejeune	NC
(5) Francis Marion	Francis Marion National Forest	SC
Sandhills		
(6) Fort Benning	Fort Benning	GA
(7) North Carolina Sandhills East	Calloway Tract	NC
	Carver's Creek Tract	NC
	Fort Bragg	NC
	McCain Tract	NC
	Weymouth Woods State Nature Preserve	NC
South Atlantic Coastal Plain		
(8) Fort Stewart	Fort Stewart	GA
(9) Osceola/Okefenokee	Osceola National Forest	FL
	Okefenokee National Wildlife Refuge	GA
Upper East Gulf Coastal Plain		
(10) Bienville	Bienville National Forest	MS
Upper West Gulf Coastal Plain		
(11) Sam Houston	Sam Houston National Forest	TX
West Gulf Coastal Plain		
(12) Angelina/Sabine	Angelina National Forest	TX
	Sabine National Forest	TX
(13) Vernon/Fort Polk	Fort Polk	LA
	Vernon Unit, Calcasieu Ranger District, Kisatchie National Forest	LA

TABLE 2. Designated secondary core populations (10) by recovery unit. Location (state) and individual properties comprising recovery populations are also listed. At delisting, at least 9 of these populations will contain 250 or more potential breeding groups. See 7 for more information, including definitions of recovery roles and recovery units. See map insert also.

Recovery Unit **Population**	**Property Full Name**	**State**
East Gulf Coastal Plain		
(1) Conecuh/Blackwater	Blackwater River State Forest	FL
	Conecuh National Forest	FL
(2) DeSoto	DeSoto Ranger District, DeSoto National Forest	MS
(3) Homochitto	Homochitto National Forest	MS
Ouachita Mountains		
(4) Ouachita	Ouachita National Forest	AR
Piedmont		
(5) Oconee/Piedmont	Oconee National Forest	GA
	Piedmont National Wildlife Refuge	GA
Sandhills		
(6) South Carolina Sandhills	Carolina Sandhills National Wildlife Refuge	SC
	Sand Hills State Forest	SC
South Atlantic Coastal Plain		
(7) Savannah River	Savannah River Site	SC
Upper East Gulf Coastal Plain		
(8) Oakmulgee	Oakmulgee Ranger District, Talladega National Forest	AL
West Gulf Coastal Plain		
(9) Catahoula	Catahoula Ranger District, Kisatchie National Forest	LA
	Winn Ranger District (portion), Kisatchie National Forest	LA
(10) Davy Crockett	Davy Crockett National Forest	TX

TABLE 3. Designated essential support populations (16) by recovery unit. Location (state) and individual properties comprising recovery populations are also listed. At delisting, North Carolina Sandhills West, Northeast North Carolina/Southeast Virginia, and Talladega/Shoal Creek will each contain 100 or more potential breeding groups, and 6 populations (including at least 2 of the following: Avon Park, Big Cypress, and Ocala) in South/Central Florida will each contain 40 or more potential breeding groups. See 7 for more information, including definitions of recovery roles and recovery units. See map insert also.

Recovery Unit **Population**	**Property Full Name**	**State**
Cumberlands/Ridge and Valley		
(1) Talladega/Shoal Creek	Shoal Creek Ranger District, Talladega National Forest	AL
	Talladega Ranger District, Talladega National Forest	AL
Mid-Atlantic Coastal Plain		
(2) Northeast North Carolina/ Southeast Virginia	Alligator River National Wildlife Refuge	NC
	Dare County Bombing Range	NC
	Palmetto-Peartree Preserve	NC
	Pocosin Lakes National Wildlife Refuge	NC
	Piney Grove Preserve	VA
Sandhills		
(3) North Carolina Sandhills West	Camp Mackall	NC
	Sandhills Game Lands	NC
South/Central Florida		
(4) Avon Park	Avon Park Air Force Range	FL
	Kicco Wildlife Management Area	FL
(5) Babcock/Webb	Babcock/Webb Wildlife Management Area	FL
(6) Big Cypress	Big Cypress National Preserve	FL
(7) Camp Blanding	Camp Blanding Training Site	FL
(8) Corbett/Dupuis	J. W. Corbett/Dupuis Wildlife Management Area	FL
(9) Goethe	Goethe State Forest	FL
(10) Hal Scott Preserve	Hal Scott Preserve	FL
(11) Ocala	Ocala National Forest	FL
(12) Picayune Strand	Picayune Strand State Forest	FL
(13) St. Sebastian River	St. Sebastian River State Buffer Preserve	FL
(14) Three Lakes	Three Lakes Wildlife Management Area	FL
(15) Withlacoochee – Citrus Tract	Withlacoochee State Forest - Citrus Tract	FL
(16) Withlacoochee – Croom Tract	Withlacoochee State Forest - Croom Tract	FL

PART I. INTRODUCTION

1. LISTING

A. REASONS FOR LISTING

The red-cockaded woodpecker was listed as endangered in 1970 (35 Federal Register 16047) and received federal protection with the passage of the Endangered Species Act in 1973. Once a common bird distributed continuously across the southeastern United States, by the time of listing the species had declined to fewer than 10,000 individuals in widely scattered, isolated, and declining populations (Jackson 1971, Ligon *et al.* 1986).

This precipitous decline was caused by an almost complete loss of habitat. Fire-maintained old growth pine savannahs and woodlands that once dominated the southeast, on which the woodpeckers depend, no longer exist except in a few small patches. Longleaf pine (*Pinus palustris*) ecosystems, of primary importance to red-cockaded woodpeckers, are now among the most endangered systems on earth (Simberloff 1993, Ware *et al.* 1993). Shortleaf (*P. echinata*), loblolly (*P. taeda*), and slash pine (*P. elliottii*) ecosystems, important to red-cockaded woodpeckers outside the range of longleaf, also have suffered severe declines (Smith and Martin 1995).

Loss of the original pine ecosystems was primarily due to intense logging for lumber and agriculture. Logging was especially intense at the turn of the century (Frost 1993, Martin and Boyce 1993, Conner *et al.* 2001). Two additional factors resulting in the loss of original pine systems in the 1800's and earlier were exploitation for pine resins and grazing by free-ranging hogs (*Sus scrofa*; Wahlenburg 1946, Frost 1993). Later, in the 1900's, fire suppression and detrimental silvicultural practices had major impacts on primary ecosystem remnants, second-growth forests, and consequently on the status of red-cockaded woodpeckers (Frost 1993, Ware *et al.* 1993, Ligon *et al.* 1986, 1991, Landers *et al.* 1995, Conner *et al.* 2001). Longleaf pine suffered a widespread failure to reproduce following initial cutting, at first because of hogs and later because of fire suppression (Wahlenburg 1946, Ware *et al.* 1993). These factors are discussed in more detail below.

Loss of the Original Ecosystems

Southern pine savannahs and open woodlands once dominated the southeastern United States, and may have totaled over 80 million ha (200 million ac) at the time of European colonization (Conner *et al.* 2001). Longleaf pine communities characterized the Atlantic and Gulf coastal regions, and covered an estimated 24 to 37 million ha (60 to 92 million ac; Wahlenburg 1946, Frost 1993, Ware *et al.* 1993, Landers *et al.* 1995). Roughly one quarter of the longleaf communities also supported other pines such as loblolly, shortleaf, slash, and pond pine (*P. serotina*) in various proportions depending on soil conditions, especially in transitional zones between the coastal plains and other physiographic regions (Frost 1993, Landers *et al.* 1995).

Today, longleaf forests have declined to less than 1.2 million ha (3 million ac; Landers *et al.* 1995), of which roughly 3 percent remains in relatively natural condition (Frost 1993). Little old growth remains, and virtually no longleaf forest has escaped changes in the natural fire regime (Simberloff 1993, Walker 1999). Shortleaf pine was prevalent outside the range of longleaf, especially on dry slopes and ridges in the Interior Highlands and Oklahoma, and has declined considerably (Landers 1991, Smith and Martin 1995). In the precolonial forests, loblolly pine was present as a minor component of riparian hardwood ecosystems or in association with shortleaf pine in some upland interior forests (White 1984, Landers 1991, Christensen 2000).

Southern pine forests today are very different from precolonial communities not only in extent, but also in species composition, age, and structure (Ware *et al.* 1993, Noel *et al.* 1998). Original pine forests were old, open, and contained a structure of two layers: canopy and diverse herbaceous groundcover. These forests were dominated by longleaf pine in the coastal plain, longleaf and shortleaf pines in the Piedmont and interior highlands, and slash pine (*P. elliottii* var. *densa*) in south Florida. Forests dominated by loblolly pine were restricted to a portion of southern Arkansas and perhaps eastern Virginia and extreme northeastern North Carolina (White 1984, Christensen 2000). In contrast, much of today's forest is young, dense, and dominated by loblolly pine, with a substantial hardwood component and little or no herbaceous groundcover (Ware *et al.* 1993, Noel *et al.* 1998).

Original longleaf communities in the Atlantic and Gulf coastal plains were first heavily impacted by exploitation for naval stores and then virtually eliminated by widespread logging and the subsequent reproductive failure of longleaf pine (Frost 1993, Ware *et al.* 1993). Naval stores industries harvested pine resin for the production of tar, pitch, and turpentine—commodities in high demand during colonial times. Pine woodlands were logged for lumber and conversion to agricultural fields. Impacts to easily accessible areas began with the arrival of Europeans, but technological developments of the 1800's, such as the copper still, steam power, and especially railroads, dramatically increased the rate and area of loss (Frost 1993). In the late 1800's logging operations moved to the previously inaccessible interior forests of longleaf, shortleaf, and loblolly pines. For over a decade these operations removed a reported 3 to 4 billion board feet per year (Frost 1993); an estimated 13 billion board feet of longleaf was extracted in 1907 alone (Wahlenburg 1946, Landers *et al.* 1995). This especially intense period of logging from 1870 to 1930 resulted in the loss of nearly all of the remaining old growth forest in the southeast (Frost 1993, Martin and Boyce 1993, Conner *et al.* 2001).

A common logging practice before the late 1800's was to leave a fair number of residual trees, including small trees, some of those infected with red heart fungus (*Phellinus pini*), and some that had been boxed for resin production (Wahlenburg 1946, Conner *et al.* 2001). Cavity trees of red-cockaded woodpeckers probably were left in much higher proportion than their numbers, due to the likelihood of red heart infection and the abundant resin coating. These residual pines enabled the red-cockaded woodpeckers to survive the original devastation (Phillips and Hall 2000). Loss of residual trees in the twentieth century has been a major factor in the decline of woodpecker populations (Costa and Escano 1989, Conner *et al.* 2001; see 2D).

Fire Suppression

Precolonial fire frequencies in the southeast have been estimated at 1 to 3 years for the Atlantic and lower Gulf coastal plains (Stout and Marion 1993, Ware *et al.* 1993, Frost 1998), 4 to 6 years for the Piedmont and upper Gulf coastal plain, and 7 to 25 years for the southern Appalachians and interior highlands (Masters *et al.* 1995, Frost 1998). Fire frequency increases with size of fire compartments, and natural firebreaks in the southeastern coastal plains were rare (Ware *et al.* 1993, Frost 1998). Historically, fires were ignited by Native Americans and by lightning. Lightning was the primary ignition source shaping the evolution of these fire-maintained ecosystems, but Native Americans may have played a substantial role in maintaining them (Delcourt *et al.* 1993, Frost 1993). Such maintenance vanished, of course, as Native Americans were severely impacted by the diseases and aggression of incoming Europeans. Natural fire frequency also declined as fires were reduced in area because of roads, plowed fields, and other human-made firebreaks (Frost 1993, Ware *et al.* 1993).

Europeans brought their perceptions of fire with them as they colonized North America. In Europe, fire was an integral part of traditional swidden agriculture (i.e., shifting cultivation) and was celebrated by peasants as a source of renewal (Pyne 1998). In contrast, urban intellectuals and authorities viewed fire as a destructive force. This view was rooted in a social context: controlling the use of fire could facilitate control of the populace by discouraging the nomadic system (Pyne 1998). Such socially constructed perceptions of fire impacted natural fire regimes in all of Europe’s colonies (Pyne 1998).

In North America, after European settlement and prior to the mid 1800’s, farmers burned the woodlands regularly to improve forage for free-ranging livestock. Burning the open woods decreased with the fencing of livestock in the mid to late 1800’s (Frost 1993), although many people continued to use fire in agricultural fields well into the 1900’s (Martin and Boyce 1993). In the twentieth century, the rise of mechanical and chemical agriculture has replaced fire-based agricultural methods.

Active fire suppression began to be institutionalized in the southeastern United States between 1910 and 1930 (Frost 1993, Ware *et al.* 1993). Several factors influenced its rise. First was the existing bias against fire brought to this continent by European intellectuals (Pyne 1998). Then, in the late 1800’s, fire suppression grew in response to the extreme intensity of fires burning the logged-over slash across the entire eastern United States. Fires in pine resin orchards were similarly intense and had been suppressed for some time to protect resin production (Frost 1993). Many ecologists denounced fire as detrimental to southern pines rather than an integral or useful component of the natural system. Suppression of fire increased with the rise of pine plantations, a land use that began in the 1930's and 40's and continues to increase today (Martin and Boyce 1993, Stout and Marion 1993, Ware *et al.* 1993).

Fire suppression has severe and numerous impacts on southern pine ecosystems, including changes in tree species composition and forest structure. Longleaf pine cannot reproduce without access to the mineral soil, and will be replaced under fire suppression by other species of pines and hardwoods. The structure of the forest changes from two layers, a canopy and a diverse groundcover, to a multi-layered midstory and canopy with little or no groundcover. With increasing hardwood midstory, arthropod communities change in species abundance, species composition, and distribution on the substrate (Collins 1998, Provencher *et al.* 2001a). Red-cockaded woodpeckers are directly and adversely affected by each of these changes (see 2D and 2E).

Reproduction of longleaf pine has been severely restricted since the precolonial era, first because of the impacts of free-ranging hogs and more recently because of the absence of fire (Wahlenburg 1946, Frost 1993, Ware *et al.* 1993). A short period of reproduction took place after hogs were fenced and before fires were suppressed. Most second-growth longleaf in existence today is 70 to 100 years in age and reproduced naturally during this short period of opportunity (Kelly and Bechtold 1990, Frost 1993, Landers *et al.* 1995). Reproduction of longleaf in the twentieth century has been, and still is, constrained by hardwood midstory developed as a result of fire suppression (Landers *et al.* 1995, Frost 1993, Peet and Allard 1993).

Detrimental Silvicultural Practices

Several silvicultural practices have been detrimental to red-cockaded woodpeckers, including short rotations, clearcutting, and conversion to sub-optimal pine species. Cutting of second-growth longleaf pines began during World War II and continues today. Removal of second-growth longleaf has exceeded growth by over 40 percent, and much of the remaining longleaf is aging without replacement (Landers *et al.* 1995).

The years following World War II also saw the rise of plantation forestry. Plantations of dense slash or loblolly pines covered over 4.9 million ha (12 million ac) by the mid 1960's and over 6.1 million ha (15 million ac) at present (Ware *et al.* 1993). Plantations typically have been under rotations of 35 to 70 years for sawtimber production and 20 to 40 years for pulp production (Conner *et al.* 2001), and industry has continued to shift from logs and poles to pulp (Landers *et al.* 1995). With technological developments such as chainsaws, the practice of leaving 'cull' pines that were infected with red heart fungus or boxed for resin production declined. These two practices—short rotations and the removal of all trees—had substantial negative impacts on the woodpecker populations that remained after the initial logging (Conner *et al.* 2001).

B. Current Threats

Despite protection under the Endangered Species Act in 1973, populations of red-cockaded woodpeckers continued to decline throughout the 1970's and into the 1980's in all parts of the species' range (Baker 1983, Ligon *et al.* 1986, 1991, Ortego and Lay 1988, Conner and Rudolph 1989, Costa and Escano 1989, James 1991, 1995, Haig *et al.* 1993, Kelly *et al.* 1994). Only one population was reported to be increasing during this time (Hooper *et al.* 1991a). In the 1990's, most populations were stabilized and many have shown increases (R. Costa, pers. comm.). Stabilizing the declines was the result of a new understanding of population dynamics (see 2B) and the use of powerful management tools such as artificial cavities, translocation, and prescribed burning (see 3B and 3F). Our challenge now is to bring about the widespread increases in population sizes necessary to recover the species.

Primary threats to species viability for red-cockaded woodpeckers all have the same basic cause: lack of suitable habitat. Red-cockaded woodpeckers require open mature pine woodlands and savannahs maintained by frequent fire, and there is very little of this habitat remaining (Lennartz *et al.* 1983, Frost 1993, Simberloff 1993, Ware *et al.* 1993). On public and private lands, both the quantity and quality of red-cockaded woodpecker habitat are impacted by past and current fire suppression and detrimental silvicultural practices (Ligon *et al.* 1986, 1991, Baker 1995, Cely and Ferral 1995, Masters *et al.* 1995, Conner *et al.* 2001). Serious threats stemming from this lack of suitable habitat include (1) insufficient numbers of cavities and continuing net loss of cavity trees (Costa and Escano 1989, James 1995, Hardesty *et al.* 1995); (2) habitat fragmentation and its effects on genetic variation, dispersal, and demography (Conner and Rudolph 1991b); (3) lack of foraging habitat of adequate quality (Walters *et al.* 2000, 2002a, James *et al.* 2001); and (4) fundamental risks of extinction inherent to critically small populations from random demographic, environmental, genetic, and catastrophic events (Shaffer 1981, 1987).

Fire suppression and exclusion is still a profound threat to red-cockaded woodpecker populations (see 2D, 2G). Hardwood encroachment due to fire suppression has been a leading cause of loss of woodpecker groups on both public and private lands and continues to be a major threat throughout the species' range (Van Balen and Doerr 1978, Hovis and Labisky 1985, Conner and Rudolph 1989, 1991a, Costa and Escano 1989, Loeb *et al.* 1992, Baker 1995, Cely and Ferral 1995, Escano 1995, Masters *et al.* 1995). Moreover, most assessments of the impacts of fire suppression on woodpecker groups have been restricted to effects of hardwood midstory on nesting and roosting habitat. Recent research indicates that exclusion of fire from foraging habitat has negative impacts as well (James *et al.* 1997, 2001, Hardesty *et al.* 1997, Doster and James 1998, Walters *et al.* 2000, 2002a). Even if nesting and roosting habitat is frequently burned, lack of fire in the foraging habitat can reduce group size and productivity (James *et al.* 1997, 2001, Hardesty *et al.* 1997, Walters *et al.* 2000, 2002a). Thus, negative effects of fire suppression are more pervasive than previously thought.

Widespread and frequent application of early-mid growing season fire throughout lands managed for red-cockaded woodpeckers is essential to the recovery of the species (Conner and Rudolph 1989, 1991a, Baker 1995, James 1995). Regrettably, there are several major difficulties affecting the increased use of fire across the southeast. These difficulties include lack of funding for both public land management agencies and private landowners; prohibitive smoke regulations; increasing density of human populations and associated development; proliferation of firebreaks such as roads, fields, and power lines; and perhaps most importantly, the prejudice against fire held by many private citizens and some public land managers. As this prejudice, built by decades of intensive anti-fire publicity, shifts toward acceptance of the natural role of fire and its benefits for resource management and catastrophic fire prevention, smoke regulations and funding constraints may change. Extreme caution is needed, however, in moving from restoration to maintenance burns. Should restoration burns of fuel-heavy forests cause loss of human life or property, public perception will be slow to change.

Logging is a potential threat to woodpecker populations on private lands (Cely and Ferral 1995), as harvests of mature pines continues at a high rate. One recent study estimated the current rate of pine cutting on private lands in parts of South Carolina and Georgia at 4.0 percent per year, a rate much higher than those estimated by similar methods for temperate or tropical rainforest (Pinder *et al.* 1999). Trees being cut were in older, natural stands established during the 1930's and 1940's. Other researchers have predicted that as these second-growth forests mature, there may well be another episode of substantial forest harvest (Ware *et al.* 1993, Landers *et al.* 1995). Moreover, the total area of both private and public lands that support longleaf pine is still sharply declining, from an estimated 1.53 million ha (3.77 million ac) in 1985 (Kelly and Bechtold 1990) to 1.19 million ha (2.95 million ac) in 1995 (Outcalt and Sheffield 1996). Privately owned lands have sustained the greatest losses. Private lands continue to support significant amounts of longleaf, although much of it occurs in parcels of less than 20.2 ha (50 ac; Outcalt and Sheffield 1996). One of the most common ways longleaf pine cover is lost is by replacement of other pine species after logging (Outcalt and Sheffield 1996). Widespread conversion of longleaf to plantations of other pine species began in the 1940's and this process still continues today. Plantations of off-site pine species (species that were not the original cover type) now cover over 6.1 million ha (15 million ac) in the southeast (Stout and Marion 1993, Ware *et al.* 1993).

Silvicultural practices on public lands have improved in recent years. Agency responses to legislated protection of red-cockaded woodpeckers include longer rotation times (USFS 1995), increases in the area under protection (USFS 1995), and elimination of intentional conversion of native pines to off-site species. Enlightened management plans emphasize prescribed burning, pine thinning to open dense second-growth stands, and retention of scattered relict old growth pines (USFS 1995). For many public lands, timber removal is now an important management tool rather than an overriding objective (USFS 1995). Overall, current timber production and conversion to off-site pines on public lands are less of a threat than earlier this century, although effects of past practices are still nearly overwhelming.

As described above (this section and 1A), fire suppression and past timber harvests have resulted in an almost complete loss of habitat for red-cockaded woodpeckers. Species recovery is only possible through habitat restoration (see 2D, 2E, 3F, 3G; James 1995, Smith and Martin 1995). However, restoration of habitat may itself jeopardize red-cockaded woodpeckers, if approached without suitable caution. Clearcutting of off-site pine species to restore longleaf and shortleaf pines can potentially disrupt woodpecker populations (Ferral 1998, F. C. James, pers. comm.). Restoration of native pines is best achieved through conversion of habitat patches rather than large clearcuts, especially if woodpeckers are using off-site pines for foraging or dispersal (Ferral 1998, see 3G).

One of the primary threats to red-cockaded woodpeckers, stemming from past habitat loss, is a severe bottleneck in the number of pines available as cavity trees (Costa and Escano 1989, Rudolph *et al.* 1990b, Conner *et al.* 1991a, Walters *et al.* 1992a). Red-cockaded woodpeckers require older pines for cavity excavation for two reasons: (1) only older pines have sufficient heartwood to house a cavity at preferred cavity heights (Jackson and Jackson 1986, Clark 1993, Conner *et al.* 1994) and (2) older pines are more likely to be infected with red heart fungus (Wahlenburg 1946, Conner *et al.* 1994), which substantially reduces the time required for cavity excavation (Conner and Rudolph 1995a, see 2D). Red-cockaded woodpeckers survived the 20th century (although at drastically reduced numbers) because timber harvest practices of the 19th and early 20th century left some relict pines standing. Harvest methods used during the mid 20th century did not follow this practice, and many relict pines were cut during this period. Still, most cavity trees in existence today are survivors of the original removal of the primary forest (Jackson *et al.* 1979, Rudolph and Conner 1991). These pines are older than the surrounding forest and suffer high rates of mortality due to increased effects of wind, lightning, southern pine beetles (*Dendroctonus frontalis*) and other pests, and natural senescence (Jackson *et al.* 1978, Conner *et al.* 1991a, Conner and Rudolph 1995b, Rudolph and Conner 1995, Watson *et al.* 1995). Because the surrounding forest is much younger in age, few potential cavity trees are available as replacements. As second-growth forests are allowed to age, more potential cavity trees will become available. In the meantime, a net loss of cavity trees threatens current populations (Costa and Escano 1989). Crisis intervention through intensive cavity management (artificial cavities and restrictors; see 3B) is helping to offset cavity loss but the threat will remain until mature and old growth trees are restored.

A second major impact of habitat loss on the viability of red-cockaded woodpeckers is the resultant fragmented distribution. Fragmentation and isolation have occurred both among groups within a population and among populations, with serious consequences for red-cockaded woodpeckers. Red-cockaded woodpeckers are particularly sensitive to effects of isolation because of the limited dispersal characteristic of cooperative breeders (Walters *et al.* 1988a, Daniels and Walters 2000a; see 2B). Fragmentation among populations increases the vulnerability of those populations to adverse genetic, demographic, and environmental events (Walters *et al.* 1988a, Conner and Rudolph 1991b, Hooper and Lennartz 1995; see below and 2C), because the dispersal that can help offset such threats is easily disrupted. Fragmentation and isolation of groups within a population can substantially increase that population's risk of extinction (Crowder *et al.* 1998, Letcher *et al.* 1998, Walters *et al.* 2002b). Populations of red-cockaded woodpeckers are surprisingly persistent if the spatial arrangement of groups within the population is tightly clumped. If groups are isolated and dispersal behavior disrupted, risk of population extinction increases (Crowder *et al.* 1998, Letcher *et al.* 1998, Walters *et al*. 2002b, see 2C).

Managers have some limited tools to combat effects of fragmentation (e.g., strategic location of recruitment clusters, retention of forest cover, and translocation). More importantly, as populations recover, isolation effects will not be as intensely acute as they are at present, because larger populations have greater resistance to impacts from environmental and demographic threats, greater retention of genetic variation, and thus greater probability of persistence. However, effects of fragmentation are likely to remain serious threats to population viability throughout the period of recovery.

A third threat to red-cockaded woodpeckers from past habitat loss is lack of suitable foraging habitat. As described above, recent research indicates that optimal foraging habitat is maintained by fire and contains an old growth or mature pine component (Conner *et al.* 1991b, Hardesty *et al.* 1997, James *et al.* 1997, 2001, Walters *et al.* 2000, 2002a). Restoration of foraging habitat will likely increase red-cockaded woodpecker densities (Walters *et al.* 2000, 2002a, James *et al.* 2001; see 2E), which in turn will positively influence demography and dispersal. However, the threat to woodpecker populations from low-quality or insufficient foraging habitat is not as immediate as threats from habitat fragmentation and lack of suitable nesting habitat. Fragmentation and lack of nesting habitat are presently limiting populations and are responsible for recent declines (Walters 1991). Foraging habitat, on the other hand, affects population densities; it may be a secondary factor currently limiting populations and will likely become a primary limiting factor once abundant nesting habitat is provided (Walters *et al.* 2000, 2002a). Foraging habitat is therefore an important concern for long-term viability.

One last identified threat to species viability that stems from habitat loss is the set of risks inherent to critically small populations. These are similar to fragmentation effects, but rather than occurring through isolation, these threats are related to population size. Small populations may be extirpated because of random environmental, demographic, genetic, and catastrophic events (Shaffer 1981, 1987; see 2C). Random environmental events affect an entire population; for example, an exceptionally severe winter that causes high adult mortality. Random demographic events act on individuals within populations; for example, a death due to predation, or a brood consisting of all males. Random genetic events are losses or gains in frequency of any given gene, simply due to chance inheritance. Lastly, catastrophic events, which can affect large as well as small populations, are similar to environmental events but larger in scale. Any of these processes alone or in concert can cause the extirpation of a small population. Such processes will continue to remain threats until population sizes are sufficient to withstand them (Shaffer 1981, 1987, Crowder *et al.* 1998, Letcher *et al.* 1998, Walters et al. 2002b; see 2C). Catastrophes will continue to threaten even the largest populations in perpetuity, although the species as a whole will not be in danger once enough large populations are established (e.g., Hooper and McAdie 1995).

Other factors unrelated to habitat loss may threaten red-cockaded woodpeckers, but their importance has not yet been determined. Foremost among unevaluated threats are the risks from pesticides and other environmental contaminants. Suburban groups of woodpeckers may be at especially high risk of adverse effects from toxins. Similarly, impacts of exotic species have not yet been assessed. Exotic species such as melaleuca (*Melaleuca quinquenervia*) and red imported fire ants (*Solenopsis invicta*) may be negatively affecting woodpeckers in some parts of their range.

Unlike many endangered and threatened species, red-cockaded woodpeckers are well studied (see Jackson 1995). Biologists are developing a good understanding of what constitutes optimal habitat for this species. Further information from experimental research is certainly needed to understand the best ways to restore ecosystems and habitat for red-cockaded woodpeckers, but a detailed picture of excellent red-cockaded woodpecker habitat is now emerging. In addition, managers are now equipped with effective tools to stabilize existing populations until sufficient quantity and quality of habitat for self-sustaining populations can be provided (Walters 1991). However, such habitat restoration and interim crisis management requires ample funding and a strong political will (Conner *et al.* 2001). Any weakness in determination or political will, with accompanying changes in law and policy, would constitute an extremely serious threat to the species.

2. GENERAL BIOLOGY AND ECOLOGY

A. TAXONOMY AND SPECIES DESCRIPTION

Red-cockaded woodpeckers are currently recognized as *Picoides borealis.* The species is endemic to the southeastern United States but other members of the genus are found throughout the Americas. Red-cockaded woodpeckers were first described for science as *Picus borealis*, “le pic boreal”, by the French businessman and amateur naturalist Vieillot (1807). In 1810, unaware of Vieillot’s description, Alexander Wilson described the species as *Picus querulus* because of its distinctive vocalizations (Wilson 1810).

Wilson gave the species the English common name we use today, red-cockaded woodpecker, in reference to the several red feathers of males, located between the black crown and cheek patch, that are briefly displayed when the male is excited. In Wilson’s time, “cockade” was a common term for a ribbon or other ornament worn on a hat as a badge. The cockade is a poor field mark because it is rarely seen in the field, but does identify the sexes of adult birds in the hand.

Red-cockaded woodpeckers are relatively small. Adults measure 20 to 23 cm (8 to 9 in) and weigh roughly 40 to 55 g (1.5 to 1.75 oz; Jackson 1994, Conner *et al.* 2001). They are larger than downy woodpeckers (*Picoides pubescens*), similar in size to yellow-bellied sapsuckers (*Sphyrapicus varius*), and smaller than other southeastern woodpeckers. Size of red-cockaded woodpeckers varies geographically, with larger birds to the north (Mengel and Jackson 1977). Because of this, Wetmore (1941) considered the birds of peninsular Florida to be a subspecies (*P. b. hylonomus*) which was later recognized by the American Ornithologists' Union (1957). Mengel and Jackson (1977), however, examined a larger series of specimens and considered the variation in the species to be smoothly clinal with no justification for distinguishing the birds in south Florida from those elsewhere.

Red-cockaded woodpeckers are black and white with a ladder back and large white cheek patches. These cheek patches distinguish red-cockaded woodpeckers from all others in their range. Red-cockaded woodpeckers are black above with black and white barring on their backs and wings. Their breasts and bellies are white to grayish white with distinctive black spots along the sides of breast changing to bars on the flanks. Central tail feathers are black and outer tail feathers are white with black barring. Adults have black crowns, a narrow white line above the black eye, a heavy black stripe separating the white cheek from a white throat, and white to grayish or buffy nasal tufts. Bills are black, and legs are gray to black.

Sexes of adult red-cockaded woodpeckers are extremely similar in plumage and generally indistinguishable in the field. In contrast, sexes of juveniles can be distinguished in the field until the first fall molt, because juvenile females have black crowns whereas juvenile males have red crown patches. Sexes of nestlings in the hand often can be distinguished by eight days of age: capital feather tracks, observed through the transparent skin before feather emergence, appear grayish black in females and reddish in males (Jackson 1982).

Juveniles may be distinguished from adults in the field by duller plumage, white flecks often present just above the bill on the forehead, and by diffuse black shading in the white cheek patch. In the hand, red-cockaded woodpeckers can be aged by the relative length and shape of the vestigial tenth primary until this primary is molted in the fall. This primary of juveniles is longer and more rounded than that of adults (Jackson 1979a). Second-year red-cockaded woodpeckers often can be identified because juveniles do not molt their secondaries during their first fall molt, whereas older birds do. As a result, the secondaries of juveniles during the second calendar year appear more worn and brown in contrast to newer black primaries (Jackson 1994).

B. SOCIOBIOLOGY AND COOPERATIVE BREEDING

The Breeding System

Red-cockaded woodpeckers live in groups that share, and jointly defend, all-purpose territories throughout the year. Group living is a characteristic of their cooperative breeding system. Red-cockaded woodpeckers are one of only a handful of bird species found in the United States that exhibit this unusual system. In cooperative breeding systems, some mature adults forego reproduction and instead assist in raising the offspring of others (Emlen 1991). The cooperative breeding system of red-cockaded woodpeckers is well studied, and several recent reviews are available (Walters 1990, 1991, Jackson 1994). In this species, most helpers are males that remain and assist the breeders, who typically are their parents or other close kin, on their natal territory (Ligon 1970, Lennartz and Harlow 1979, Lennartz *et al.* 1987, Walters *et al.* 1988a). A few females become helpers on their natal territories, and a few individuals of each sex disperse to become helpers of unrelated breeders in other groups (Lennartz *et al.* 1987, Walters *et al.* 1988a, DeLotelle and Epting 1992). Helpers are strictly non-breeders (Haig *et al.* 1994b), but participate in incubation, feeding and brooding of nestlings and feeding of fledglings, as well as territory defense, nest defense, and cavity excavation. Groups may contain as many as four helpers, but most groups consist of only a breeding pair with no helpers, or a breeding pair plus one helper. Groups containing more than two helpers are uncommon.

Red-cockaded woodpecker groups are highly cohesive. Each individual has its own roost cavity, but typically group members congregate immediately after emerging from their cavities at dawn, and then move together through their large territories until they return to their cavities at dusk. Much like a primate troop, they visit only a portion of their territory or home range each day, and travel different routes on different days.

Group formation is best understood in terms of alternative life-history tactics practiced by young birds (Walters 1991). Young birds may either disperse in their first year to search for a breeding vacancy, or they may remain on the natal territory and become a helper. The proportion of each sex adopting each strategy varies among populations (Lennartz *et al.* 1987, Walters *et al.* 1988a, DeLotelle and Epting 1992), but dispersal is always the dominant strategy for females whereas both strategies are common among males. A dispersing individual, if it survives, may become a breeder at age one, but many fail to locate a breeding vacancy and exist as a floater at age one, or in a few cases as a helper in a new group (Walters *et al.* 1988a, 1992a). Some dispersing males locate a territory but no mate, and hence are solitary males at age one. Solitary males and floaters, like helpers (see below), may become breeders at subsequent ages.

It is those individuals who choose to remain at home as helpers rather than disperse that are primarily responsible for group formation. Individuals may remain helpers for up to eight years, but most become breeders within a few years (Walters *et al.* 1988a, 1992a). Helpers may become breeders by inheriting breeding status on their natal territory or by dispersing to a nearby territory to fill a breeding vacancy. When helpers move, it is usually to an adjacent territory, and they rarely disperse across more than two territories.

In contrast, individuals of both sexes dispersing in their first year sometimes move long distances, more than 100 km in a few cases (Walters *et al.* 1988b, Conner *et al.* 1997c, Ferral *et al.* 1997). Still, typical dispersal distances of even first-year birds are much lower than in other avian species. The median dispersal distance of females is only two territories from the natal site, and about 90 percent settle 1 to 4 territories from the natal site (Daniels 1997, Daniels and Walters 2000a). Males are even more sedentary, since many of them adopt the helping strategy. About 70 percent of males become breeders on the natal territory or an immediately adjacent one (Daniels 1997).

Once a male acquires a breeding position, by whatever pathway, he almost invariably holds it until his death (Walters *et al.* 1988a). Females, however, regularly practice breeding dispersal: roughly 10 percent of breeding females switch groups between breeding seasons each year (Walters *et al.* 1988a, Daniels and Walters 2000b). Females invariably depart when their sons inherit breeding status on their territory, but usually remain when a helper unrelated to them inherits breeding status. Females also are likely to leave if their mate dies and there are no helpers to assume the breeding vacancy, rather than pair with an immigrant replacement male, although not all do so. This may be a means to avoid young males as mates (Daniels and Walters 2000b, below). Also, young females (age one or two) that experience reproductive failure are likely to move (Daniels and Walters 2000b). Like first-year birds, dispersing adult females occasionally move very long distances (Walters *et al.* 1988b), but typically move to a neighboring group (Walters *et al.* 1988a, Daniels 1997).

Reproduction

Red-cockaded woodpeckers are highly monogamous. The group produces a single brood, and the breeding male and female within the territory are almost invariably the genetic parents of all offspring (Haig *et al.* 1993, 1994b). There is no evidence that helpers ever sire offspring, and the frequency of extra-pair fertilization involving individuals outside the group is among the lowest yet recorded in birds (Haig *et al.* 1994b).

Typical values of reproductive parameters, and the range of variation among years and populations, are available from several published studies (Lennartz *et al.* 1987, Walters *et al.* 1988a, Walters 1990, DeLotelle and Epting 1992, LaBranche and Walters 1994, DeLotelle *et al.* 1995, James *et al.* 1997) and project final reports (North Carolina Sandhills and coastal North Carolina, Walters and Meekins 1997, Walters *et al.* 1997, 1998; Eglin Air Force Base and Apalachicola National Forest, Florida, Hardesty *et al.* 1997). Unless otherwise indicated, values reported below represent a summary of data from these sources.

Not all groups attempt nesting in a given year. On average about 10 percent of the groups do not nest, but this ranges from as low as 3 percent to as high as 21 percent. Groups with young breeders, especially one-year-old males, are especially likely to forego nesting (Walters 1990). If the group does nest, the eggs are usually laid in the most recently completed cavity available, which typically is the breeding male's roost cavity (Conner *et al.* 1998a). If the nest fails, the group may renest. On average about 30 percent of nest failures are followed by a second attempt, but annual variation in the rate of renesting is high. There are records of a group making a third nesting attempt following two failed nests, and of a group attempting a second brood after a successful first nest (LaBranche *et al.* 1994, Schillaci and Smith 1994, reviewed by Phillips *et al.* 1998), but both are exceedingly rare (Phillips *et al.* 1998). Equally rare are instances of two nests of a single pair in existence at the same time (Rossell and Britcher 1994, R. Conner *et al.*, unpublished, J. Walters, unpublished). It seems that almost any odd variation of the typical reproductive process can occur in rare instances. Other examples include two females residing together within a group and laying clutches synchronously in a common nest, or laying in separate nests. Successful instances of the former, but not the latter, have been observed. Such instances are of theoretical interest because they constitute plural breeding, which is characteristic of more complex types of cooperative breeding systems (Emlen 1991).

Normally, however, one brood is produced as a result of one or perhaps two nesting attempts involving only two parents. Most groups that attempt nesting fledge young, as nest failure rates are low for a species in the temperate zone, although fairly typical for a primary cavity nester (Martin and Liu 1992, Martin 1995). Nest failure rates average about 20 percent, and this is fairly consistent among years and among populations. Nest predation, nest desertion, and loss of nest cavities to cavity kleptoparasites appear to be the primary causes of nest failure. Failure rate is higher during the egg stage than during the nestling stage, which suggests that nest desertion, rather than nest predation or loss of cavities to kleptoparasites, is the major cause of failure (Ricklefs 1969). The relative frequencies of these three causes of nest loss have never been measured directly, however.

Nest predation rates may be lower than in other cavity nesters because of the protection provided by the resin barrier around the cavity, which clearly interferes with climbing by snakes (Rudolph *et al.* 1990b). The frequency of nest predation may vary regionally, although there is no direct evidence of this. One possibility is that it is higher in areas where most cavities are in species other than longleaf, and thus where the resin barrier is diminished (Conner *et al.* 1998a), for example in Arkansas (Neal 1992).

In contrast to nest predation, nest desertion may be more common than in other cavity nesters because of the complex social system and resulting intense competition for breeding vacancies (see below) characteristic of this species. Lennartz *et al.* (1987) suggested that nest failure is often associated with repeated territorial intrusions by conspecifics, and other forms of social disruption. Immigrants often associate with groups as affiliated floaters or unrelated helpers (Walters *et al.* 1988a). Such individuals are a particularly likely source of social disruption that might cause groups to forego nesting, or fail if they do attempt to nest (DeLotelle and Epting 1992).

The primary cavity kleptoparasites linked to nest failure are red-bellied woodpeckers (*Melanerpes carolinus*), red-headed woodpeckers (*M. erythrocephalus*), eastern bluebirds (*Sialia sialis*), and southern flying squirrels (*Glaucomys volans*). These species are known to usurp nest cavities from red-cockaded woodpeckers and to destroy nests in cavities they usurp. Occasionally, red-headed woodpeckers, red-bellied woodpeckers, and flying squirrels may consume eggs and small nestlings (Jackson 1994).

Although red-cockaded woodpecker groups produce broods fairly reliably, these broods are relatively small. This is because clutch size is modest and, more importantly, because partial brood loss is greater than in other species of primary cavity nesters in the United States (LaBranche and Walters 1994). Most clutches contain 2 to 4 eggs, although the full range is 1 to 5 eggs. Even larger clutches are occasionally reported, but these probably (and in some cases certainly) result from two females laying in the same nest (see above). There is variation among populations in clutch size, with population averages ranging from 2.9 to 3.5 eggs, but there does not appear to be a regular geographic pattern in this variation.

Incubation begins before the clutch is complete, and eggs hatch asynchronously (Ligon 1970). As often occurs in species with asynchronous hatching, partial brood loss occurs soon after hatching. Some reduction in brood size is due to failure of eggs to hatch, but much of it is due to mortality of nestlings within the first few days after hatching. The relative frequencies of these forms of loss are not known precisely, and neither are the mechanisms producing the mortality. Eggs may fail to hatch because they are infertile, but it is likely that some do not hatch because the birds cease incubating them after the first eggs hatch. It is also likely that the last young to hatch often starve. A recent study, the first to use video cameras mounted in modified artificial cavities, found that youngest nestlings were most likely to die (Sanders 2000). This study also found no evidence of sibling aggression, so it appears improbable that siblicide is a regular component of partial brood loss.

Partial brood loss, measured by dividing the number of fledglings by the number of eggs in successful nests, averages about 40 percent. It is, however, highly variable among years and among populations. This is one parameter that appears to exhibit systematic geographic variation. Partial brood loss tends to be higher in coastal populations compared to inland ones, and in southern populations compared to northern ones. Population averages vary from around 30 percent in a northern, inland population (North Carolina Sandhills) to about 50 percent in a southern, coastal population (Eglin Air Force Base in Florida), and 59 percent in central Florida.

The average number of young fledged from successful nests is about two in northern populations. Broods of 1 to 4 are common, and rarely five young are fledged from a single nest. Because some groups do not nest and others fail in their attempts, the average number of young produced per group is about one-half fledgling less, ranging from 1.4 to 1.7 among populations, and from 1.0 to 1.9 among years within populations. Thus one can expect about 1.5 young to be produced per group in northern populations. Productivity in Florida populations typically is somewhat less, due largely to greater partial brood loss. In Florida most groups fledge only one or two young, occasionally three. Annual values range from 0.9 to 1.6, and the typical value for a Florida population is about 1.2 fledglings per group per year.

For the first several days after fledging, the young birds are somewhat reluctant to fly, and spend considerable time perched high up in the pines, clinging to the trunk. Parents and helpers sometimes forage some distance away from the young at this time, but return frequently to feed them. During this initial period, the fledglings often do not return to the cluster with the adults in the evening, but instead roost in the open wherever the adults leave them at the end of the day. The next morning, the adults return and locate the fledglings, and resume feeding them.

By the end of the first week out of the nest, however, the young are much more active, and move with the adults as the group travels through the territory. Frequently fledglings will follow adults closely, and beg loudly for food as the adult forages. They may even displace the adult from a particularly productive foraging location. Fledglings often are highly aggressive toward one another, and clear dominance hierarchies are evident among siblings. Males, which are recognizable from their red crown patches, usually are dominant to females. Most of the aggression consists of a dominant fledgling displacing a subordinate from an adult that is carrying food or foraging. The fledglings gradually begin to obtain food for themselves, but continue to beg for food and squabble with each other for some time. It is not unusual to see young being fed two months after fledging, and young are occasionally seen begging as late as the subsequent winter (Ligon 1970).

The sex ratio among fledglings has been reported as biased toward males in a South Carolina population (Gowaty and Lennartz 1985), biased toward females in a Florida population (Epting and DeLotelle, unpublished) and unbiased (i.e., 1:1) in three North Carolina populations (Walters 1990, unpublished, LaBranche 1992) and another Florida population (Hardesty *et al.* 1997). Examination of data on fledgling sex ratios from other populations across the region reveals similar variability (R. DeLotelle, unpublished). It has been proposed that in some cooperatively breeding birds sex ratios are biased toward the helping sex as an adaptive evolutionary strategy (Gowaty and Lennartz 1985, Emlen *et al.* 1986, Lessells and Avery 1987, Ligon and Ligon 1990). This hypothesis has been referred to as the repayment model (Emlen *et al.* 1986). However, in a close examination of the repayment model, Koenig and Walters (1999) found it unable to account for sex ratios in red-cockaded woodpeckers and that the model itself may not be correct. Also, the model does not explain the observed variation in sex ratios among populations of red-cockaded woodpeckers. Generally the cause of this variation is poorly understood, and in particular the relationship between other demographic factors and fledgling sex ratios remains unknown. Sex ratio likely will continue to be of theoretical interest, but it has little bearing on management.

As discussed previously, many fledglings remain with the group through their first year and beyond, and become helpers. But even young that disperse in their first year may remain with the group for many months. Some young disperse in late summer, only weeks after fledging. However, most of those who have not yet departed by the onset of cooler weather in autumn remain with their natal group through the winter, and disperse in late February, March or even April. Although both natal and breeding dispersal can occur at any time, the two primary periods during which movement occurs are just before and just after the breeding season.

Helpers contribute substantially to both incubating eggs and feeding young, and their presence increases productivity. Groups with helpers produce more young than groups without helpers, but this is due in part to an association between the presence of helpers and high territory quality, as well as actual contributions of helpers to reproduction. The best estimate of the helper effect, controlling for effects of territory quality, is that productivity is increased by 0.39 fledglings per group per year by the presence of a helper, and by an additional 0.36 fledglings by the presence of a second helper (Heppell *et al.* 1994). For unknown reasons, the usual positive effect of helpers on productivity seems to be lacking in two of the Florida populations (DeLotelle and Epting 1992, Hardesty *et al.* 1997, but see James *et al.* 1997).

The mechanism by which helpers increase productivity is not entirely clear. One might assume that since helpers contribute substantially to feeding, groups with helpers should be able to raise larger broods. Indeed, in some cooperative breeders feeding by helpers results in higher provisioning rates, and reduced partial brood loss. In others, however, feeding by helpers instead results in reduced feeding effort by the breeders, and positive impacts of helpers are due to reduced nest failure rather than reduced partial brood loss (Emlen 1991). The latter scenario may characterize red-cockaded woodpeckers, but the evidence is equivocal. Lennartz *et al.* (1987) reported that higher productivity by groups with helpers on the Francis Marion National Forest was due to reduced partial brood loss. The extent of partial brood loss also is related to the age of the breeders (see below), however, and breeder age can be confounded with presence of helpers in small data sets. Using a much larger sample, and controlling for the age of the female breeder, Reed and Walters (1996) found that in the North Carolina Sandhills higher productivity of groups with helpers was not due to reduced partial brood loss. Instead, groups with helpers were more likely to attempt nesting, and less likely to fail. Khan (1999) found, for this same population, that feeding by helpers resulted in less feeding by parents rather than more food being delivered to nestlings.

Reproductive success is strongly affected by age in both sexes. Young birds are less successful than old birds, and this is manifested in all components of reproduction. That is, young birds are less likely to attempt nesting, more likely to fail, and suffer more partial brood loss. Productivity of one-year-old birds of both sexes is especially poor, but reduced productivity is evident through age three, and the effect is somewhat stronger in males. Ages 4 to 8 are the peak reproductive years, as productivity is reduced somewhat at ages 9 and beyond in both sexes. This may represent senescence (see below).

Mortality

Data on mortality rates come from the same sources as data on reproduction (see above). Good estimates are available from completely marked populations or subpopulations, and patterns are clear and consistent. For a bird of its size residing in temperate regions, the red-cockaded woodpecker exhibits exceptionally high survival rates. Survival rates of adult male helpers and breeders generally are about 5 percent higher than that of breeding females. There is distinct geographic variation in survival similar to that observed for partial brood loss. Survival rates are about 75 percent for males and 70 percent for females in the northern, inland population in the North Carolina Sandhills, about 80 percent and 75 percent respectively in coastal populations in North Carolina, and 86 percent and 80 percent respectively in central Florida. Such an association between increased survival and reduced fecundity is common in animal life histories. Annual variation in adult survival within populations is sufficiently small that it can largely be attributed to random chance rather than changes in environmental conditions (Walters *et al.* 1988a). This level of variation can have large effects in small populations, however, and it appears that there are occasional poor years in which survival is substantially reduced. Also, some populations are vulnerable to periodic catastrophic mortality due to hurricanes (see 2C).

With survival rates as high as these, it comes as no surprise that some individuals live to old ages. A captive female lived to 17 years (J. Jackson, pers. comm.), and a male in the North Carolina Sandhills lived to 16 years of age in the wild (J. Carter III, pers. comm.). The number of very old birds is less than one might expect, however, because red-cockaded woodpeckers apparently experience senescence. In the North Carolina Sandhills survival rates fall to around 50 percent beginning at age 9 in females and age 11 in males. Survival of one-year-old males is also reduced, but only if they are breeders: helper males of age one have typical high survival rates. Survival is fairly constant at ages 1 to 10 in males, and 1 to 8 in females.

Survival during the first year is more prone to underestimation than survival at subsequent ages, due to the greater possibility of dispersal out of the sampling area. Nevertheless, it is quite clear that survival rates are much lower during the first year than thereafter. In three North Carolina populations, survival of males during the first year ranges from 46 percent to 57 percent, and of females from 36 percent to 45 percent. Within a population, survival of males is 10 to 15 percent higher than survival of females. It is not clear whether geographic variation in survival during the first year exists, although there is some evidence that survival is higher in Florida (DeLotelle and Epting 1992). Survival during the first year is affected by the proportion of individuals dispersing rather than remaining as helpers (dispersing lowers survival), and by the number of available breeding vacancies (survival improves as the number of vacancies increases), as well as by the physical environment. This makes it more difficult to detect geographic variation.

Differences between age-sex classes suggest that dispersal is associated with reduced survival. By regressing survival against the proportion of birds dispersing among various categories of females, Daniels and Walters (2000b) estimated the mortality cost of movement for breeding females in the North Carolina Sandhills at 33 percent. That is, dispersal between breeding seasons adds another 33 percent to the probability of mortality above what is expected for sedentary birds. Specifically, the expected survival rate for females that do not move is 74 percent, whereas that for females that do move is 41 percent. This is a surprisingly high cost, given the short distances that most individuals move. This result may reflect the intensity of competition for breeding vacancies, the benefits of belonging to a group, or perhaps the benefits of ready access to a suitable roost cavity.

Overall the mortality pattern is fairly typical of cooperatively breeding avian species. It is characterized by relatively low survival during the first year, especially of dispersers; relatively high survival of breeders and helpers; and senescence at the end of the life span. Compared to non-cooperative species, survival of both juveniles and adults is high, and the life span is long.

Population Dynamics

The population dynamics of the red-cockaded woodpecker are intimately related to the species' unusual social system (Walters 1990, 1991). In demographic terms, population dynamics are strongly affected by the presence of a large class of non-breeding adults, helpers. Helpers provide a pool of replacement breeders in addition to young of the year, and thereby act as a buffer between mortality and productivity in regulating population size. That is, the number of breeding groups in one year is not strongly affected by either productivity or mortality in the previous year. Instead, the size of the helper class is affected by these variables, while the number of potential breeding groups remains remarkably constant. If mortality exceeds productivity, the number of helpers will decrease, because the number of replacement breeders drawn from the helper class will exceed the number of fledglings recruited into it. If productivity exceeds mortality, the opposite will occur, and the number of helpers will increase. Therefore average group size is an important indicator of population health, as it indicates the potential to maintain the size of the breeding population in the face of fluctuations in mortality and productivity. Of course the strength of the buffering effect of helpers depends on the size of the helper class. In small populations the number of helpers may be so few that poor survival or reproduction can have a direct, negative effect on the size of the breeding population (Lennartz and Heckel 1987, DeLotelle *et al.* 1995).

In evolutionary terms, adoption of the helping strategy is closely linked to patterns of territory occupancy (Walters 1990, 1991). Remaining on the natal territory as a helper can be viewed as a strategy, involving delayed reproduction and dispersal, and altered dispersal behavior, to acquire a breeding position. Helpers stay at home and wait for a breeding vacancy to arise in their vicinity, either on the natal territory or a neighboring one (Walters *et al.* 1992b). This strategy is thought to be an effective one when competition for breeding vacancies is intense (Zack and Rabenold 1989). Further, the intense competition for breeding vacancies that characterizes cooperative breeders is thought to result from unusually large variation in territory quality (Stacey and Ligon 1991, Emlen 1991, Koenig *et al.* 1992).

In red-cockaded woodpeckers, variation in territory quality is related to the presence of cavities. Because cavities take so long to construct, an individual does better to acquire a breeding position on an existing territory containing suitable cavities than to occupy vacant habitat and construct new cavities (Walters 1991, Walters *et al.* 1992a, Conner and Rudolph 1995a). Thus habitat lacking suitable cavities is poor quality, and habitat with existing, suitable cavities is high quality. The birds ignore poor quality habitat, even though they could excavate cavities and then reproduce successfully there, and compete intensely for openings in high quality habitat. When artificial cavities are added to unoccupied but otherwise suitable habitat, it immediately becomes high quality habitat, and is quickly occupied (Copeyon *et al.* 1991, Walters *et al.* 1992a).

The implication of this view of population dynamics is that the breeding population size (usually measured as the number of potential breeding groups) is determined by the number of high quality territories, which depends on the number and distribution of suitable cavities. This is consistent with the behavior of populations during the species' decline (Walters 1991), as well as with recent increases in some populations under new management. The dominant feature in population declines has been gradual abandonment of territories rather than poor survival or reproduction. In many cases it is clear that territory abandonment was related to loss of cavities to tree death or cavity enlargement, or to encroachment by hardwood midstory (Jackson 1978b, Van Balen and Doerr 1978, Conner and Rudolph 1989, Costa and Escano 1989). With so many threats to cavities, it was easy to lose territories, and thus populations declined, despite the continued presence of helpers and good productivity on those territories that remained suitable. Often territories are occupied by an unpaired male for a period prior to abandonment, so that response to loss of cavities and other adverse events is delayed (Jackson 1994). This may be because once territories deteriorate, young birds no longer remain as helpers and females no longer consider them acceptable, but the breeding male refuses to leave. The territory is no longer acceptable to dispersing males, however, so once the original breeding male dies, which may be many years later, the territory is finally abandoned.

New groups on new territories arise by two processes, pioneering and budding (Hooper 1983). Pioneering is the occupation of vacant habitat by construction of a new cavity tree cluster, which according to the view of population dynamics just presented, is expected to be rare. Budding is the splitting of a territory, and the cavity tree cluster within it, into two. Budding is common in many other cooperative breeders, and might be expected to be more common than pioneering in red-cockaded woodpeckers, since the new territory contains cavities from the outset.

The available data indicate that budding indeed is more common than pioneering, and that pioneering is quite rare. In the North Carolina Sandhills, the observed rate of pioneering over 16 years is one event per 1572 existing groups per year, and in Croatan National Forest in coastal North Carolina, over 7 years it is one event per 332 existing groups per year (J. Walters, unpublished). These translate into population growth rates of 0.06 percent and 0.3 percent per year. However, at nearby Marine Corps Base Camp Lejeune, the rate of pioneering over 10 years has been one event per 46 existing groups per year, a population growth rate of 1.5 percent per year (J. Walters, unpublished). During these same periods, rates of population growth through budding have been 0.6 percent, 2.1 percent, and 0.6 percent for the North Carolina Sandhills, Croatan National Forest, and Marine Corps Base Camp Lejeune respectively. Combining budding and pioneering, growth rates are 0.7 percent, 2.4 percent, and 2.2 percent per year respectively. During the years when the North Carolina Sandhills population was declining (1980 to 1984) the growth rate through these processes was 0.1 percent per year, whereas over the subsequent years, when the population was stable, it was 0.9 percent. A population growth rate of 10 percent per year through these processes was reported for the Francis Marion National Forest (Hooper *et al.* 1991a). In this case pioneering and budding events were inferred rather than directly observed, unlike in North Carolina, and it is possible that the rate of population growth was overestimated. Still, this study suggests that the rate of population growth through budding and pioneering potentially can be substantially greater than what has been observed in North Carolina.

Why the rates of budding and pioneering vary so much is a mystery. It appears from the North Carolina data that rates may be higher in small populations (Croatan, Lejeune) than in large ones (Sandhills), but this is inconsistent with the data from the Francis Marion. Another interpretation is that the rates are higher where turnover of breeders is less, and thus opportunities to replace deceased breeders are fewer. A third hypothesis is that budding and pioneering are stimulated by burning specifically, or habitat improvement generally. This is consistent with the North Carolina data in that rates have been higher in recent years in the Sandhills and Lejeune, following reintroduction of growing season fire, and lower in the last several years on Croatan, since burning during the growing season there has been reduced. A fourth hypothesis is that conditions for population growth may be more favorable in flatwoods habitat than in sandhills habitat.

Rates of budding and pioneering may vary for unknown reasons, but it is clear that they are almost always quite low. These rates were too low to counter losses of territories during the 1970’s and 1980’s when populations were declining, and they limit the potential for recovery currently, even if losses of territories can be prevented. Thus it is easy to understand why, until the advent of artificial cavity construction, populations generally have been stable or declining rather than increasing.

Understanding that population size is determined by the number of territories with suitable cavities makes designing management to increase populations straightforward (Copeyon *et al.* 1991, Walters 1991). To prevent loss of occupied territories, existing cavity trees should be protected, so that a sufficient number of suitable ones are maintained at all times. This can involve eliminating encroaching hardwoods, protecting cavities with restrictors, or replacing lost cavities with artificial ones. To increase the number of suitable territories, cavities can be added in unoccupied habitat, such as abandoned territories with existing cavities and completely vacant areas. In theory it might be possible to rehabilitate abandoned territories by placing restrictors on existing cavities or eliminating hardwoods. In practice, however, only recently abandoned territories seem to be reoccupied without the addition of new cavities (Doerr *et al.* 1989). This may be because cavities deteriorate if unused for long periods. Therefore, for both abandoned territories and vacant habitat, usually the only effective means to create a suitable territory is to construct new artificial cavities in open pine habitat.

Where a management strategy based on maintaining and creating suitable territories has been followed, it has been effective in increasing populations. There have been successes at Eglin Air Force Base (Hardesty *et al.* 1997, J. Walters *et al.*, unpublished), Osceola National Forest (USFWS, unpublished), Marine Corps Base Camp Lejeune (Walters *et al.* 1995), Fort Stewart (T. Beaty, unpublished), Fort Benning (M. Barron, unpublished), Noxubee National Wildlife Refuge (J. Tisdale, unpublished), and Piedmont National Wildlife Refuge (R. Shell, unpublished). Rates of population increase are similar across sites, suggesting that a rate of increase of 10 percent per year is perhaps the best that can be achieved (without resorting to translocation). It may be that the pool of new breeders (i.e., helpers, floaters, and first-year birds) generally is not large enough to permit higher rates of increase.

The current understanding of population dynamics suggests not only that management designed to increase the number of suitable territories will be effective, but also that management designed instead to increase productivity and survival will be ineffective in most circumstances. Thus measures designed to thwart nest predators, prevent cavity kleptoparasitism (except to prevent cavity enlargement), or eliminate predators of fledglings and adults often will be ineffective in promoting population growth. Such measures may be necessary, however, in intensively managed, extremely small populations where every individual is critically important. The population at the Savannah River Site provides the best example of successful, intensive management of a small population (Haig *et al.* 1993, Franzreb 1997).

Like so many other characteristic traits of this species, the origin of its complex social system and unusual population dynamics can be traced back to its most unique feature, excavation of cavities for roosting and nesting in live pine trees. The understanding of these relationships that has been achieved is cause for optimism about the future of the species. Unlike for so many other species, it appears that our understanding of the species' biology is sufficient to construct a management strategy likely to produce recovery, and recent results support this supposition. Ability to implement this strategy is now the key to recovery.

C. POPULATION AND SPECIES VIABILITY

A viable species is one that can reasonably be expected to avoid extinction over a long period of time. Similarly, a viable population is one that is self-sustaining over a long period. For any endangered species, achieving species viability is the ultimate conservation goal, and the ultimate objective of a recovery plan such as this one. How species viability relates to population viability is dependent on population structure. Species viability may be achieved by maintaining a number of independent viable populations and/or by maintaining a network of interacting populations, none of which are viable on their own. We conclude that, for red-cockaded woodpeckers, the appropriate strategy is to maintain a number of independent demographically viable populations and a number of interacting populations within and between recovery units to promote genetic viability. Here we discuss information about population structure that led us to these conclusions, and then how population viability is best achieved.

Population Structure

Given the historic distribution of its habitat and comments by early naturalists about its abundance, it is highly likely that red-cockaded woodpeckers originally were distributed fairly continuously over broad areas. Since the birds are so sedentary (see 2B), one presumes that originally there may have been considerable genetic substructure within populations, but that distinct, genetic population boundaries were lacking. That is, genetic similarity probably changed gradually with distance, rather than suddenly at population boundaries. In fact, it may have been difficult to even delineate distinct populations.

Such is not the case currently. Now the species is distributed largely as distinct populations, with large gaps of unoccupied land between them. Most of these populations are quite small, and only a few are of more than modest size (see map insert and Tables 5, 6, 7, and 9). Typical dispersal distances of both sexes are sufficiently short to maintain genetic substructure within populations even under current conditions. Daniels and Walters (2000a) found that an individual's close relatives are highly concentrated within three territories of the natal site. Thus one can expect genetic similarity to change with distance within populations, as opposed to the uniform structure that occurs when mating is random within populations.

Although this species is highly sedentary compared to other birds, some individuals move long distances (Walters *et al.* 1988a). There is sufficient documentation (Walters *et al.* 1988b, Conner *et al.* 1997c, Ferral *et al.* 1997, R. Costa, pers. comm.) to conclude that long-distance movements between populations are rare but regular events, and that the birds can move through seemingly inhospitable habitat. It appears that movement from small populations into large ones is much more common than the reverse. Because of this, and the rarity of such movements, they are of little consequence demographically; that is, their contribution to sustaining populations is trivial. However, they may be frequent enough to be important genetically, and may function to maintain genetic variability within populations. Producing immigrants that contribute to this function may be one of the primary purposes that small support populations serve.

The most reasonable conclusion, based on current information, is that demographically, populations of red-cockaded woodpeckers function as closed populations. That is, their persistence depends totally on within-population demography, and not at all on exchange between populations. Thus red-cockaded woodpeckers do not exhibit any of the various types of metapopulation structure (Stith *et al.* 1996). Local extinction followed by natural recolonization from another population is extremely unlikely for this species. (The event closest to natural recolonization was the appearance of a male from the Savannah River Site within a recruitment cluster on Fort Gordon, two years after the Fort Gordon population was extirpated. This dispersal event would not likely have resulted in the formation of a breeding pair without the use of translocation.)

Further, immigration rates are too low for one population to rescue another from extinction as occurs in another cooperatively breeding woodpecker, the acorn woodpecker (*M. formicivorous*; Stacey and Taper 1992). Neither are immigration rates high enough to enable source-sink relationships between populations. However, in areas of low density (e.g., northeastern North Carolina), widely scattered groups considerable distances apart may function as a single population. Dispersal distances are longer when population density is lower (Daniels 1997), apparently because the distance moved is a function primarily of the number of groups encountered rather than of habitat, mortality or speed of movement. Thus migration between two sizeable populations only 24.2 km (15 mi) apart may be rare (e.g., only one movement between the Camp Lejeune and Croatan National Forest populations in North Carolina over 11 years), whereas two groups 24.2 km (15 mi) apart in an area of low density (e.g., only one other group between them) may exchange individuals regularly.

Red-cockaded woodpecker populations should not be viewed as closed genetically, however. Nearly all probably experience some immigration, much of it from smaller support populations. Rates of immigration and genetic relationships between populations are not well enough known to determine precisely the rate of gene flow, nor its effect on genetic variability within populations. All that can be said is that the existence of gene flow needs to be considered when evaluating the genetic viability of populations (see below).

There are, however, both allozyme (Stangel *et al.* 1992, Stangel and Dixon 1995) and random amplified polymorphic DNA (RAPD) data (Haig *et al.* 1994a, 1996) available that reveal general genetic relationships between populations. These data indicate that most (93 percent, Haig *et al.* 1994a) genetic variation occurs among individuals within populations. Genetic differences between populations increase somewhat with geographic distance, but there is little geographic structure to genetic variability. Genetic differences between populations are greater than is typical of birds, but equivalent to those in other endangered birds. However, populations do not exhibit unique alleles. Some small populations exhibit reduced heterozygosity, but not all do, and generally there is no consistent relationship between population size and genetic variability (Stangel and Dixon 1995). All of this information is consistent with recent isolation of populations in a formerly continuously distributed species, with low levels of gene flow between populations. Populations probably are diverging genetically and losing variability currently, but isolation evidently is too recent for them to differ much yet.

Threats to Population Viability

Information on population structure indicates that the best approach to viability is to manage for independent populations that are individually viable, with appropriate recognition of low levels of gene flow between populations. To assess population viability, generally four threats are considered: (1) demographic stochasticity, (2) environmental stochasticity, (3) catastrophes and (4) genetic drift and inbreeding (Shaffer 1981, 1987). All four threats must be adequately addressed to ensure viability. Here we examine each threat, treating demographic stochasticity and environmental stochasticity together as demographic considerations, and catastrophes and genetic concerns as separate issues. In the previous recovery plan (USFWS 1985) only catastrophes and genetic factors were considered.

Demographic Considerations

Demographic stochasticity refers to effects of random events on the reproduction and survival of individuals, whereas environmental stochasticity refers to effects of unpredictable events that alter vital rates. For example, if every individual has a 50 percent probability of annual survival, in a population of 20 individuals 10 will not die each year. Instead some years by chance nine will die, in others eleven and so forth. This is demographic stochasticity, which is analogous to sampling error. It may be that in years with severe winters the probability of survival is only 30 percent, whereas in years with mild winters it is 70 percent. This is an example of environmental stochasticity.

Demographic stochasticity is inevitable, but is usually considered to be a threat only to small populations, i.e., less than 50 individuals (Meffe and Carroll 1997). Environmental stochasticity varies widely in strength, depending on the species and the nature of its interactions with its environment. Viability in the face of these threats usually is assessed by incorporating them in simulations of population dynamics, and determining the probability of extinction over long time periods in populations of various sizes. The chief obstacle to a comprehensive viability analysis previously has been lack of a suitable population model. Standard, simple population models do not incorporate the social complexity of the species, notably the buffering effect of the large, nonbreeding helper class (see 2B). These complexities can be handled by stage-based matrix models (Caswell 1989, McDonald and Caswell 1992). Application of these models to red-cockaded woodpeckers has produced important insights about population behavior and management (Heppell *et al.* 1994, Maguire *et al.* 1995). But even these models do not incorporate critically important spatial dynamics resulting from helpers filling breeding vacancies only on or very near their natal territory. A model that assumes that nonbreeders fill breeding vacancies randomly within the population cannot be expected to portray population dynamics accurately enough to perform viability analysis.

The advent of spatially-explicit, individual-based simulation models in ecology provides a tool capable of handling the complex population dynamics of red-cockaded woodpeckers (DeAngelis and Gross 1992, Judson 1994, Dunning *et al.* 1995). These models are not without their faults, a notable one being the large number of parameters that must be accurately estimated if model results are to be trusted (Conroy *et al.* 1995). A spatially-explicit, individual-based model of the population dynamics of red-cockaded woodpeckers has been developed by Letcher *et al.* (1998), using data from the North Carolina Sandhills.

Letcher *et al.* (1998) used their model to assess effects of demographic stochasticity on populations of various sizes and spatial distributions. Their most notable result was the strong effect of spatial structure on viability. If territories were highly clumped, populations of as few as 25 groups were remarkably persistent, whereas if territories were scattered, populations as large as 169 groups declined. New group formation through budding and pioneering (see 2B), which was not then incorporated into the model, would presumably be sufficient to counter the small declines experienced by the largest populations. Still, the model predicts that demographic stochasticity will be a threat to populations as large as 100 groups if spatial structure is poor, but will not be a threat to populations as small as 25 groups if spatial structure is favorable. Recent analyses indicate that even smaller populations, as small as 10 groups, can be remarkably persistent if the territories are maximally clumped (Crowder *et al.* 1998, Walters et al. 2002b). These model results are consistent with empirical evidence. Across the range it seems that small aggregates of groups persist surprisingly well, whereas small, low-density populations always seem to decline. Even in somewhat larger populations, loss of isolated groups is a problem (Conner and Rudolph 1991b).

We conclude that demographic stochasticity is, as usual, a threat only to small populations. However, the threshold of vulnerability varies considerably with spatial structure. Vulnerable populations may be twice the typical size, or half the typical size, depending on the configuration of the population. It certainly is possible to avoid this threat for populations as small as 25 groups, and it may be possible to avoid it for populations of only 10 groups. Managers therefore should strive to aggregate their populations, and to avoid isolation of groups, where isolation is defined as being beyond the dispersal range of helpers. Based on data from the North Carolina Sandhills (Walters *et al.* 1988a, Daniels 1997), 3.2 km (2 mi) appears to be a reasonable standard to use for the maximum dispersal range of helpers (less than 10 percent of helpers [17 of 240] dispersed more than 3.2 km [2 mi]; Daniels 1997). This maximum dispersal distance refers to habitat that contains no barriers to dispersal. The ideal spatial configuration is one in which every group is within dispersal range of helpers from several other groups.

Evaluating environmental stochasticity is more difficult. Letcher *et al.*'s (1998) model is suitable for this purpose, but accuracy of results will depend not only on the validity of the model, but also on estimates of the magnitude of stochasticity. Typically stochasticity is incorporated as annual variation, and therefore the appropriate variance of each demographic parameter must be determined. It is quite clear from available data that annual variation in productivity is considerable, but annual variation in mortality appears to be fairly small (Walters *et al.* 1988a).

Preliminary analyses of population viability incorporating environmental as well as demographic stochasticity have recently been completed using the model developed by Letcher *et al.* (1998). In these analyses, the magnitude of environmental stochasticity was estimated from observed annual variation in the North Carolina Sandhills population, and annual variation in productivity, adult survival, and fledgling survival was incorporated (Crowder *et al.* 1998, Walters et al. 2002b). Budding was incorporated into the simulations as well. These results suggest that populations of 100 or fewer groups are vulnerable to extinction, even when territories are maximally clumped. Populations of 250 or more groups are not vulnerable to environmental stochasticity, according to these simulations, even if territories are not highly clumped. Viability of populations between 100 and 250 groups depends on spatial configuration as well as population size, although this has not yet been analyzed in detail.

Clearly, more analyses are necessary before a more precise viability criterion can be defined, but results at hand permit some important conclusions. First, as expected, populations must be considerably larger to avoid the threat of environmental stochasticity than they need be to avoid the threat of demographic stochasticity. Second, the population sizes necessary to achieve viability against these two demographic threats are much smaller than is typical. This is an intuitive result, since the presence of helpers can be expected to dampen oscillations in the breeding population caused by variation in productivity and breeder survival. Years of poor productivity, or low breeder survival, will lead to a reduction in the size of the helper class rather than a reduced number of potential breeding groups. Third, the level of assistance, in the form of translocated birds, required to avoid extinction of small populations may be low enough to be feasible. Fourth, spatial configuration becomes increasingly important to viability as populations become smaller.

It is encouraging that population sizes required to avoid demographic threats to viability fall within a range that is achievable. Producing populations of two thousand groups, were that required, would be inconceivable. Managing to produce populations of 250 or more potential breeding groups with a favorable spatial structure, on the other hand, is a realistic goal. Indeed a few populations already match this description.

Genetic Considerations

There are two genetic threats to population viability. The first, inbreeding depression, threatens only small populations, whereas the second, genetic drift, can threaten even large populations (reviewed in Lande 1995). Inbreeding depression reduces the survival and productivity of individuals, and results from the segregation of partially recessive, deleterious alleles. The resulting negative effect on population dynamics increases vulnerability to extinction. The amount of inbreeding depression depends on the rate of inbreeding and the opportunity for selection to purge recessive lethal and semi-lethal mutations (Lande 1995). Genetic drift results in the loss of genetic variation, which may reduce a species' ability to adapt and persist in a changing environment, and thereby its viability over long time periods. The rate of loss is inversely related to population size and mutation rate, and viability is achieved when the population size is large enough that loss to drift is in equilibrium with gain from mutation.

The red-cockaded woodpecker is one of the few species for which inbreeding depression has been demonstrated in wild populations, as opposed to assumed from theoretical considerations. In the North Carolina Sandhills, productivity of both closely related (i.e., coefficient of relationship greater than 0.125) pairs and their inbred progeny is substantially lower than that of unrelated pairs and their progeny (Daniels and Walters 2000a). This is due to both reduced hatching rates of eggs and reduced survival of fledglings to age one year. These are precisely the sort of traits one expects to be affected by segregation of partially recessive, deleterious alleles, and in fact reduced hatching rate is the classical manifestation of inbreeding depression in domestic birds (Daniels and Walters 2000a).

Although inbreeding depression is clearly a threat to red-cockaded woodpecker populations, its effects may not yet be evident due to the recent nature of reductions in population size. The available genetic data indicate that most small populations do not yet exhibit high levels of homozygosity (see above). Furthermore, Stangel and Dixon (1995) found no evidence that small populations were experiencing increased morphological variability. They examined fluctuating asymmetries of paired characters, which are often used as an indicator of developmental stability (Leary and Allendorf 1989). Developmental instabilities are thought to be one of the manifestations of inbreeding depression.

Although it appears that there has not yet been sufficient time for the various manifestations of inbreeding depression to become prevalent, they can be expected to increase in the near future in populations that remain small and isolated. Franklin (1980) suggested that populations with an effective size of 50 individuals or less would be vulnerable to inbreeding effects. Since the red-cockaded woodpecker can be characterized as a species in which large populations have been reduced suddenly to small size, it is reasonable to apply this standard to this species. That is, it is unlikely that previous selection has already purged recessive alleles from red-cockaded woodpecker populations. Instead, this species probably is quite vulnerable to this threat.

Effective size refers to an idealized population in which individuals mate randomly and all contribute equally to reproduction. In this hypothetical ideal population, all individuals pass on an equal number of their genes to subsequent generations. Effective size is a theoretical standard used to estimate the retention and loss of genetic variation in a real population. The effective population size itself is never measured directly; it is calculated using formulas based on genetic theory and demographic data collected from real populations.

The actual population size is almost always higher than the effective size, because several characteristics of animals and populations act to make the genetic contribution of individuals to subsequent generations unequal. For example, some pairs or individuals may consistently produce more offspring than others, and some individuals live longer than others. It is mainly this variation in reproductive success that makes effective size less than actual size.

Thus, it is possible to calculate the effective size of a population if its demography is known. Such calculations indicate that for red-cockaded woodpeckers, the actual population size needed to achieve an effective size of 50 individuals is 31 to 39 potential breeding groups, depending on the details of the demography of particular populations (Reed *et al.* 1988b, 1993, D. Heckel and M. Lennartz, unpublished). According to Franklin's (1980) suggestion that an effective size of 50 is necessary to withstand threats from inbreeding depression, stable or increasing populations of 40 or more potential breeding groups are not threatened by inbreeding depression.

Daniels *et al.* (2000) came to a fairly similar conclusion by using the spatially explicit model developed by Letcher *et al.* (1998). They estimated inbreeding levels over time in red-cockaded woodpecker populations of various sizes and rates of immigration. In their simulations, mean inbreeding increased rapidly in very small, declining populations with no immigration, but remained tolerably low in closed, stable populations of 100 occupied territories. Moderately high levels of immigration were required to stabilize small declining populations and maintain reasonable inbreeding levels (kinship coefficients less than 0.10). That is, inbreeding depression is not expected to affect populations that are receiving 2 or more migrants per year. In the absence of immigration, Daniels *et al.* (2000) found that a stable population of 50 to 100 or more breeding groups was necessary to avoid inbreeding depression. Thus, based on the work by Daniels *et al.* (2000) as well as Franklin's (1980) initial suggestion, we conclude that stable or increasing populations of at least 40, and possibly as many as 100 potential breeding groups—or an immigration rate of 2 or more migrants per year—are required to protect against inbreeding depression.

The population size necessary to avoid loss of genetic variation due to genetic drift, however, is much larger. Franklin (1980) first proposed that an effective size of 500 individuals would allow maintenance of long-term viability, because loss of genetic variation from drift would be offset by the creation of new variation through natural mutation. Recently, however, this number has been a topic of some debate (Lande 1995, Franklin and Frankham 1998, Lynch and Lande 1998, Allendorf and Ryman, in press). Lande (1995) indicated that only populations with an effective size of over 5000 individuals can be expected to maintain viability in the absence of immigration, because not all mutations are beneficial. Others argue that an effective population size of 500 to

1000 individuals is sufficient (Franklin and Frankham 1998). At issue is the potential effects of harmful mutations: Franklin and Frankham (1998) consider these effects negligible, but others have suggested that slightly deleterious mutations are capable of causing population extinction even at effective sizes of several hundreds (Lande 1994, Lynch *et al.* 1995, Lynch and Lande 1998). The debate will likely continue, but a reasonable conclusion is that only populations with actual sizes in the thousands, rather than hundreds, can maintain long-term viability and evolutionary potential in the absence of immigration (Allendorf and Ryman, in press).

Thus, without immigration, populations of red-cockaded woodpeckers that have reached recovery goals may still be susceptible to loss of genetic variability through genetic drift. One practical way to reduce this threat is to promote immigration, both natural (from support and other core populations) and artificial (from translocation). Sufficient connectivity among populations, in the order of 1 to 10 migrants per generation in each direction (0.25 to 2.5 migrants per year), can maintain genetic variation and long-term viability for the species (Mills and Allendorf 1996). Populations connected by this level of immigration maintain genetic variation equal to that of one population as large as the sum of the connected populations (F. Allendorf, pers. comm.). As populations increase, natural dispersal among them will likely increase, but determining actual rates of natural immigration is a critical research need.

A second practical way to reduce the effects of genetic drift is to recover the species as quickly as possible. Loss of genetic variation increases with decreasing population size, but such loss also increases dramatically if populations remain small over time (Hartl 1988). Current efforts to increase populations, and the lack of such efforts, have substantial effects on the total genetic variation that will be retained by the species in the future.

Finally, one population, Central Florida Panhandle, may be large enough at delisting to retain its genetic variability despite genetic drift. This population will harbor 1000 potential breeding groups at delisting. For red-cockaded woodpeckers, 1000 potential breeding groups is considered equivalent to an effective population size of 1280 to 1560 individuals (Reed *et al.* 1988b, 1993). Several researchers consider a population of this effective size capable of maintaining genetic variability (Franklin and Frankham 1998, Allendorf and Ryman, in press).

Catastrophes

Catastrophes are rare, irregularly occurring events that produce extreme changes in demography and population dynamics. There are two types of catastrophes that threaten red-cockaded woodpecker populations: catastrophic winds (hurricanes, downbursts, and tornadoes) and outbreaks of southern pine beetles. The beetles kill cavity trees, but not birds—at least not directly. It is possible that loss of foraging habitat and cavity trees to beetles could alter survival and productivity of woodpeckers, but this has not been demonstrated. Outbreaks of sufficient size to constitute a catastrophe at the population level will probably be restricted to small populations dependent on tree species other than longleaf pine. Longleaf is sufficiently resistant to beetles to preclude outbreaks large enough to constitute a catastrophe. In other habitat types, the only real threat to population viability is loss of cavity trees, and this can be countered by construction of artificial replacement cavities. Appropriate forest management can minimize the likelihood of catastrophic outbreaks.

Hurricanes, however, are the greatest catastrophic threat to population viability. The devastation wrought by Hurricane Hugo on the population inhabiting the Francis Marion National Forest demonstrated all too clearly that such storms can produce catastrophic changes in mortality (Hooper *et al.* 1990). Further, by eliminating all cavity trees on many territories Hugo resulted in a catastrophic increase in the rate of territory abandonment, beyond that attributable to mortality alone. Because of the distribution of red-cockaded woodpeckers, most populations face a significant risk from hurricanes, although there is little risk to some inland populations (Hooper and McAdie 1995). That hurricanes will regularly strike woodpecker populations is inevitable, and therefore any strategy to ensure species and population viability must address this form of catastrophe specifically.

The first element in addressing the hurricane threat is to reduce risk to the species as a whole by maintaining a number of populations that are broadly spaced geographically, and including as many inland populations as possible among them (Hooper and McAdie 1995). The second element is to reduce risk of extinction of individual populations through rehabilitation following the catastrophes that occur. The Hugo experience demonstrates that it is possible, albeit at considerable expense, to reduce impacts at the population level and facilitate recovery to approach pre-storm levels through proper management immediately following the storm (Watson *et al.* 1995). The critical activity is to construct artificial cavities quickly, and distribute them so that as few territories as possible are completely lacking in cavity trees. This will maximize the number of territories that remain occupied, which is the most critical component of population dynamics. It is anticipated that one or two recovery populations, as well as a number of support populations, will be in the process of recovering from storms at any given time (Hooper and McAdie 1995). Some support populations may be lost to hurricanes, despite proper rehabilitation efforts, but recovery populations should not be.

The third and final element in addressing the hurricane threat is to manage individual populations at risk to reduce their vulnerability to wind damage. Hooper and McAdie (1995) offer a number of suggestions, such as reducing access of wind into stands and creating conditions for growth that favor development of greater wind resistance. More research in this area is needed before a detailed policy can be developed, but managers of populations at risk should consider the factors discussed by Hooper and McAdie (1995) in developing their forest management plans.

A Strategy for Species Viability

The strategy to recover the red-cockaded woodpecker consists of recovering a number of individual populations, designated recovery populations, to levels at which they are individually viable against environmental stochasticity. Populations large enough to be resilient to environmental stochasticity will also be able to withstand threats from demographic stochasticity and inbreeding. Currently, our best estimate of the population size necessary to withstand effects of environmental stochasticity is 250 potential breeding groups. However, this is a minimum estimate based on model simulations, and it may contain some error. To be conservative, a number of larger populations (350 potential breeding groups) will exist at the time of recovery. These two population sizes, 250 and 350 potential breeding groups, are probably insufficient to avoid loss of genetic variation through genetic drift, at least in the absence of immigration. (Some researchers consider 350 breeding groups the minimum size necessary to produce enough novel variation to offset loss from drift).

There are several strategies to reduce the loss of genetic variation as much as possible. First, recovery populations should be increased as far beyond the above population sizes as the habitat base will allow. Second, populations should be recovered as rapidly as possible, because loss of genetic variation increases with the length of time that populations remain small. Third, recovery populations represent the full range of habitat types now occupied by red-cockaded woodpeckers, and this range will aid the conservation of local genetic resources. Finally, dispersal between populations should be facilitated to the fullest extent possible. We have increased the total number of designated recovery populations identified in the 1985 recovery plan (USFWS 1985) in part to enhance the likelihood of natural dispersal among these populations once the species is recovered. We stress the importance of support populations as sources of immigrants to replace lost variability, and that support populations should be maintained until and after recovery. We recognize that translocation may need to be employed to maintain genetic variation within populations and species-wide, if natural dispersal is found to be insufficient.

Support populations should include at least 40 to 100 potential breeding groups, depending on spatial configuration, in order to eliminate demographic stochasticity and inbreeding depression as threats to their existence. If they can be maintained at even higher levels, their likelihood of extirpation due to environmental stochasticity will be reduced. Support populations that cannot meet the 40 to 100 size criterion can still serve the purpose of providing genetic variability to other populations, but extirpation of some of these is anticipated. We recommend that they be maintained at the largest size the habitat base will support.

The value of support populations depends on their genetic and spatial relationship to recovery populations. Value cannot be assessed precisely until more information about actual immigration, or how probability of immigration depends on distance and intervening habitat type, is available. The number of support populations required for each recovery population cannot be determined until information on levels of gene flow necessary to compensate for lost genetic variability is available. In the meantime, all support populations, including those of less than 40 potential breeding groups, should be considered necessary to species viability.

The designated recovery populations were selected to eliminate the risk of extinction to the species as a whole due to hurricanes. Measures designed to reduce vulnerability to wind damage and to rehabilitate populations following storms should be sufficient to prevent extirpation of those individual recovery populations at risk. However, some support populations may be lost to hurricanes, with risk being a function of population size, location, and expected frequency of storms.

Populations must be managed to achieve favorable spatial configuration, as well as large size. Specifically, groups should be clustered to the extent possible, so that each group has multiple other groups within 3.2 km (2 mi). Special attention should be paid to the edges of the population, to keep isolation of individual groups there to a minimum.

Habitat restoration within populations is a critical aspect of species recovery. Populations are limited by available cavities and by the quality of foraging habitat. Limitation by available cavities has been documented by experimental research (Walters *et al.* 1992). Limitation by quality of foraging habitat is evidenced by smaller territories in areas where the habitat is better (see 2E). Without restoration of nesting and foraging habitat, species viability is not achievable.

In summary, the strategy to achieve species viability is to maintain a number of recovery populations within each recovery unit that, with immigration, are individually viable to genetic and demographic threats. Development and maintenance of viable recovery populations is dependent on restoration and maintenance of appropriate habitat. The threat to species viability from hurricanes is substantially reduced by maintaining a sufficient number of recovery populations, including inland ones, so that anticipated, periodic catastrophic reductions in some recovery populations do not threaten the species as a whole.

D. CAVITIES, CAVITY TREES, AND CLUSTERS

Red-cockaded woodpeckers are unique among North American woodpeckers in that they nest and roost in cavities they excavate in living pines (Steirly 1957, Short 1982, Ligon *et al.* 1986). This unusual behavior is thought to have evolved in response to the scarcity of snags and hardwoods in the fire-maintained pine ecosystems of the southeast (Ligon 1970, Jackson *et al.* 1986). Excavation of cavities in live pines has given rise to additional unusual and complex behaviors, ranging from cooperative breeding (Walters *et al.* 1992a; see 2B) to daily excavation of resin wells to create resin barriers against predatory rat snakes (*Elaphe obsoleta,* Ligon 1970, Dennis 1971b, Jackson 1974, 1978a, Rudolph *et al.* 1990b). Use of live pines is also the primary reason why the species requires mature pines, the loss of which has resulted in endangerment. Cavities are an essential resource for red-cockaded woodpeckers throughout the year, because they are used for both nesting and roosting. Thus, a thorough understanding of cavity tree ecology is fundamental to red-cockaded woodpecker biology, management, and recovery. This section describes current knowledge in support of the guidelines for management of cavity trees and clusters presented in 8F.

Cavity Excavation and Selection of Cavity Trees

Excavation of cavities in live pines is an amazingly difficult task. Birds must first select an old pine (Jackson and Jackson 1986, Conner and O'Halloran 1987, DeLotelle and Epting 1988, Rudolph and Conner 1991), then excavate through 10 to 15 cm (4 to 6 in) of live sapwood, avoid dangerous pine resin that seeps from the cavity during excavation, and construct a cavity completely contained within the heartwood (Jackson 1977, Hooper *et al.* 1980, Conner and Locke 1982, Conner and O'Halloran 1987, Hooper 1988, Hooper *et al.* 1991b). Cavity excavation typically takes many years (Jackson *et al.* 1979, Rudolph and Conner 1991, Conner and Rudolph 1995a, Harding 1997).

The difficulty of cavity excavation is considered a major factor in the evolution of cooperative breeding in red cockaded woodpeckers (Walters 1990, Walters *et al.* 1988a, 1992a, 1992b; see 2B). Birds cannot easily exploit previously unoccupied habitat and build cavities, and so competition for territories with existing cavities is unusually intense. Young males delay reproduction and remain on their natal territory as helpers to increase their likelihood of obtaining a breeding site with existing cavities (Walters 1990, Walters *et al.* 1988a, 1992b). Natural formation of groups in previously unoccupied habitat (pioneering, Hooper 1983) is rare; its estimated annual rate is less than 3 percent of total groups in a population under current conditions (Walters 1990; see 2B).

Red-cockaded woodpeckers use a variety of pine species as cavity trees including longleaf, loblolly, shortleaf, slash, pond, pitch (*P. rigida*), and Virginia pines (*P. virginiana*; Steirly 1957, Lowery 1960, Mengel 1965, Sutton 1967, Hopkins and Lynn 1971, Jackson 1971, Murphy 1982). Longleaf, loblolly, and shortleaf pines are the most common species used for cavity trees and longleaf is considered preferred (Lowery 1960, Hopkins and Lynn 1971, Jackson 1971, Baker 1981, Bowman *et al.* 1997). All cavities are excavated in live pines, but occasionally woodpeckers roost and even nest in cavities in trees that have recently died (Hooper 1982, Patterson and Robertson 1983, R. Costa, pers. comm.).

Red-cockaded woodpeckers are able to exploit the resin of the live pine to protect against predation of nests and adults by arboreal snakes (Ligon 1970, Dennis 1971b, Jackson 1974, 1978a, Rudolph *et al.* 1990b). The birds create and maintain resin wells, or wounds in the cambium, to coat the trunk with resin which then effectively interferes with the snakes' ability to climb the tree (Rudolph *et al.* 1990b).

Longleaf pine may be preferred for use as cavity trees because it produces more resin and can sustain resin flow for more years than other southern pines (Wahlenburg 1946, Hodges *et al.* 1977, 1979, Bowman and Huh 1995, Ross *et al.* 1995). The production of more resin affords the birds greater protection against snakes, and also provides the tree with greater protection against insects such as southern pine beetles (Hodges *et al.* 1979). Annual survival of longleaf cavity trees was twice that for loblolly and shortleaf cavity trees in east Texas, in part because of longleaf pine's greater resistance to southern pine beetles (Conner and Rudolph 1995a). Because of higher survival and the ability to sustain resin flow over time, longleaf pines may remain in use as cavity trees for several decades—much longer than shortleaf or loblolly pines (Conner and Rudolph 1995a, Harding 1997).

Cavity excavation time appears to be longer in longleaf pines than in either loblolly or shortleaf pines. In Texas, excavation time averaged 6.3 years in longleaf pines, two to three times greater than the average times for loblolly and shortleaf pines (Conner and Rudolph 1995a). In North Carolina, excavation times for cavities in longleaf averaged from 10 to 13 years, and from 6 to 9 years for loblolly (Harding 1997). Cavity excavation is an intermittent process, with month-long or longer breaks to allow resin flow to subside through resinosis (saturation of sapwood with hardened resin; Conner and Rudolph 1995a). Thus, longleaf may require longer excavation times because of its greater resin flow (Conner and Rudolph 1995a). Variation in estimated excavation times may result from geographic variation in resin flow (Harding 1997), itself a function of site and tree factors (Hodges *et al.* 1979, Ross *et al.* 1995), or from variation in research methods.

Selection of and Requirement for Old Trees

Red-cockaded woodpeckers select and require old pines for cavity excavation (Jackson and Jackson 1986, Conner and O'Halloran 1987, DeLotelle and Epting 1988, Rudolph and Conner 1991). Age of cavity trees depends on the ages of pines available, but there is a minimum age, generally 60 to 80 years depending on tree and site factors, below which use as a cavity tree is highly unlikely or simply not possible (DeLotelle and Epting 1988, Hooper 1988, Rudolph and Conner 1991). Currently, cavity trees average roughly 80 to 150 years in age and can be much older (Rudolph and Conner 1991, Hedrick 1992). Cavity trees are generally the oldest trees available in today's forests (Jackson *et al.* 1979, Engstrom and Evans 1990, Rudolph and Conner 1991), and the optimal age for cavity trees may be well above the average age of cavity trees under current forest conditions. For example, red-cockaded woodpeckers in national forests of Texas continue to select the oldest trees available for initiation of cavities as the forests have aged 20 years during the course of study (Rudolph and Conner 1991).

One reason red-cockaded woodpeckers require old trees for cavity excavation is that they need sufficient heartwood diameter at preferred cavity heights to construct the cavity completely within the heartwood. Cavities must be completely within the heartwood to prevent pine resin in the sapwood from entering the chamber (Jackson and Jackson 1986, Clark 1993), and the estimated minimum amount of heartwood required is 14.0 to 15.2 cm (5.5 to 6 in; Conner *et al.* 1994). Preferred cavity heights generally range from 6.1 to 15.2 m (20 to 50 ft; Baker 1971b, Hopkins and Lynn 1971, Hooper *et al.*

1980, Conner and O'Halloran 1987), a possible adaptation to minimize likelihood of ignition by frequent fire (Conner and O'Halloran 1987, Clark 1992, Conner *et al.* 1994). The age of the tree determines heartwood diameter at cavity height, as older pines have more heartwood at greater heights. In eastern Texas, longleaf pines between 70 and 90 years old had adequate heartwood at appropriate heights to contain a cavity (Conner *et al.* 1994). Fifty year-old longleaf pines examined by Clark (1992) had insufficient heartwood for cavity excavation.

A second reason that woodpeckers select old trees for cavity excavation is that old pines have a higher frequency of infection by red heart fungus, and the associated decay of the heartwood becomes more advanced as the tree ages (Wahlenburg 1946). Woodpeckers can and do excavate cavities into undecayed heartwood (Beckett 1971, Conner and Locke 1982, Hooper 1988, Hooper *et al.* 1991b), but the presence of red heart fungus can substantially reduce the time required for cavity excavation (Conner and Rudolph 1995a). In Texas, for example, average excavation times for cavities in pines with and without decayed heartwood were 3.7 and 5 years, respectively (Conner and Rudolph 1995a).

Heartwood decay by red heart fungus was not frequently found in longleaf cavity trees in Texas until they were over 120 years old (Conner *et al.* 1994). Red heart is a very slow growing fungus (Affeltranger 1971, Conner and Locke 1982, 1983), and at least 12 to 20 years may be required between initial inoculation and the decay of sufficient heartwood to house a cavity (Conner and Locke 1983). Also, red heart fungus enters the heartwood of the tree through heartwood in large branches, and so trees must be old enough to have large branches before bole heartwood can be infected (Affeltranger 1971, Conner and Locke 1982). However, regional differences may exist in the ages and rates at which pines become infected with heartwood decaying fungi. A study in Texas reported a 46 percent infection rate for 50 longleaf cavity trees that averaged 126 years in age (Conner *et al.* 1994), whereas this rate was more than doubled for similarly aged longleaf cavity trees in South Carolina (97 percent infection rate for trees averaging 130 years in age; Hooper 1988).

Red-cockaded woodpeckers actively select pines with heartwood decayed by red heart fungus (Steirly 1957, Jackson 1977, Conner and Locke 1982, Hooper 1988, Hooper *et al.* 1991b, Rudolph *et al.* 1995). In fact, red-cockaded woodpeckers are able to detect and locate cavities in the specific area of the bole that is infected (Rudolph *et al.* 1995). Preference for decayed heartwood results in the selection of cavity trees that are older than necessary for them to have enough heartwood to contain a cavity (Hooper 1988, Hooper *et al.* 1991b, Rudolph *et al.* 1995). For example, cavity trees in Texas averaged 24.8 cm (9.75 in) in heartwood diameter, considerably larger than the 15.2 cm (6 in) estimated minimum (Rudolph *et al.* 1995). In fact, preference for red heart infection rather than age itself may drive the general preference for old trees (Hooper 1988).

Red-cockaded woodpeckers have been shown to select pines that have thinner sapwood and greater heartwood diameters than pines generally available nearby (Conner *et al.* 1994). This is also related to age: such trees are older, growing more slowly, and usually have a higher rate of red heart infection than pines not used for cavity excavation. Diameter growth of trees typically accelerates annually as younger trees mature, attains a maximum, and slows as trees approach maturity (Kramer and Kozlowski 1979). Heartwood diameter increases significantly with tree size and age in both loblolly and longleaf pines (Clark 1992, 1993).

Old growth pines are relatively rare throughout the south. Old growth remnants (both single trees and stands) within today's forests are critically important habitat and will continue to be so over the next 20 to 30 years, until second and third-growth forests mature and potential cavity trees become more widely available. Woodpeckers require potential cavity trees in abundance throughout the landscape, because of currently high mortality of natural cavity trees and high rates of damage to existing cavities by pileated woodpeckers (*Dryocopus pileatus*; Conner *et al.* 1991a, Conner and Rudolph 1995b, Saenz *et al.* 1998; see 2F).

Selection of Trees with High Resin Production

Red-cockaded woodpeckers are known to select, as cavity trees, pines that have higher resin flow than surrounding pines (Bowman and Huh 1995, Conner *et al.* 1998a). Moreover, breeding males select the cavity tree with the highest resin flow for use as the nest tree (Conner *et al.* 1998a). Thus, woodpeckers benefit from pines with high resin production potential, likely indicated by high crown volume and crown weight (Conner and O'Halloran 1987). Ross *et al.* (1997) showed that longleaf pine cavity trees in stands with low densities and on forest edges produced significantly more resin than similar cavity trees within interior forest stands with higher stem densities. Several studies have observed the tendency of red-cockaded woodpeckers to place their cavities near forest edges and in areas of low tree densities (Conner and O'Halloran 1987, Conner *et al.* 1991b, Ross *et al.* 1997), presumably because of higher resin flow in these locations.

The Cavity Tree Cluster

Each red-cockaded woodpecker in a group roosts in a cavity year-round, and it is usually the breeding male's cavity that holds the group's nest in the spring. The aggregation of active (in use) and inactive (previously used) cavity trees within an area defended by a single group is called the cluster (Walters *et al.* 1988a). This aggregation of cavity trees is dynamic, changing in shape as new cavity trees are added through excavation and existing cavity trees are lost to death or a neighboring group. To protect cavity trees, a buffer zone of continuous forest, 61 m (200 ft) in width, is generally established around the minimum convex polygon containing a group's active and inactive cavity trees. For this recovery plan, the term cluster is defined as the minimum convex polygon containing all of a group's cavity trees *and* the 61 m (200 ft) buffer surrounding that polygon. The minimum cluster area size is 4.05 ha (10 ac), as some clusters may only contain one cavity tree. To facilitate record keeping and protection, individual cavity trees within a cluster are commonly marked with metal numbered tags, painted for easy detection, and mapped.

Disturbance within the Cluster

Human-caused disturbances in cluster areas during the nesting season may disrupt red-cockaded woodpecker nesting activities, decrease feeding and brooding rates, and cause nest abandonment. Such activities may include but are not limited to all-terrain and other off-road vehicles, motorized logging equipment, and other vehicles that make excessive noise and disturbance to which the woodpecker groups have not previously become accustomed. Use of vehicles and other activities throughout the year may cause indirect impacts to red-cockaded woodpeckers through excessive soil compaction, damage to cavity tree roots, and disturbance of the groundcover. Soil compaction and root damage elevate cavity tree mortality (Nebeker and Hodges 1985, Hicks *et al.* 1987, Conner *et al.* 1991a); changes in the groundcover may affect prey abundance (Collins 1998), nutrient value of prey (James *et al.* 1997), and fire frequency and intensity through changes in fuel.

Geographic Variation in Habitat

There is geographic variation in nesting and roosting habitat of red-cockaded woodpeckers. The largest populations tend to occur in the primarily longleaf pine forests and woodlands of the Coastal Plains and Carolina Sandhills (Carter 1971, Hooper *et al.* 1982, James 1995, Engstrom *et al.* 1996). Woodpeckers are also found in shortleaf/loblolly forests of the Piedmont, Cumberlands, and Ouachita Mountain regions (Mengel 1965, Sutton 1967, Steirly 1973). Pine habitat occupied by red-cockaded woodpeckers covers a wide moisture gradient ranging from hydric slash pine (*P. elliottii* var. *densa)* flatwoods in Florida (Beever and Dryden 1992, Bowman and Huh 1995) to dry ridge and mountain tops in Oklahoma (Masters *et al.* 1989, Kelly *et al.* 1993), Alabama, and Mississippi. Density of pine overstory in areas occupied by red-cockaded woodpeckers varies from fairly dense in Texas (Conner and O'Halloran 1987, Conner and Rudolph 1989), to sparse in the Orlando, Florida vicinity (DeLotelle *et al.* 1987), to extremely low in the Big Cypress National Preserve (Patterson and Robertson 1981).

Structure of Vegetation within Clusters

Alteration of the natural fire regime during the past century has caused fundamental changes in the vegetation structure of upland habitats throughout the south. These changes include a gradual encroachment of hardwoods, increasing dominance of off-site pine species such as slash and loblolly, and more densely wooded forests in general (Jackson *et al.* 1986, Ware *et al.* 1993). Loblolly pine was present historically, but forests dominated by loblolly were very rare; its presence and dominance has increased dramatically as a result of fire suppression (White 1984). Each of these changes is detrimental to red-cockaded woodpeckers, and hardwood encroachment especially is a major cause of the species' decline and endangered status (see 1A).

The association of red-cockaded woodpeckers with open, park-like pine woodlands has long been known (Thompson and Baker 1971, Van Balen and Doerr 1978, Locke *et al.* 1983, USFWS 1985). Encroachment of hardwood midstory causes abandonment of cavity trees and clusters (Beckett 1971, Hopkins and Lynn 1971, Van Balen and Doerr 1978, Locke *et al.* 1983, Hovis and Labisky 1985, Conner and Rudolph 1989, Loeb *et al.* 1992). Cluster abandonment has been documented when hardwood and pine midstory basal area exceeds 5.7 m^2/ha (25 ft^2/ac; Conner and Rudolph 1989, Loeb *et al.* 1992). Negative effects of midstory growth above 3.7 m (12 ft) have also been shown (Hooper *et al.* 1980).

Thus, effective midstory control is an absolute prerequisite to management, conservation, and recovery of red-cockaded woodpeckers throughout their range. Such control is not an easy task. After seven decades of fire suppression, many clusters have developed an extensive hardwood component with an impressive underground root stock, particularly in the more mesic sites where loblolly and shortleaf pines are the dominant tree species (Conner and Rudolph 1989). Repeated prescribed burning during the late dormant or early growing season is an effective means to remove hardwoods and restore native groundcovers, and has the least detrimental impacts on soil structure and desired groundcovers (Provencher *et al.* 2001a, 2001b, see 3G). However, excessive quantities of hardwoods (or very large trees) may require removal by hand, mechanical means (Conner *et al.* 1995), one-time herbicide application (Conner 1989), or a combination of these methods prior to restoration burning. Chemical and/or mechanical techniques may be useful if rapid midstory reduction is required, for example if a cluster has been recently abandoned or supports only a solitary male because of excessive hardwoods. If chemical and/or mechanical techniques are used, it is important that regular prescribed burning follows these treatments. Maintenance of open habitat structure is best achieved through use of early to mid growing-season fire fueled by native grasses; late growing season fire can be detrimental to overstory pines (Sparks *et al.* 1998, 1999).

Reduction of hardwood midstory and thinning of overstory pines in clusters outside of the nesting season does not negatively affect red-cockaded woodpeckers (Conner and Rudolph 1991a), but mechanical removal of midstory should not be done when red-cockaded woodpeckers are nesting (Jackson 1990). If clusters have been abandoned due to unsuitable habitat conditions, they should be conserved and restored to suitable midstory conditions to increase the probability of reoccupation by woodpeckers (Doerr *et al.* 1989).

Red-cockaded woodpeckers can tolerate some hardwood overstory trees (basal area less than 2.3 m^2/ha; 10 ft^2/ac) within clusters (Hooper *et al.* 1980, Hovis and Labisky 1985, Conner and O'Halloran 1987). Small numbers of overstory hardwoods or large midstory hardwoods at low densities are consistent with historic landscapes in some habitats, and do not have the same negative effects on red-cockaded woodpeckers as the dense hardwood midstories resulting from fire suppression. Oak inclusions and upland hardwood species, such as post oak (*Quercus stellata*) and bluejack oak (*Q. incana*), occur naturally in association with the pine ecosystems of the south. Such species are integral components of the southern pine ecosystem and should not be cut in the name of red-cockaded woodpecker management.

Stream drainages, with associated shrub and midstory layers and hardwoods, are also integral parts of the southern pine ecosystems. However, woodpeckers may not be able to tolerate the complex vegetative structure of stream drainages near cavity trees. Therefore, management of cavity tree habitat for red-cockaded woodpeckers should be primarily focused in upland portions of the forest landscape. Stands developed and managed to recruit new woodpecker groups or replace cluster habitat should be located away from stream drainages whenever possible.

Density of pines in clusters varies according to habitat type, geography, and silvicultural history. The sparsest woods occupied by red-cockaded woodpeckers are the hydric slash pine woodlands of south Florida (Beever and Dryden 1992). Slightly more dense are the clusters in longleaf woodlands of south and central Florida; average basal area of clusters in these Florida longleaf woodlands currently ranges from 1.8 to 5.7 m^2/ha (8 to 25 ft^2/ac; DeLotelle *et al.* 1983, Shapiro 1983, Hovis and Labisky 1985, Bowman *et al.* 1997). For clusters in longleaf pine woodlands north of Florida, estimated average basal area ranges from 9.2 to 13.8 m^2/ha (40 to 60 ft^2/ac) of basal area (Crosby 1971, Hopkins and Lynn 1971, Thompson and Baker 1971). Clusters in natural loblolly and/or shortleaf pine forests average slightly higher densities (Thompson and Baker 1971, Hooper *et al.* 1980, Conner and O'Halloran 1987, Conner and Rudolph 1989).

Woodpecker cluster stands are typically less dense than surrounding stands (Crosby 1971, Thompson and Baker 1971, Grimes 1977, Locke *et al.* 1983, Shapiro 1983, Wood 1983, Hovis and Labisky 1985, Conner and O'Halloran 1987, Conner *et al.* 1991b, Loeb *et al.* 1992, Bowman *et al.* 1997) and they may be the least dense stands available. For example, Conner *et al.* (1991b) reported a preference for seed-tree and shelterwood cuts for cavity excavation in longleaf pine woodlands. For clusters, basal areas as low as 9.2 m^2/ha (40 ft^2/ac) in longleaf stands and from 9.2 to 13.8 m^2/ha (40 to 60 ft^2/ac) in shortleaf/loblolly stands are suitable (Conner *et al.* 1991b). However, seed-tree and shelterwood cuts with excessive pine or hardwood midstory are not acceptable as nesting habitat.

There are several reasons why red-cockaded woodpeckers might select stands with relatively low pine density as cluster sites. Pines in low-density stands grow larger in diameter, have greater crowns and root systems, and higher resin flow. Such pines are more resistant to wind damage and attacks by bark beetles, may be used as cavity trees at younger ages, and provide woodpeckers with greater protection against predation. In addition, sparse woods may have a greater proportion of area in grass and forb groundcovers than more dense forests, and these groundcovers in turn affect arthropod abundance (Collins 1998) and the ability of the stand to carry fire. Another reason for the preference for sparsely wooded stands, apart from the above benefits, may be that the low density of pine itself is a reflection of frequent fire.

Cavity Tree Mortality and Protection

Southern Pine Beetles

Infestation by southern pine beetles is the major cause of cavity tree mortality in loblolly and shortleaf pines (Conner *et al.* 1991a). Cavity trees are lost to southern pine beetles during epidemics, such as the death of 350 cavity trees including more than 50 entire clusters during the early 1980's in the Sam Houston National Forest (Conner *et al.* 1991a, 1997a). Cavity trees are also lost to southern pine beetles at endemic population levels, at a lower but steady rate (Conner *et al.* 1997a). Loss of cavity trees resulting from both epidemic and endemic southern pine beetles can substantially impact woodpeckers, particularly small populations in the loblolly and shortleaf pines of Texas, Arkansas, Louisiana, Mississippi, and elsewhere (Conner and Rudolph 1995b, Rudolph and Conner 1995).

Factors that increase risk to cavity trees and other important, mature pines in the cluster to southern pine beetle infestation include physical disturbance of soils and roots during thinning and midstory reduction, high density of pines within the cluster, and excessive hardwood midstory outside the cluster (Thatcher *et al.* 1980, Nebeker and Hodges 1985, Hicks *et al.* 1987, Conner *et al.* 1997a).

Fortunately, pines with artificial cavities, used to mitigate losses of cavity trees to southern pine beetles, are not infested at a rate significantly different from pines with naturally excavated cavities (Conner *et al.* 1998b). Risk of beetle infestation can be reduced by favoring pines with high resin producing ability, by pine thinning, and by minimizing disturbance during periods of high beetle activity (Mitchell *et al.* 1991). Loblolly and shortleaf pine stands should be maintained at basal areas less than 18.4 m^2/ha (80 ft^2/ac) or an average spacing of at least 7.6 m (25 ft) between pines in mature stands, to retard the spread of beetle infestations (Thatcher *et al.* 1980, Hicks *et al.* 1987, Nebeker and Hodges 1985, Mitchell *et al.* 1991). For southern pines, defense against bark beetle attack is positively related to the trees' ability to produce oleoresins (Lorio 1986). Because of differences in resin production, longleaf pines are much less susceptible to beetle attack than loblolly and shortleaf pines, and shortleaf pines are less susceptible than loblolly.

Other Causes of Mortality

Wind is the second greatest cause of cavity tree mortality in non-hurricane situations (Conner *et al.* 1991a). Cavity trees can be uprooted or snapped by high velocity winds. Patterns of harvest near clusters should be carefully planned to avoid funneling wind toward cavity trees (Conner *et al.* 1991a, Conner and Rudolph 1995c). A forest buffer of uncut trees greater than 61 m (200 ft) wide around cavity trees is adequate protection to minimize wind damage, wind snap, and wind throw during isolated severe summer thunderstorms (Conner and Rudolph 1995c).

Hurricane winds are a major threat to coastal woodpecker populations (Engstrom and Evans 1990, Hooper *et al.* 1990, Hooper and McAdie 1995, Lipscomb and Williams 1995). For example, when Hurricane Hugo struck the Francis Marion National Forests in South Carolina during September 1989, it destroyed 87 percent of the cavity trees, 67 percent of the woodpeckers, and 70 percent of the foraging habitat (Hooper *et al.* 1990, Hooper and McAdie 1995). Drilled and inserted artificial cavities (Copeyon 1990, Allen 1991, Taylor and Hooper 1991), having just been developed, enabled the rapid recovery of the Francis Marion population (Watson *et al.* 1995). Conservation of inland populations and many separate coastal populations will minimize the risk of extinction from hurricanes (USFWS 1985, Hooper and McAdie 1995). Hooper and McAdie (1995) also suggest that pines needed for future nesting habitat be grown in open conditions to promote the development of large crowns, extensive root systems, and strong boles. Another strategy to minimize impacts from hurricane winds is to avoid the creation of openings greater than 10.1 ha (25 ac) in or near forests managed for red-cockaded woodpeckers in hurricane-prone areas.

The third major cause of cavity tree mortality is fire. Managers must take appropriate measures to protect cavity trees from prescribed burns and wildfires so that loss is minimized. Foremost among these protective measures is regular burning within the cluster and around cavity trees, to keep fuel at acceptable levels. Other techniques are described in 8K.

Implications for Management

Cavities, cavity trees, and cavity tree clusters currently limit red-cockaded woodpecker populations, and thus their careful management is foremost in woodpecker conservation and recovery. Red-cockaded woodpeckers require large old trees as nesting and roosting sites, in habitat that is free of pine and hardwood midstory. Each cavity tree is an important resource that must be protected, and until potential cavity trees become more widely available, additional cavities and clusters must be judiciously provided through the use of artificial cavity technology. Hardwood encroachment causes abandonment of cavity tree clusters, with direct effects on population status. Encroaching hardwoods must therefore be controlled, preferably by frequent, early to mid growing season fire. These management actions—protection of existing cavity trees, provisioning of artificial cavities and clusters as appropriate, and hardwood control—form the basis of red-cockaded woodpecker management (see 8B, 8E, 8F, and 8K for more information). Loss of cavity trees and hardwood encroachment were primary factors in the decline of the species throughout its range (see 1A). Removal of these limiting factors is therefore fundamental to recovery.

E. FORAGING ECOLOGY

Our understanding of the foraging ecology of red-cockaded woodpeckers is increasing, although much work remains to be done. Natural geographic variation in forest ecology and woodpecker demography as well as the highly altered structure of today's forests make documenting habitat preferences and requirements a complex and challenging task. Despite these difficulties, a body of research has been developed describing foraging ecology and habitat relationships of red-cockaded woodpeckers. Here, we summarize research into diet, habitat selection, and habitat effects on fitness. In 8I, we present guidelines for providing foraging habitat that is suitable in quality and quantity based on current knowledge. Further research will help us to better understand foraging habitat requirements and may result in revisions of present guidelines.

Diet and Prey Abundance

Diet of Adults and Nestlings

Over 75 percent of the diet of red-cockaded woodpeckers consists of arthropods, especially ants and roaches, but also beetles, spiders, centipedes, true bugs, crickets, and moths (Beal *et al.* 1941, Baker 1971a, Harlow and Lennartz 1977, Hanula and Franzreb 1995, Hess and James 1998, Hanula and Engstrom 2000, Hanula *et al.* 2000b). Ants are particularly common in the diet of adults, comprising over half the stomach contents of adults and sub-adults in the Gulf coast region (Beal *et al.* 1941) and the Apalachicola National Forest in Florida (Hess and James 1998). Other arthropods comprised an estimated 34 percent and 17 percent, respectively, of the adult diet in these two studies (Beal *et al.* 1941, Hess and James 1998). *Crematogaster ashmeadii* was the most prominent of the ant species in the diet of red-cockaded woodpeckers in the Apalachicola, comprising 74 percent of the ant biomass taken (Hess and James 1998). Species composition of arthropod prey taken by adults elsewhere in the range has not yet been evaluated.

Fruits and seeds make up the small remaining portion of the adult diet. Red-cockaded woodpeckers have been known to eat the fruits or seeds of pines (*Pinus spp.*), poison ivy (*Rhus radicans*), magnolia (*Magnolia spp*.), myrtle (*Myrica spp*.), wild cherry (*Prunus serotina*), wild grape (*Vitus spp*.), blueberry (*Vaccinum spp*.), and blackgum (*Nyssa sylvatica*). Fruits and seeds comprised 14 percent by volume of the stomach contents of adults collected throughout the year in the Gulf Coastal Plain (Beal *et al.* 1941). Similarly, fruits and seeds made up 16 percent of the yearly diet of adults in Florida (Hess and James 1998). Plant material was rarely seen in the diets of woodpeckers in the Francis Marion National Forest of South Carolina (Hooper and Lennartz 1981).

The diet of nestlings also consists principally of arthropods, and fruits may be given on occasion (Baker 1971a, Harlow and Lennartz 1977, Hanula and Engstrom 2000, Hanula *et al.* 2000b). Large arthropod prey are commonly fed to nestlings in addition to or instead of ants (Hanula and Franzreb 1995, Hess and James 1998, Hanula and Engstrom 2000, Hanula *et al.* 2000b), and there is some evidence that breeding groups increase their reproductive success by feeding large prey (Schaefer 1996). In the Apalachicola National Forest, the diet of nestlings (as estimated by stomach contents) consisted mainly of roughly equal proportions of ants, beetles, spiders, and centipedes (Hess and James 1998). In several populations in Georgia and South Carolina, wood roaches were the most common item fed to nestlings, comprising from 26 to 62 percent of the nestling diet (as estimated from photographs of feeding visits; Hanula and Franzreb 1995, Hanula and Engstrom 2000, Hanula *et al.* 2000b).

Prey Selection, Location, and Abundance

Red-cockaded woodpeckers generally capture arthropods on and under the outer bark of live pines and in dead branches of live pines. Pines that have recently died are also a notable source of prey (Ligon 1968, Hooper and Lennartz 1981, Schaefer 1996, Bowman *et al.* 1997). Red-cockaded woodpeckers rarely excavate through the bark of live pines to capture prey, but do excavate into dead branches (Ligon 1968, Ramey 1980, Hooper and Lennartz 1981, Porter and Labisky 1986, Schaefer 1996).

Differences in foraging behavior between the sexes in red-cockaded woodpeckers are well documented (Ligon 1970, Hooper and Lennartz 1981, Engstrom and Sanders 1997, Hardesty *et al.* 1997). Males commonly forage in the crown of the tree, and are often on dead branches. Females commonly forage on the trunk, especially the lower trunk, and rarely forage on dead branches. This difference may serve to expose males and females, separately, to the areas of the tree with highest concentrations of arthropods (Hooper 1996, Hanula and Franzreb 1998). Recently, C. Rudolph (pers. comm.) suggested that foraging behaviors differ by social status as well as sex. Breeding males may spend more time in the inner crown of the tree, whereas helper males may forage more on the crown's outer branches (C. Rudolph, pers. comm.).

Several studies have assessed abundance and location of potential prey of red-cockaded woodpeckers (Hooper 1996, Hanula and Franzreb 1998, Hess and James 1998, Hanula *et al.* 2000a). Relative abundance of arthropods changes depending on the part of the tree sampled. On the boles of the tree, the most abundant arthropods were true bugs, spiders, and roaches (Hooper 1996). On live branches, roaches, spiders, beetles and ants were most common (Hooper 1996). Ants appear to be by far the most common arthropod on dead branches (Hooper 1996, Hanula and Franzreb 1998). A large proportion of the arthropods on pine trees have gotten there by crawling up from the ground, which points to the condition of the ground cover as an important factor influencing abundance of prey for red-cockaded woodpeckers (Hanula and Franzreb 1998).

Thus, several studies have documented a variety of arthropod species in the diet of red-cockaded woodpeckers, and others have described patterns of arthropod abundance and distribution. Whether birds are selecting prey species in greater proportion than their availability remains unknown. Assessing prey selection is extremely difficult, in large part because of extraordinary variability in the distributions of arthropods but also because each method of studying diet has its bias. In addition, diets of both adults and nestlings are highly variable: ants, for example, comprised from 0 to 94 percent of the stomach contents of nestlings and from 4 to 95 percent of the stomach contents of adults in Florida (Hess and James 1998). Nor is it clear whether plant material is a preferred or sub-optimal food. Plants may be selected to fill a nutritional need or exploited when prey is scarce.

Factors Affecting Prey Abundance

Arthropod abundance and biomass increases with the age and size of pines (Hooper 1996, Hanula *et al.* 2000a). Whether this relationship continues to increase with age, or levels off and declines at some threshold age, is an issue of some controversy at the present time (R. Conner, pers. comm.). Hanula *et al.* (2000a) found that arthropod abundance per tree increased linearly with stand age, and that biomass per tree increased until approximately age 60 after which it began to decline. This study showed a similar, positive relationship between arthropods and tree diameter, and negative relationships between density of pines and arthropod abundance and biomass per tree. It is not yet clear which factors—size, age, and/or density—are more important in determining arthropod abundance and distribution. Further research is required before the relationships among tree age, size, and density and prey abundance are fully understood.

Fire frequency also affects arthropod abundance and diversity. Large-scale, well-replicated research into longleaf pine ecosystem restoration in Florida documented increases in densities of herb-layer arthropods as a result of prescribed burning, and proposed their use as indicators of restoration success (Provencher *et al.* 2001a). In Texas, the abundance of arthropods on the boles of shortleaf and loblolly pines was higher in stands with grass and forb groundcover than in stands with substantial hardwood midstory (Collins 1998). Hanula *et al.* (2000a) documented positive relationships between tree age and the abundance of both herbaceous groundcovers and insects, although there were no direct relationships between measures of herb and insect abundance. Other studies have emphasized that the effects of fire on arthropods vary by species; that is, fire can have negative, neutral, or positive effects on various insects (New and Hanula 1998, J. Hanula, pers. comm.).

Most importantly, several recent studies have shown a positive relationship between fire frequency (as shown by groundcover) and fitness of red-cockaded woodpeckers (James *et al.* 1997, 2001, Hardesty *et al.* 1997). James *et al.* (2001) specifically documented an increase in fledging rate following the reintroduction of growing season fire, relative to control plots burned during the dormant season.

Frequent fire increases fitness of red-cockaded woodpeckers through more than one mechanism: first, by reducing hardwoods, and secondly, by increasing abundance and perhaps nutrient value of prey (James *et al.* 1997, Provencher *et al.* 1998, but see Hanula *et al.* 2000). The increase in insect abundance is at least partially independent of the reduction in hardwoods. James *et al.* (1997) revealed this independence by showing an effect of fire on fitness in a study area that had few hardwoods. Provencher *et al.* (1998) documented two to seven-fold increases in insect densities following growing season fire of hardwood-encroached longleaf stands. They then showed that reductions in hardwoods by herbicides and mechanical felling did not result in similar increases in insect densities until the stands were burned during the growing season (Provencher *et al.* 2001a). Thus, frequent growing season fire may be critically important in providing red-cockaded woodpeckers with abundant prey.

Selection of Foraging Habitat

Throughout their range, red-cockaded woodpeckers use open pine habitats for foraging. Considerable geographic variation in habitat types exists, illustrating the species' ability to adapt to a wide range of ecological conditions within the constraints of mature or old growth, open southern pine ecosystems. Red-cockaded woodpeckers use such natural habitat types as longleaf pine savannahs, flatwoods, sandhills, and clayhills; slash pine savannahs and flatwoods; pond and/or slash pine pocosins; shortleaf pine savannahs and forests, and shortleaf/loblolly pine savannahs and forests (Nesbitt *et al.* 1978, Ramey 1980, DeLotelle *et al.* 1983, Hooper and Harlow 1986, Porter and Labisky 1986, Bradshaw 1995, Epting *et al.* 1995, Bowman *et al.* 1997). Red-cockaded woodpeckers also use loblolly pine forests for foraging, although historically pure stands of loblolly were rare (White 1984). Longleaf pine ecosystems provide the optimal habitat for red-cockaded woodpeckers and were historically the most extensive habitat type (Conner *et al.* 2001).

Red-cockaded woodpeckers show a strong preference for living pines as foraging substrate (Hooper and Lennartz 1981, Porter and Labisky 1986, Jones 1994, Bowman *et al.* 1997). Pines used for foraging include longleaf, slash, loblolly, shortleaf, Virginia, and pond. Sand pine may be used rarely (Hardesty *et al.* 1997), and cypress is used on occasion, averaging an estimated 10 percent of foraging time in south-central Florida (Nesbitt *et al.* 1978, DeLotelle *et al.* 1983). Hardwoods are also used on occasion. Use of hardwoods typically accounts for 0 to 5 percent of foraging time (Hooper and Lennartz 1981, Repasky 1984, Porter and Labisky 1986, Bradshaw 1995, Hardesty *et al.* 1997). Reports of somewhat higher use include 7 percent of foraging time in Louisiana (Jones 1994) and 12 percent in Kentucky (Zenitsky 1999). Thus, hardwoods comprise a trivial or minor component of foraging substrate for red-cockaded woodpeckers throughout their range.

Dying and recently dead pines are an important foraging resource for red-cockaded woodpeckers (Ligon 1968, Hooper and Lennartz 1981, Schaefer 1996, Bowman *et al.* 1997). Pines infested with or recently killed and vacated by southern pine beetles may be an especially important, though unpredictable, food source in shortleaf and loblolly habitats (Schaefer 1996). Red-cockaded woodpeckers feed on southern pine beetles themselves, especially pupae in the bark. The birds also feed on adults and larvae of secondary attackers to beetle-infested trees, such as long-horned beetles

(*Cerambycidae*) and metallic wood-boring beetles (*Buprestidae*). However, southern pine beetle epidemics can cause dramatic losses of critical nesting habitat. If beetle populations are large and pines near cavity trees (or cavity trees themselves) are infested, some pines are generally removed in the attempt to control growing beetle infestations and prevent loss of nesting and foraging habitat.

Selection of Tree Species

Whether red-cockaded woodpeckers prefer to forage on a particular species of pine has not been clearly demonstrated, and it may be that no such preference exists. Previous research has yielded conflicting results, all of which could be confounded by other factors such as tree age and size, density of surrounding trees, and presence of hardwood midstory. Longleaf pine stands were selected over slash pine stands in northern Florida (Porter and Labisky 1986), but elsewhere in Florida slash pines were selected over longleaf (Nesbitt *et al.* 1978). Bowman *et al.* (1997) suggested that slash pine in south central Florida may provide important foraging in addition to longleaf. In the North Carolina Sandhills, woodpeckers did not select trees based on tree species, but over 90 percent of available pines were longleaf (Walters *et al.* 2000, 2002a). Woodpeckers in coastal North Carolina did not select among longleaf, loblolly, and pond pines, even though the proportion of loblolly and pond pines together averaged over 20 percent of available pines (Zwicker and Walters 1999). Finally, it may be that in habitats that were traditionally longleaf, dominance of longleaf was sufficient to retard the evolution of selection among pine species by red-cockaded woodpeckers. Future research in habitat containing mixed pine species both historically and currently would help document the presence or absence of this behavior.

Selection of Older and Larger Trees

All studies examining selection of individual trees by foraging red-cockaded woodpeckers have found that the birds select large, old trees over small, young trees (Hooper and Lennartz 1981, Porter and Labisky 1986, DeLotelle *et al.* 1987, Bradshaw 1995, Jones and Hunt 1996, Engstrom and Sanders 1997, Hardesty *et al.* 1997, Zwicker and Walters 1999, Walters *et al*. 2000, 2002a). Reports vary as to the specific sizes at which trees are avoided and preferred. Also, some researchers suggest that all trees over a specific size (generally, 25.4 cm [10 in] dbh) are equal in foraging value (Hooper and Harlow 1986), whereas others suggest that foraging value of trees increases continually with increasing size and age of trees (Engstrom and Sanders 1997, Hardesty *et al.* 1997, Doster and James 1998, Zwicker and Walters 1999, Walters *et al.* 2000, 2002a). Such disagreements are likely due to differences in study methods and to differences in available habitat, because what the birds select or avoid must always be a subset of what is available. Available habitat changes because of natural geographic variation but also because of variation in the extent of forest alteration (e.g., fire suppression and tree cutting). Despite the disagreements, it is clear that tree age and size strongly influence selection of pines for foraging. Results of previous studies are summarized below.

Reported sizes below which trees are avoided (that is, used less than their availability) varies from 12.7 cm (5 in) dbh in coastal South Carolina (Hooper and Lennartz 1981) to 20.3 and 25.4 cm (8 and 10 in) dbh in northwest Florida (Porter and Labisky 1986, Hardesty *et al.* 1997) and Louisiana (Jones and Hunt 1996), and 25.4 cm (10 in) dbh in the North Carolina Coastal Plain and Sandhills (Zwicker and Walters 1999, Walters *et al.* 2000, 2002a). Reported sizes above which trees are selected (used more than their availability) include 20.3 and 25.4 cm (8 and 10 in) dbh in northwestern Florida (Porter and Labisky 1986, Hardesty *et al.* 1997), 25.4 cm (10 in) dbh in coastal South and North Carolina (Hooper and Lennartz 1981, Zwicker and Walters 1999), 30.5 cm (12 in) dbh in southwestern Georgia (Engstrom and Sanders 1997), the North Carolina Sandhills (Walters *et al.* 2000, 2002a), coastal Virginia (Bradshaw 1995), and Arkansas (Doster and James 1998), and 40 cm (15.7 in) in Louisiana (Jones and Hunt 1996). Again, these differences are due in part to differences in available habitat, because what the birds select or avoid depends on what is there.

Fewer studies have assessed specific ages at which individual pines are avoided or selected, although several more have assessed effects of average stand age (see below). Age and size of trees are highly correlated, at least until age 80 or greater (Platt *et al.* 1988b, Walters *et al.* 2000), and at present it is not known whether tree age, size, or both age and size is most important to foraging woodpeckers. In the Coastal Plain and Sandhills of North Carolina, trees under 60 years in age were avoided whereas those over 60 years (Coastal Plain) and 70 years (Sandhills) were selected (Zwicker and Walters 1999, Walters *et al.* 2000, 2002a). In northwestern Florida, trees less than 50 years in age were avoided, trees 50 to 150 years in age were used in proportion to their availability, and trees 150 years in age and older were preferred (Hardesty *et al.* 1997).

A preference by woodpeckers for the oldest and largest trees available has been shown in several studies (Hardesty *et al.* 1997, Engstrom and Sanders 1997, Zwicker and Walters 1999, Walters *et al.* 2000, 2002a). Bradshaw (1995) also reported a preference for the largest trees, although he combined all trees over 30.5 cm (12 in) dbh into one category. Such preference for the oldest and largest trees available suggests that tree selection by red-cockaded woodpeckers may be operating in either of two ways: (1) woodpeckers always select the oldest and largest trees in any habitat, or (2) an optimal size and age exists above which selection becomes equal, but this optimum remains unseen because currently these trees are not generally available in meaningful amounts (Zwicker and Walters 1999). In contrast, other studies report that selection tapers off above middle-aged, medium-sized trees—suggesting that middle-aged trees are of equal importance to the oldest and largest trees (Hooper and Lennartz 1981, Hooper and Harlow 1986). Again, such disagreements are likely due to differences in study methods and available habitat. As public forests regain an old growth component and research methods are standardized, biologists will likely reach a consensus on what ages and sizes of trees are preferred by foraging red-cockaded woodpeckers.

Patch Selection

Habitat selection at a scale larger than individual trees, but smaller than stands, is referred to here as patch selection. Patch selection by red-cockaded woodpeckers has been explored in three studies. Bowman *et al.* (1997) found that woodpeckers foraged in patches containing fewer but larger trees than patches chosen randomly. Walters *et al.* (2000, 2002a) found that woodpeckers used patches containing larger trees and lower hardwood midstory than unused patches. Doster and James (1998) found that red-cockaded woodpeckers prefer to forage in patches containing larger pines, a lower overstory pine density, and less hardwood midstory than randomly chosen patches nearby.

Stand Selection

Use of stands by red-cockaded woodpeckers is influenced by the size of the stand, stand age, density of pines, density of large pines, fire history (hardwood midstory), season, and proximity to cavity trees and territorial boundaries (Hooper and Harlow 1986, Porter and Labisky 1986, DeLotelle *et al.* 1987, Epting *et al.* 1995, Bradshaw 1995, Walters *et al.* 2000, 2002a). Two studies documented a positive relationship between stand use and stand age after controlling for effects of cavity trees and territorial boundaries (DeLotelle *et al.* 1987, Epting *et al.* 1995). Porter and Labisky (1986) reported that preferred stands were much older than avoided stands (mean stand age = 72 and 18 years, respectively). Similarly, Jones (1994) reported that stands of trees less than 50 years old were avoided, and stand use increased continually with increasing stand age (Jones 1994, Jones and Hunt 1996). Hooper and Harlow (1986) also reported a positive effect of stand age on use but considered it to be weak.

Stand use and density of all pines may be positively related if densities are generally low (DeLotelle *et al.* 1987) and unrelated or negatively related if densities are high (Hooper and Harlow 1986, Bradshaw 1995). Effects of pine density on stand use also changes depending on the size of trees in question: increasing density of large trees is beneficial (Hooper and Harlow 1986, Bradshaw 1995, Walters *et al.* 2000, 2002a), whereas high densities of small pines are detrimental (Porter and Labisky 1986, Walters *et al.* 2000, 2002a). For example, stand use increased with increasing density of pines greater than or equal to 30.5 cm (12 in) dbh in Virginia (Bradshaw 1995), 35.6 cm (14 in) dbh in central North Carolina (Walters *et al.* 2000, 2002a), and 22.9, 35.6, and 48.3 cm (9, 14, and 19 in) dbh in coastal South Carolina (Hooper and Harlow 1986, although they considered these effects to be weak and, for the largest size class, due mainly to the presence of cavity trees.) Stand use decreased with increasing densities of pines less than 25.4 cm (10 in) dbh in central North Carolina (Walters *et al.* 2000, 2002a); similarly, dense stands of young trees (average 559 stems/ac and 18 yrs in age) were avoided in northwest Florida (Porter and Labisky 1986).

Hardwoods appear to have a negative influence on stand use. Stand use decreased with increasing density of hardwoods in several studies (Hooper and Harlow 1986, Epting *et al.* 1995, Bradshaw 1995, Jones and Hunt 1996), and stand use was negatively influenced by the average height of midstory hardwoods in North Carolina (Walters *et al.* 2000, 2002a). Jones and Hunt (1996) found that stands in which greater than 10 percent of canopy trees were hardwoods were avoided.

Finally, during the non-breeding season red-cockaded woodpeckers may travel long distances to access open stands of large pines, whereas during the breeding season birds may use stands containing smaller pines or a greater hardwood component if they are near nest cavities (Bradshaw 1995, Jones and Hunt 1996).

Home Range and Habitat Quality

Size of home ranges of red-cockaded woodpeckers have been described over much of the species' range and in several habitat types (Hooper *et al.* 1982, Wood 1983, Nesbitt *et al.* 1983, Repasky 1984, Porter and Labisky 1986, DeLotelle *et al.* 1987, Epting *et al.* 1995, Bradshaw 1995, Engstrom and Sanders 1997, Bowman *et al.* 1997, Hardesty *et al.* 1997, Doster and James 1998, Walters *et al.* 2000, 2002a). In studies with sample sizes of over 10 groups, average year-round home range size was estimated to be 83.0 ha (205 ac) in south-central North Carolina (Walters *et al.* 2000, 2002a), 87.0 ha (215 ac) in coastal South Carolina (Hooper *et al.* 1982), roughly 80.1 ha (198 ac) in coastal Georgia (Epting *et al.* 1995), 129.0 ha (319 ac) in central Florida (DeLotelle *et al.* 1995), and 108.9 ha (269 ac) in northwestern Florida (Hardesty *et al.* 1997). In addition, notable studies among those estimating home range based on fewer than 10 groups include one study in the northern edge of the species' current range (Bradshaw 1995), one in the southern edge of the species current and historic range (Nesbitt *et al.* 1983), and one in extremely rare old growth longleaf forest in southwest Georgia (Engstrom and Sanders 1997). Bradshaw (1995) reported that average year-round home range size for 6 groups in coastal Virginia was 120.2 ha (297 ac); Nesbitt *et al.* (1983) estimated that summer range for 5 groups in south Florida was 144.5 ha (357 ac); and Engstrom and Sanders (1997) reported that home range size for 7 groups in old growth forest in southwest Georgia was 46.9 ha (116 ac), the smallest average size yet reported (based on all-day follows). Also, Doster and James (1998) reported an average home range of only 24.7 ha (61 ac) for 5 groups of woodpeckers in shortleaf pine habitat of Arkansas, but this estimate was not based on all-day follows because rough terrain inhibited data collection.

Thus, home ranges in Florida tend to be larger than those farther north (DeLotelle *et al.* 1987, Hardesty *et al.* 1997), and those in fire-maintained old growth forest are substantially smaller than those in second-growth (Engstrom and Sanders 1997). Larger samples would be helpful in confirming these effects, but are not available for specific cases (e.g., Virginia Coastal Plain, old growth forest). Together these results suggest that the natural size and density of pines as well as degree of forest alteration (such as history of harvests and fire suppression) impact home range size. The size of a home range or territory may also increase if it is not constrained by the presence of neighboring groups (DeLotelle *et al.* 1987).

Several studies have related variation in home range (or territory) size within a population to habitat characteristics of the home range (Hooper *et al.* 1982, Bowman *et al.* 1997, Hardesty *et al.* 1997, Walters *et al.* 2000, 2002a). Hooper *et al.* (1982) reported that for 24 groups in coastal South Carolina, territory size generally increased with increasing pine density and basal area. In contrast, Hardesty *et al.* (1997) reported that for 25 groups in northwest Florida, home range size decreased with increasing pine density and basal area. Walters *et al.* (2000, 2002a) found home range size of 30 groups in south-central North Carolina was independent of pine density and basal area, but increased with increasing invasion by hardwoods. Thus, home range size depends on the quality of available foraging habitat: less habitat is needed if the quality of that habitat is high. Increasing pine density may be beneficial if pine density is low, or detrimental if density is high. This inverse relationship between quality and quantity of foraging habitat provides important evidence that foraging habitat can limit red-cockaded woodpecker populations, and underscores the critical need to restore quality of foraging habitat (F. C. James, pers. comm.).

In summary, studies of home range size suggest that red-cockaded woodpeckers require from 40.5 to 161.9 ha (100 to 400 ac) per group, depending upon the quality of foraging habitat, and that high quality foraging habitat has an open structure with an intermediate pine density and sparse or absent hardwood midstory. These characteristics of high-quality foraging habitat are consistent with those suggested by analyses of patch and stand selection (above) and group fitness (below). Moreover, this evidence points to the limitation of woodpecker populations by the quality of their foraging habitat, and illustrates the need for broad-scale habitat restoration.

Group Fitness and Habitat Quality

Understanding the relationships between group fitness (e.g., reproductive success, group size, adult survival) and quantity and quality of foraging habitat is key to formulating appropriate foraging guidelines for red-cockaded woodpeckers. However, current habitats are quite altered from original conditions, and this altered state diminishes our ability to see effects of habitat on group fitness and to determine an optimal amount of foraging habitat. Also, at least two other factors are important to group fitness: presence of helpers (Lennartz *et al.* 1987, Walters 1990, Neal *et al.* 1993a, Beyer *et al.* 1996) and increasing age and experience of breeders (Lennartz *et al.* 1987, Walters 1990, DeLotelle and Epting 1992) are known to increase reproduction. Finally, habitat effects are hard to identify because sample sizes are low, in number of groups studied and/or number of years with which group fitness is estimated. Substantial variation in reproduction can be attributed to stochastic environmental events (e.g., Neal *et al.* 1993a), which can mask other effects in small samples. Despite constraints of available habitat, confounding effects of other factors, and low power due to small samples, important progress has been made in determining effects of habitat quality on fitness.

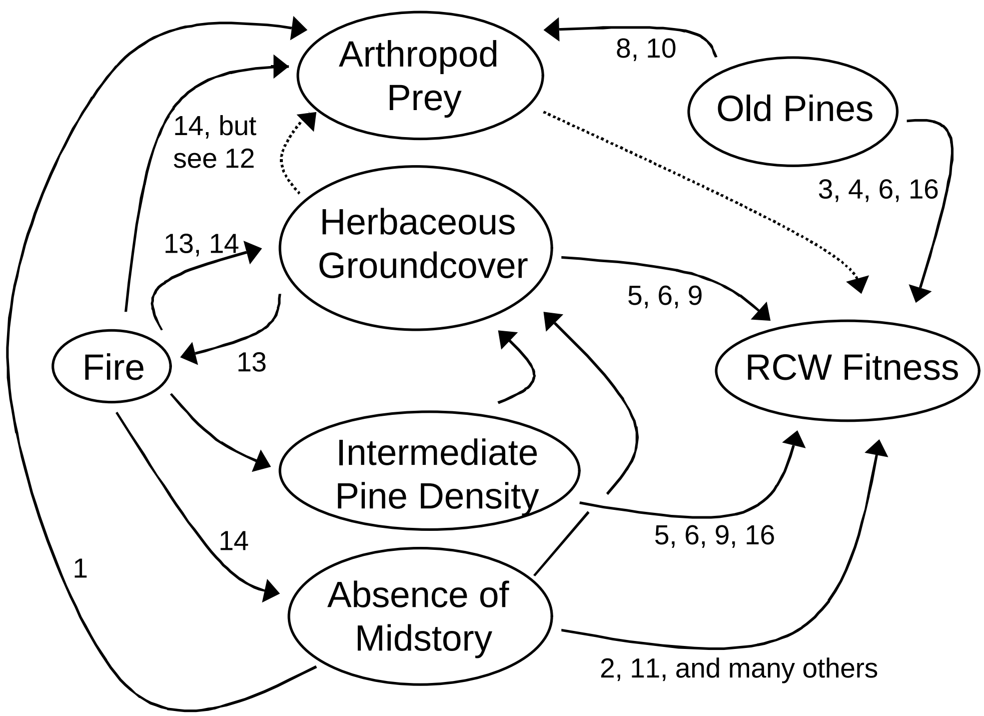
Several aspects of foraging habitat may affect group fitness. First, territory or home range size has been shown to affect group size and/or reproduction in some populations (DeLotelle and Epting 1992, Hardesty *et al.* 1997, USFWS 1985) but not in others (James *et al.* 1997, Walters *et al.* 2000, 2002a). For two studies reporting an influence of home range/territory size on fledgling production, much of the effect appears to have come from whole brood loss or failure to nest (DeLotelle and Epting 1992, Hardesty *et al.* 1997). This suggests that there is a threshold home range size below which reproduction becomes difficult, and it is possible that studies not showing this effect did not sample below the threshold. Home range size for successfully and unsuccessfully nesting groups in northwest Florida averaged 126.3 and 72.4 ha (312 and 179 ac) respectively (Hardesty *et al.* 1997); a threshold home range size for this population under current habitat conditions would fall between these two estimates.

Effects of home range size on fitness vary, of course, with the quality of foraging resources. This point is best illustrated by the large, healthy groups on home ranges averaging only 46.9 ha (116 ac) in the fire-maintained, old growth longleaf forest of the Wade Tract, GA (including considerable overlap among home ranges, Engstrom and Sanders 1997). These groups have the smallest average home range and the highest average group size and reproduction yet reported (average group size 3.0 to 3.6; average fledglings from successful nests 2.3 to 2.5; Engstrom and Sanders 1997). In addition, effects of foraging habitat on group fitness may interact with the general health of the population. For example, Conner and Rudolph (1991b) reported that loss of foraging habitat affected group size in small isolated populations but not in larger populations.

Recent research has revealed that fire history of the foraging habitat affects group fitness in several different ways (Figure 1). Group size and/or reproduction is negatively affected by dense stands of pines (Hardesty *et al.* 1997, James *et al.* 1997, 2001, Walters *et al.* 2000, 2002a), positively related to percent of ground covered by wiregrass (*Aristida spp.*) or forbs (Hardesty *et al.* 1997, James *et al.* 1997), and negatively related to increasing hardwood midstory (Walters *et al.* 2000, 2002a). At Eglin Air Force Base in Florida, reproduction was negatively affected by pine density above 16.1 m^2 of basal area per ha (70 ft^2/ac). Similarly, group size in the North Carolina Sandhills was negatively affected by density of pines less than 35 cm dbh (14 in; Walters *et al.* 2000, 2002a). Frequent fire increases the quality of foraging habitat in several ways: it provides an open structure by reducing density of overstory and midstory pines and hardwoods, it encourages grass and forb groundcovers, and it may also increase nutrient cycling through the ecosystem and the nutrient content of prey (James *et al.* 1997; Figure 1).

Finally, group fitness increases with increasing numbers of old trees in the foraging habitat (Figure 1). In Louisiana, density of groups, group fitness, and the number of old growth trees (90 to 120 years in age) were all strongly positively related (Conner *et al.* 1999). In Texas, group size increased with increasing area of pines greater or equal to 60 years in age both within 400 meters of the cluster (Conner and Rudolph 1991b) and at a larger, regional scale (520 to 5200 ha, Rudolph and Conner 1994). Similarly, in central North Carolina group size increased with increasing density of flat-tops (very old pines) in home ranges (Walters *et al.* 2000, 2002a). Effects of habitat quality on group size are of utmost importance, because of stabilizing effects of helpers on population dynamics, the increase in reproduction in larger groups, and decrease in groups consisting of solitary males.

FIGURE 1. Relationships among fire, habitat components, arthropods, and fitness of red-cockaded woodpeckers (RCW) as illustrated by a summary of research. Solid lines indicate a positive effect (direct or indirect) that has been documented in at least one study; dotted lines indicate potential effects not yet documented. Numbers refer to the citations listed below.



1. Collins 1998
2. Conner and Rudolph 1989
3. Conner and Rudolph 1991b
4. Conner *et al.* 1999
5. James *et al.* 1997
6. James *et al.* 2001
7. Hanula and Franzreb 1998
8. Hanula *et al.* 2000
9. Hardesty *et al.* 1997
10. Hooper 1996
11. Loeb *et al.* 1992
12. New and Hanula 1998
13. Platt *et al.* 1988
14. Provencher *et al.* 1998, 1999, 2001
15. Rudolph and Conner 1994
16. Walters *et al.* 2000, 2002a

Other studies have not found a relationship between group fitness and the amount and quality of foraging habitat as measured by traditional variables such as the number and basal area of pines greater than 25 cm (10 in) dbh (Hooper and Lennartz 1995, Beyer *et al.* 1996, Ferral 1998, Wigley *et al.* 1999).

At the present time, we recognize that fitness of woodpecker groups increases if they have substantial amounts of foraging areas that are burned regularly and have little or no hardwood midstory, an abundant grass and forb groundcover, low densities of small and medium-sized pines and higher densities of large old pines. Again, these results are consistent with those from studies of tree selection, patch selection, stand selection, and home range/habitat quality relationships (see above).

Geographic Variation in Foraging Habitat

There is substantial geographic variation in habitat occupied by red-cockaded woodpeckers. Historically, longleaf pine ecosystems were the most common habitat type and still support most of the largest remaining populations (Carter 1971, Hooper *et al.* 1982, James 1995, Engstrom *et al.* 1996). Within these longleaf pine habitats there is variation in structure and species composition according to soil type and moisture. Red-cockaded woodpeckers also exist in other habitat types including shortleaf pine communities of Arkansas and Oklahoma (Wood 1983, Masters *et al.* 1989, Kelly *et al.* 1993, Hines and Kalisz 1995, Zenitsky 1999), transitional zones of the Piedmont (Steirly 1957), pond pine communities of eastern North Carolina (J. Carter III, pers. comm.), native hydric slash pine system of south Florida (Beever and Dryden 1992), and loblolly forests in many areas (e.g., Hooper and Harlow 1986). Despite natural geographic variation in habitats, the basic ecology of red-cockaded woodpeckers remains unchanged throughout their range: red-cockaded woodpeckers select old pines in open stands for nesting and foraging, and the open structure that characterizes nesting and foraging habitat is best maintained by frequent, growing season fire.

Longleaf Pine Communities

Species composition and structure of longleaf pine communities vary according to interacting moisture, soil, and fire factors. Frequently burned sites with deep sandy soils support what are variously known as sandhill, high pine, or xeric sand communities. These xeric sand communities are found throughout the southeast, on alluvial sands, recently exposed terraces, and relict dunes of the entire Coastal Plain as well as along the fall line that marks the transition between Coastal Plain and Piedmont in the Carolinas and Georgia. Two distinct longleaf ecosystems occur on these deep sandy soils: xeric and subxeric longleaf pine woodlands (Peet and Allard 1993, Christensen 2000). Xeric longleaf pine woodlands are characterized by widely scattered longleaf pines, a sparse midstory of turkey (*Quercus laevis*) and bluejack oaks, and sparse groundcovers dominated by wiregrasses (*Aristida stricta* north of the Congaree/Cooper rivers in South Carolina and *A. beyrichiana* to the south, Peet 1993). Within this xeric woodland type, five series have been identified (Peet and Allard 1993): fall line, Atlantic, and southern (Gulf) xeric longleaf woodlands, and Atlantic and Gulf maritime longleaf woodlands. Subxeric longleaf pine woodlands contain the above species as well as many more that are adapted to somewhat moister conditions (Christensen 2000). This ecosystem type dominated much of the Coastal Plain uplands prior to European settlement (Ware *et al.* 1993, Christensen 2000). Peet and Allard (1993) identified three series within the subxeric ecosystem type: fall line, Atlantic, and Gulf subxeric longleaf pine woodlands.

Mesic longleaf pine communities include flatwoods and savannahs, which differ from each other mainly in structure. Savannahs are characterized by an open canopy and grass groundcover, whereas flatwoods have a somewhat denser canopy and a midstory of shrubs and subcanopy trees (Christensen 2000). The primary cause of variation between flatwoods and savannahs is interacting effects of fire and soil moisture (Peet and Allard 1993). There is no generally accepted classification of these mesic longleaf pine communities (Christensen 2000). Southern flatwoods include saw palmetto (*Serenoa repens*), gallberry-fetterbush (*Ilex glabra-Lyonia lucida*), and fern phases. If burned more frequently, these flatwoods may become more like savannahs (Christensen 2000). Longleaf pine savannahs in the Atlantic and Gulf regions contain many endemic species (Peet and Allard 1993, Walker 1993, Christensen 2000), and species diversity for these community types is among the highest in North America (Walker and Peet 1983).

All of these longleaf community types can support red-cockaded woodpeckers if sufficient old growth and mature pines are available for cavity trees. However, researchers have suggested that in some locations, such as sites of low productivity, extremely dry or wet locations, red-cockaded woodpeckers may need more foraging habitat than those in mesic habitats (Hardesty *et al.* 1997, DeLotelle *et al.* 1987, 1995). These researchers have observed very large home ranges in some locations, possibly because arthropods are limited by sparse groundcovers or low pine density. Expansion of home range size in these habitat types may be a response to low site productivity or a result of past alteration of the forest through overharvest or fire suppression. Low site productivity can also affect how an ecosystem recovers following alteration (Provencher *et al.* 1997, 1998, 2001). Whether the effect is natural or human-induced, some populations of red-cockaded woodpeckers in wet or very dry sites are using more foraging habitat. Further research is required before we fully understand how differences in longleaf pine community types influence the foraging ecology of red-cockaded woodpeckers.

Shortleaf Pine Communities

Shortleaf pine communities supporting red-cockaded woodpeckers are found in the Ouachita Mountains of Arkansas and Oklahoma (McCurtain County Wilderness Area and Ouachita National Forest) and in eastern Texas (parts of Sam Houston National Forest, Davy Crockett National Forest, and the W. G. Jones and I. D. Fairchild State Forests). The western edge of the Cumberland Plateau in Kentucky (Daniel Boone National Forest) supported red-cockaded woodpeckers in shortleaf pine habitats until severely impacted by southern pine beetles in the summer of 2000. Shortleaf pine communities are fire maintained, with a two-layered structure of pine overstory and diverse bunchgrass groundcover much like those of longleaf communities. Loblolly and other pines may be present as secondary components. Unlike most longleaf pine woodlands, many shortleaf pine communities supporting red-cockaded woodpeckers are in regions of complex topography (Masters *et al.* 1989, 1995, Kalisz and Boettcher 1991, Hines and Kalisz 1995, Zenitsky 1999). These rugged areas have steep and narrow ridges, and communities dominated by shortleaf pine are confined to slopes of southern and western exposure and to the ridgetops (Masters *et al.* 1989, Foti and Glenn 1991, Kalisz and Boettcher 1991). Mesic sites such as drainages and north-facing slopes are typically dominated by white oak (*Quercus alba*) and some maples (*Acer* spp.; Masters *et al.* 1989, Foti and Glenn 1991).

Historic shortleaf pine/bunchgrass communities have sustained massive intrusion by hardwoods as a result of fire suppression and exclusion, and this intrusion has caused precipitous declines of red-cockaded woodpeckers in these regions (Masters *et al.* 1989, 1995). Return intervals of fire prior to European settlement have been estimated as 3 to 6 years for shortleaf pine ecosystems in rugged terrain (Masters *et al.* 1995). Reintroduction of fire, using a prescribed burning program patterned after the precolonial fire regime, is vital to the survival and recovery of red-cockaded woodpeckers in these regions (Masters *et al.* 1989, 1995).

Several studies indicate that foraging behavior of red-cockaded woodpeckers in shortleaf habitat is similar to that of woodpeckers on the coastal plain. Woodpeckers foraging on shortleaf pines select large old trees in patches that have less hardwood midstory than the surrounding forest (Murphy 1982, Doster and James 1998, Zenitsky 1999). One study of the once critically endangered and now extirpated population in Kentucky reported a preference for hardwoods as foraging substrate, for 2 of 5 groups during the 1991 nesting season only (Hines and Kalisz 1995). However, further research in this population showed no such effect (Zenitsky 1999). Again, the severe decline of red-cockaded woodpeckers in Kentucky (prior to 1997) and other shortleaf habitats was directly related to hardwood encroachment (Masters *et al.* 1989, 1995), and their foraging behavior did not appear to differ from red-cockaded woodpeckers elsewhere in the range (Murphy 1982, Doster and James 1998, Zenitsky 1999).

Red-cockaded woodpeckers can tolerate some overstory hardwoods in foraging habitat, and even in clusters if more than 15.2 m (50 ft) from cavity trees. Inclusions of xeric hardwood species such as post, blackjack (*Quercus marilandica*), and other oaks (*Quercus* spp.), especially in shortleaf forests, are natural components of the ecosystem and do not need to be totally removed for woodpecker management. However, such hardwoods must remain a minor component overall. In the shortleaf forests of Oklahoma, precolonial density of hardwoods was an estimated 4.6 to 5.7 m^2 basal area per ha (20 to 25 ft^2/ac; Masters *et al.* 1995). Such densities should be considered maximum for red-cockaded woodpecker management. Estimated pine basal area of precolonial Oklahoma is similar to that of longleaf forests, at 8.0 m^2/ha (35 ft^2/ac; Masters *et al.* 1995).

Loblolly Pine Habitats

Because of fire sensitivity, loblolly pine historically was much less widespread than today (White 1984, Landers 1991, Christensen 2000). Prior to fire suppression, loblolly pine was a minor component of riparian and other mesic forests in the coastal plain and a secondary component of mixed pine and pine hardwood forests in interior uplands. Forests dominated by loblolly were rare and restricted to a portion of southern Arkansas and perhaps eastern Virginia/northeastern North Carolina (White 1984, Christensen 2000). Currently, because of fire suppression during the past century and silvicultural practices favoring the species (White 1984), loblolly pine is the dominant pine throughout the southeast, in areas that were historically covered by longleaf pine, shortleaf pine, and shortleaf/loblolly pine forests (White 1984). These off-site loblolly pine forests have provided and continue to provide important resources for red-cockaded woodpeckers. However, ample opportunities exist for the careful restoration of site-appropriate pines in areas currently dominated by off-site loblolly. Foraging ecology of red-cockaded woodpeckers in off-site loblolly is consistent with that of red-cockaded woodpeckers in predominantly longleaf forests: red-cockaded woodpeckers foraging on loblolly select older pines in open stands (e.g., Hooper and Harlow 1986, Zwicker and Walters 1999). The rare forests dominated by natural, historically occurring loblolly pine warrant special consideration and conservation. Foraging ecology of red-cockaded woodpeckers within this habitat type has not been addressed.

Pond Pine Communities

The remaining pond pine communities that support red-cockaded woodpeckers are found primarily in northeastern North Carolina (J. H. Carter III, pers. comm.). Pond pines were likely sparsely distributed in the upland shrub bogs known as pocosins, but fire suppression has led to increased pine density and hardwood encroachment. Foraging requirements of red-cockaded woodpeckers in this habitat type have not been studied at all. Management of woodpeckers in pond pines is complicated by the catastrophic nature of the natural fire regime, dangerous accumulation of fuels during years of fire suppression, southern pine beetle outbreaks, and high rates of cavity enlargement by pileated woodpeckers (J. H. Carter III, pers. comm.). Reintroduction of fire is required for continued survival and recovery of woodpeckers in these habitats, but further research is necessary to determine best methods of prescribed burning and foraging habitat requirements.

South Florida Slash Pine Communities

Native slash pine communities support red-cockaded woodpeckers in south Florida (Beever and Dryden 1992). This subspecies of slash pine (*Pinus elliottii* var. *densa*) is the only native pine in this region and is similar to longleaf in both appearance and fire resistance. Native slash pine has a grass stage and large taproot as does longleaf pine (Landers 1991). Much of the native slash used by red-cockaded woodpeckers is in hydric communities (Beever and Dryden 1992). It may be that slash pine replaces longleaf pine in this region because it can better tolerate very wet conditions.

For red-cockaded woodpeckers, native slash pine habitats differ from those farther north in that the pines are generally smaller and may be more sparsely distributed (Patterson and Robertson 1981, Beever and Dryden 1992, Landers and Boyer 1999). The largest size that south Florida slash pines achieve, even in old growth woodlands, is typically 20 to 30 cm (8 to 12 in). Cavity trees in this habitat type are much smaller than normally found in other habitats (Beever and Dryden 1992, Bowman and Huh 1995). However, the presence of fire and old trees in both nesting and foraging areas are critically important here as elsewhere.

Woodpeckers in native slash pine have not been well studied. Preliminary research has indicated that home ranges of birds in native slash pine are larger than those in other habitats (Patterson and Robertson 1981, Beever and Dryden 1992), but the relationship between habitat requirements and habitat quality has not been investigated in this forest type. Thus, it is not known whether larger home ranges in south Florida result from degraded habitat, natural differences in habitat quality, population density, or even lack of cavity trees. Although further research is necessary to determine the cause of large home ranges in south Florida, results from studies elsewhere suggest that as habitat quality increases, the size of these home ranges will decrease. It is likely that, as pine density, age, and herbaceous groundcovers of south Florida slash pine woodlands increase, resident woodpeckers will still require more foraging habitat than woodpeckers in most other regions but less than they appear to be using at the present time.

Slash pine (*Pinus elliottii* var. *elliottii*) was historically a minor component of coastal pine forests. It is a mesic pine that was generally found in damp swales, narrow drainages, and along pond margins within longleaf pine forests (Landers 1991, Christensen 2000). Slash pine is now much more widespread than historically, as a result of fire suppression and aggressive planting programs. Off-site slash pine forests support small numbers of red-cockaded woodpeckers in some areas. Restoration of these sites to site-appropriate pines would be beneficial; however, caution must be used to avoid unnecessary impacts to red-cockaded woodpeckers (Ferral 1998, see 3G).

Previous Management Guidelines

Previous guidelines for management of foraging habitat (USFWS 1985, Henry 1989) emphasized the number of pines greater than 25.4 cm (10 in) dbh that should be provided each group of woodpeckers, in stands meeting some broad criteria (e.g., overstory hardwoods 50 percent or less of canopy tree basal area, pines 30 years in age or greater). These guidelines were important and useful in several ways: the guidelines provided much-needed protection against overharvest of pines; they stressed that red-cockaded woodpeckers require a large quantity of land and they furnished this large quantity of land fairly successfully; and they represented the best estimate of foraging requirements available from research at that time. However, these guidelines were also flawed in some ways: the actual number of pines recommended was based on one population and a small sample (n=18); the guidelines may have encouraged high densities of small and medium sized pines now known to be detrimental; and most importantly, researchers have been unable to detect any relationship between the total number or total basal area of pines greater or equal to 25.4 cm (10 in) dbh within a group's foraging area and measures of fitness such as group size or reproduction (e.g., Hooper and Lennartz 1995, Beyer *et al.* 1996, Wigley *et al.* 1999). This continued failure to find any relationship between fitness and total number of small and medium sized pines strongly suggests that these variables are not the best way to measure quality or quantity of foraging habitat.

This last point – the lack of relationship between number of pines greater than 25.4 cm (10 in) dbh and group size and/or reproduction—is shown clearly in an analysis recently performed by R. Hooper (unpublished), combining data from nine data sets for a total of 198 groups with mean group size greater or equal to 2 adults. In only two of the data sets did mean number of pine stems greater or equal to 25.4 cm (10 in) dbh approach the standard of 6350 pines set by the 1985 Recovery Plan (USFWS 1985), and one of those data sets determined the original standard. With one exception (Hooper and Lennartz (1995) lacked habitat data for individual groups), these data were pooled for regression analyses of number of pine stems greater or equal to 25.4 cm (10 in) dbh against mean fledglings produced and mean group size. These regressions were significant or nearly significant, but they explained a trivial amount of the variation in independent variables (mean fledglings: df = 1, 196; $R^2 = .02$; $P < 0.05$; mean group size: df = 1, 179; $R^2 = .04$; $P < 0.01$). Thus, number of young fledged and group size were at best weakly related to the number of pine trees $\geq$ 25.4 cm (10 in) dbh available to the various groups, and unspecified factors accounted for 98 percent of the variation in number of young fledged and 96 percent of the variation in the group size. Thus, number of pines greater or equal to 25.4 cm (10 in) dbh is not a particularly good measure of foraging habitat requirements.

Implications for New Management

Supplying good quality foraging habitat is a critical aspect of red-cockaded woodpecker recovery, especially over the long term, as immediate threats from cavity and cluster limitation are reduced. Our understanding of what constitutes good quality foraging habitat comes from a synthesis of research into selection of foraging habitat and effects of habitat characteristics on group fitness.

Both habitat selection and group fitness are influenced by the structure of the foraging habitat. Important structural characteristics include (1) healthy groundcovers of bunchgrasses and forbs, (2) minimal hardwood midstory, (3) minimal pine midstory, (4) minimal or absent hardwood overstory, (5) a low to intermediate density of small and medium sized pines, and (6) a substantial presence of mature and old pines (e.g., Figure 2). Thus, the quality of foraging habitat is defined by habitat structure. Although geographic variation in habitat types exist, these structural characteristics of good quality habitat remain true for all geographic regions and habitat types. Previous guidelines

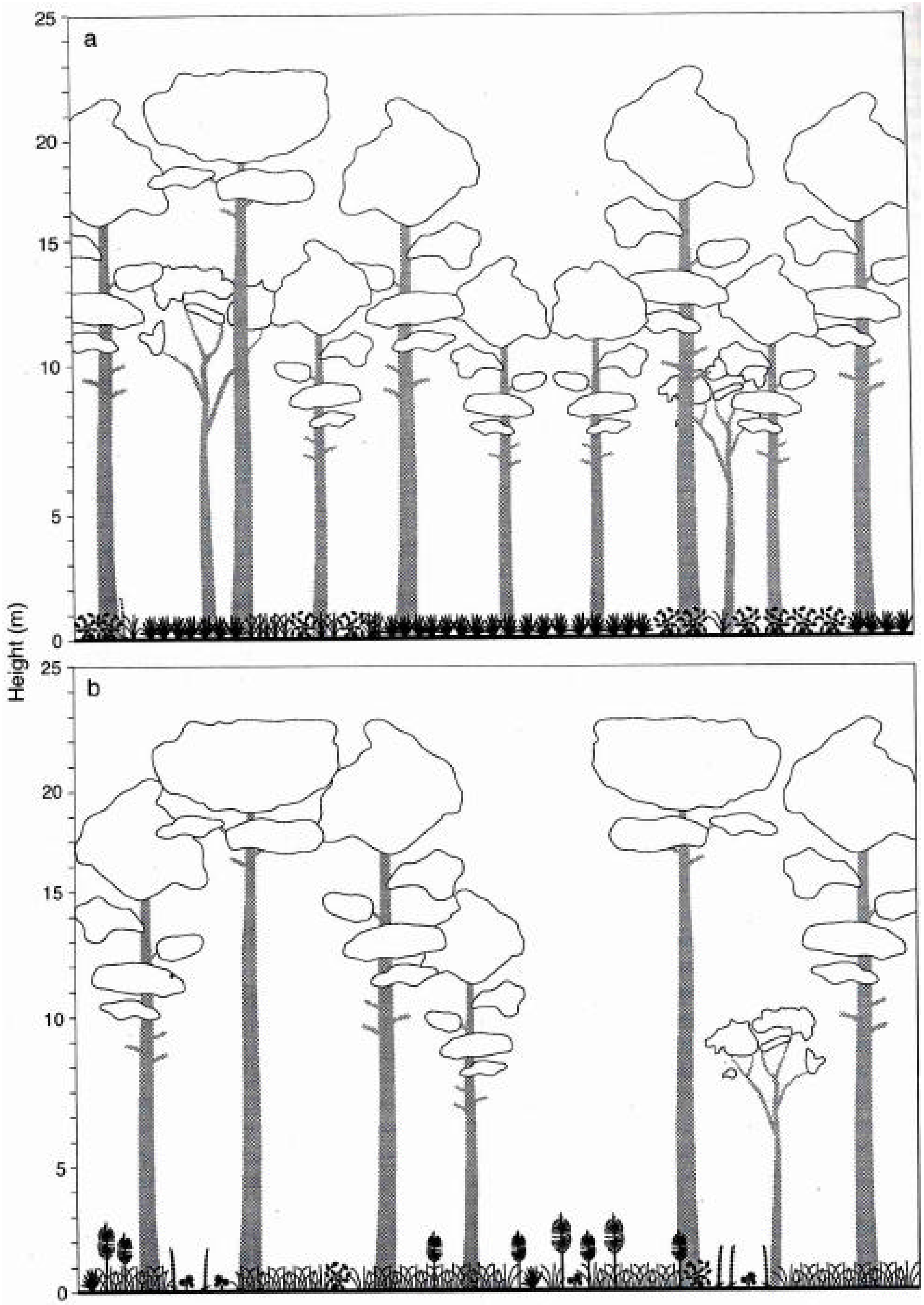


FIGURE 2. Diagrams of (a) adequate and (b) good foraging habitat, as illustrated by James *et al.* (2001). Copyright Ecological Applications; used with permission.

stressed quantity of foraging habitat, as defined by number of medium and large trees. Here we expand this emphasis to include habitat quality, as defined by habitat structure, and use area metrics to address quantity. Red-cockaded woodpeckers require foraging habitat that is suitable in both quantity and quality.

Quantifying habitat structure (and thus habitat quality) is more complex than simply requiring a given amount of habitat or number of trees, because habitat structure is measured by multiple variables. Guidelines for foraging habitat (see 8I) are based on the quantification of structural characteristics to the best of current abilities. Frequent fire can facilitate the restoration and maintenance of all but one of these structural characteristics (mature and old pines), and may provide further benefits by increasing the availability of nutrients. In addition, appropriate silvicultural methods will protect, throughout the landscape, the mature and old trees on which red-cockaded woodpeckers thrive.

F. Community Ecology: Cavity Kleptoparasitism, Cavity Enlargement, and Predation

Red-cockaded woodpeckers are a keystone species of fire-maintained southern pine ecosystems because the cavities they create influence the presence or abundance of a suite of cavity-dwelling species in an otherwise cavity-poor environment (Rudolph *et al.* 1990a, Conner and Rudolph 1995a). Excavation of cavities into live pines by red-cockaded woodpeckers requires a relatively long period of time (Jackson *et al.* 1979, Conner and Rudolph 1995a, Harding 1997). Thus, these cavities are in high demand (Dennis 1971a, Harlow and Lennartz 1983, Rudolph *et al.* 1990b, Loeb 1993, Conner et al. 1997b). Approximately 27 species of vertebrates are known to use cavities excavated by red-cockaded woodpeckers (Table 4; Baker 1971b, Beckett 1971, Dennis 1971a, Hopkins and Lynn 1971, Jackson 1978a, Belwood 1981, Harlow and Lennartz 1983, Rudolph *et al.* 1990a, Loeb 1993, Kappes and Harris 1995, Conner et al. 1997b, Loeb and Hooper 1997, Phillips and Gault 1997). Many of these vertebrates use either enlarged (below) or abandoned cavities, but red-bellied woodpeckers, red-headed woodpeckers, eastern bluebirds, several other bird species, and southern flying squirrels use normal, unenlarged cavities that red-cockaded woodpeckers could also use. Southern flying squirrels are generally the most commonly observed species in red-cockaded woodpecker cavities other than red-cockaded woodpeckers (Rudolph *et al.* 1990a, Loeb 1993, Kappes and Harris 1995, Laves and Loeb 1999, Mitchell *et al.* 1999), although these observations were made during daylight hours. Eastern bluebirds were more common than flying squirrels in coastal South Carolina (Loeb and Hooper 1997).

Cavity Kleptoparasitism

If a cavity created and used by red-cockaded woodpeckers is usurped by another species, the interaction between that species and red-cockaded woodpeckers is termed cavity kleptoparasitism (Kappes 1997). Until recently, authors have referred to this

TABLE 4. Species using normal and enlarged cavities excavated by red-cockaded woodpeckers[1].

Taxon	Species	Scientific Name
Birds	Wood duck	*Aix sponsa*
	Tufted titmouse	*Baeolophus bicolor*
	Northern flicker	*Colaptes auratus*
	Pileated woodpecker	*Dryocopus pileatus*
	American kestrel	*Falco sparverius*
	Red-bellied woodpecker	*Melanerpes carolinus*
	Red-headed woodpecker	*Melanerpes erythrocephalus*
	Great crested flycatcher	*Myiarchus crinitus*
	Eastern screech owl	*Otis asio*
	Red-cockaded woodpecker	*Picoides borealis*
	Carolina chickadee	*Poecile carolinensis*
	Eastern bluebird	*Sialia sialis*
	White-breasted nuthatch	*Sitta carolinensis*
	Brown-headed nuthatch	*Sitta pusilla*
	European starling	*Sturnus vulgaris*
Mammals	Wagner's mastiff bat	*Eumops glaucinus floridanus*
	Southern flying squirrel	*Glaucomys volans*
	Evening bat	*Nycticeius humeralis*
	Raccoon	*Procyon lotor*
	Eastern gray squirrel	*Sciurus carolinensis*
	Eastern fox squirrel	*Sciurus niger*
Reptiles/Amphibians	Corn snake	*Elaphe guttata*
	Rat snake	*Elaphe obsoleta*
	Broadhead skink	*Eumeces laticeps*
	Five-lined skink	*Eumeces spp.*
	Gray treefrog	*Hyla spp.*
	Lizard spp.	Lacertilia
Invertebrates	Honeybee	*Apis mellifera*
	Spider spp.	Arachnida
	Wasp spp.	Hymenoptera
	Ant spp.	Hymenoptera
	Moth spp.	Lepidoptera
	Mud daubers	Sphecidae

[1]Sources: Baker 1971b, Beckett 1971, Dennis 1971a, Hopkins and Lynn 1971, Jackson 1978a, Belwood 1981, Harlow and Lennartz 1983, Rudolph *et al.* 1990a, Loeb 1993, Kappes and Harris 1995, Conner et al. 1997b, Loeb and Hooper 1997, Phillips and Gault 1997.

interaction as cavity competition (e.g., Ligon 1970, Jackson 1978a, Carter *et al.* 1983, Rudolph *et al.* 1990a, Loeb 1993, Kappes and Harris 1995), but the term cavity kleptoparasitism is more correct (Kappes 1997). As Kappes (1997) explains, competition describes an interaction in which both species exhibit a negative effect from the presence of the other. Because cavity usurpers are acquiring a limited resource created by another species, the interaction provides benefits for the usurping species and negative effects on red-cockaded woodpeckers. Kleptoparasitism is the appropriate term for such a positive-negative relationship.

Cavity kleptoparasitism may negatively affect individual woodpeckers or woodpecker groups on occasion (see below). Occasional loss of nests or cavities is unlikely to have population-level impacts in red-cockaded woodpecker populations that are healthy and of medium to large size. However, critically small populations or isolated groups may not be able to tolerate high rates of kleptoparasitism. Also, effects of kleptoparasites may vary with habitat quality. Further research is needed into relationships among kleptoparasites, habitat quality, and red-cockaded woodpecker abundance.

Red-bellied Woodpeckers

Red-bellied woodpeckers are a common cavity kleptoparasite of red-cockaded woodpeckers (Neal *et al.* 1992, Kappes 1997). Usurpation of cavities by red-bellied woodpeckers may result in open roosting for red-cockaded woodpeckers. For example, Kappes (1997) observed 15 adults open roosting during a winter in Florida; 14 of these 15 had suffered loss of cavities to red-bellied woodpeckers. However, how much open roosting may affect survival or territory occupancy is not yet known. Rates of kleptoparasitism by red-bellied on red-cockaded woodpeckers may vary inversely with habitat quality (F. James, pers. comm.). Similarly, red-cockaded woodpeckers in optimal habitat are likely to suffer less impact from each usurpation event. Thus, increasing the overall quality of the habitat for red-cockaded woodpeckers may be an effective means of controlling effects of cavity usurpation by red-bellied woodpeckers. Retention of snags and provision of nest boxes may reduce effects of red-bellied woodpeckers as well (Loeb and Hooper 1997, below).

Southern Flying Squirrels

Reported rates of occupancy of red-cockaded woodpecker cavities by southern flying squirrels range from 9 to 34 percent (Dennis 1971a, Rudolph *et al.* 1990a, Loeb 1993, Laves and Loeb 1999, Mitchell *et al.* 1999). Southern flying squirrels prefer active cavities with non-enlarged entrance tunnels over those with entrance tunnels enlarged (Rudolph *et al.* 1990a, Loeb 1993), and cavity inserts over natural cavities (Lotter 1997). From among active cavities, southern flying squirrels prefer cavities with enlarged chambers over those with regular chambers (Rossell and Gorsira 1996).

Southern flying squirrels could potentially affect red-cockaded woodpeckers through usurpation of cavities or through predation. There is disagreement among researchers over whether cavity usurpation has any negative effects. Some suggest that cavity usurpation lowers nest attempts (Loeb and Hooper 1997), but others have found no evidence that the presence or abundance of southern flying squirrels increases open roosting or decreases nest attempts (Rudolph *et al.* 1990a, Conner *et al.* 1996, Laves 1996, Mitchell *et al.* 1999). Whether or not flying squirrels are significant predators of red-cockaded woodpecker nests is discussed below.

It has been suggested in the past that southern flying squirrels increase with increasing hardwood midstory (Conner and Rudolph 1989, Loeb *et al.* 1992). Yet, Conner *et al.* (1996) observed regular use of red-cockaded woodpecker cavities by southern flying squirrels in loblolly-shortleaf pine habitat with and without hardwood midstory and in open longleaf pine habitat that was nearly devoid of hardwood vegetation. Southern flying squirrels are abundant and ubiquitous, and at the present time the influence of plant species composition and vegetative structure on flying squirrel distributions is not understood.

Reducing Impacts from Cavity Kleptoparasites

The availability of snags may reduce potential impacts of cavity kleptoparasites on red-cockaded woodpeckers. Rates of cavity kleptoparasitism appear to be inversely related to the density of snags within clusters (Harlow and Lennartz 1983, Kappes and Harris 1995). Placement of nest boxes within cavity tree clusters may have a similar effect of lowering use of red-cockaded woodpecker cavities by other species (DeFazio *et al.* 1987, Loeb and Hooper 1997). Improving overall habitat quality and increasing woodpecker density may also reduce effects of kleptoparasites.

Cavity Enlargement

Enlarged cavities are those whose entrance tunnels have been widened by one of several species of woodpeckers (Conner *et al.* 1991a, Neal *et al.* 1992). Cavity enlargement is generally done by pileated woodpeckers, but red-bellied and red-headed woodpeckers and northern flickers also enlarge cavities created by red-cockaded woodpeckers (J. H. Carter III, pers. comm.). Pileated woodpeckers greatly expand entrance tunnels and can also enlarge the cavity chamber if sufficient heartwood is present (Conner *et al.* 1991a). Over a period of thirteen years in the Angelina National Forest in eastern Texas, pileated woodpeckers enlarged 41 percent (114 of 276) of unprotected natural red-cockaded woodpecker cavities (Saenz *et al.* 1998).

Cavity enlargement by pileated woodpeckers can have strong negative impacts on individual red-cockaded woodpeckers and, more importantly, on the entire population. Red-cockaded woodpeckers will abandon their clusters if damage to cavities by pileated woodpeckers is great. However, the enlarged cavities created by pileated woodpeckers provide important habitat for many other relatively large secondary cavity users, such as American kestrels (*Falco sparverius*), eastern screech owls (*Otus asio*), and fox squirrels (*S. niger;* Conner *et al.* 1997b, Saenz *et al.* 1998). In fact, just as red-cockaded woodpeckers are the primary source of cavities for other similar-sized cavity users, pileated woodpeckers are key to the availability of cavities for large cavity-nesting species (Saenz *et al.* 1998). Therefore, the challenge to management is to reduce the effects of cavity enlargement on red-cockaded woodpeckers without overly impacting large cavity-nesting species of concern.

Why pileated woodpeckers enlarge cavities is unknown. Enlarged cavities are rarely used by pileated woodpeckers for roosting or nesting (Conner et al. 1997b). Saenz *et al.* (1998) suggest that pileated woodpeckers are attracted to trees bearing signs of woodpecker excavation, but that heavy resin flow often prevents complete nest excavation. Damage by pileated woodpeckers decreases with increasing availability of snags in the general area (Saenz *et al.* 1998), just as rates of cavity kleptoparasitism may decrease with increasing snags. Thus, managers should retain snags throughout lands managed for red-cockaded woodpeckers and consider their protection during prescribed burns.

Cavity damage by pileated woodpeckers may also be related to human disturbance. Initial attempts at midstory control within the cluster may attract pileated woodpeckers if midstory outside the cluster is excessive (J. H. Carter III, pers. comm., R. Costa, pers. comm.). Again, restoration of high quality habitat for both foraging and nesting may reduce impacts from pileated woodpeckers.

Cavity Restrictors

Metal plates that restrict the entrance diameter of red-cockaded woodpecker cavities (Carter *et al.* 1989) can be used to rehabilitate some currently unsuitable cavities or to prevent the enlargement of currently suitable cavities (see 3B). Although these plates may prevent further damage by larger species of woodpeckers, they will not deter the use of cavities by southern flying squirrels or other small species of birds. When cavity availability is limited (less than four suitable cavities per group or less than one suitable cavity per group member) and enlargement by pileated woodpeckers is common, use of cavity restrictors is absolutely essential to protect existing cavities from enlargement and rehabilitate cavities with minor to moderate entrance enlargement. Use of restrictors to prohibit use of cavities by red-bellied woodpeckers is not recommended (see 3B).

Restrictors require careful monitoring on an annual basis, to ensure that negative effects on red-cockaded woodpeckers are minimized (see 3B). For this reason, their use must be judicious rather than haphazard or wholesale. In addition, enlarged cavities that have been abandoned for several years should not be restricted or should have any existing restrictors removed, so that they may be available to secondary cavity nesters.

Similarly, if cavities are not limited, then restrictors are not necessary and some enlarged cavities can be tolerated.

Predation

Rat Snakes

Red-cockaded woodpeckers excavate resin wells around cavity entrances to create a coat of fresh resin, typically extending several meters below and above the entrance and occasionally to the ground. They also scale loose bark from the bole of the cavity tree and nearby pines. During the 1970's, several biologists realized that these behaviors serve to protect the nests against predation by rat snakes (Ligon 1970, Dennis 1971b, Jackson 1974, 1978a), and in the late 1980's Rudolph *et al.* (1990a) documented experimentally the effectiveness of the resin barrier against climbing rat snakes.

Rat snakes are excellent tree climbers (Jackson 1976) and frequently prey on cavity-nesting birds (Fitch 1963, Jackson 1970). They attempt to climb cavity trees and cavity trees with nests more often than expected by chance alone, evidence that rat snakes are able to detect which trees contain cavities and also which cavity trees contain nests (Neal *et al.* 1993b). Sometimes, rat snakes are able to breach the resin barrier and prey on cavity contents such as eggs, nestlings, or even adults (Jackson 1978a, Neal *et al.* 1993b, 1998).

However, reports of individual predation events by rat snakes on red-cockaded woodpeckers are relatively scarce, and there is no evidence that such predation affects woodpeckers at the population level. For example, there was no difference in average reproduction between nests in cavity trees fitted with snake exclusion devices and untreated cavity trees over three years in the longleaf pines of northwest Florida (L. Phillips, unpublished). It is likely that the resin barrier is a highly effective means of deterring rat snakes, especially in longleaf pine.

Southern Flying Squirrels

Although flying squirrels are known to eat eggs of red-cockaded woodpeckers on occasion (Harlow and Doyle 1990), there is little consistent evidence that flying squirrels significantly depress reproduction of red-cockaded woodpeckers. Two experimental studies have been conducted comparing reproductive success of red-cockaded woodpeckers in clusters with and without squirrel removal (Laves and Loeb 1999, Mitchell *et al.* 1999). Laves and Loeb (1999) reported lowered reproduction in clusters without squirrel removal, resulting from increased whole brood loss in one year and increased partial brood loss in the following year. Mitchell *et al.* (1999) reported no difference in overall reproduction between clusters with and without squirrel removal, but noted increased partial brood loss in clusters that had squirrels removed. In addition, Conner *et al.* (1996) did not detect any relationship between abundance of southern flying squirrels and reproductive success of red-cockaded woodpeckers in eastern Texas. No study has yet shown an effect of flying squirrels on red-cockaded woodpeckers at the population level (Mitchell *et al.* 1999). Thus, it appears that impacts of flying squirrels on red-cockaded woodpeckers are not strong, at least in the populations in which they have been assessed.

Indirect Interactions

Red-cockaded woodpeckers, their cavity kleptoparasites, and nest predators such as rat snakes likely have direct and indirect interactions among them (J. Kappes, pers. comm.). Predation by snakes on kleptoparasites may reduce potential impacts of kleptoparasites on red-cockaded woodpeckers. Snake predation could potentially cause red-bellied woodpeckers or other cavity nesters to shift nest sites to snags, which are less easily climbed than live pine trees. Further research is required before we begin to understand such complex species interactions.

Implications for Management

In general, predator control is not an effective method of achieving stabilization or increases in bird populations, because predators rarely regulate population size in birds (Côté and Sutherland 1997). For red-cockaded woodpeckers, predators were not among the original causes of decline, and their removal will not result in population increases. Only habitat restoration, including prescribed burning, protection of mature and old growth trees, and cavity provisioning, can stabilize and increase populations by removing the original causes of decline.

Critically small populations, however, may not be able to withstand the loss of an occasional nest to predation by southern flying squirrels or rat snakes. For these populations, predator management techniques (see 3C) may be considered, but should not take the place of more fundamental management. Such methods are not appropriate in larger populations, because they may cause unintentional harm and can focus attention and resources away from habitat management and restoration. Further research into both direct and indirect species interactions is desirable before managers use predator exclusion techniques. Such exclusion may have unanticipated consequences, including negative effects on red-cockaded woodpeckers (J. Kappes, pers. comm.). Effects of such actions are simply not sufficiently understood to warrant their widespread use. Those who choose to use predator management techniques in small populations are encouraged to apply an experimental approach with adequate controls.

In contrast, cavity enlargement by pileated woodpeckers can have population-level effects in even fairly large populations by causing cluster abandonment. Restrictors (see 3B) are an essential management tool to be used judiciously in appropriate circumstances, with proper maintenance. Whether cavity kleptoparasitism by red-bellied woodpeckers negatively affects red-cockaded woodpecker populations requires further study. Effects of cavity kleptoparasitism by flying squirrels are under debate but are not considered strong or consistent enough to warrant flying squirrel removal or exclusion except perhaps in critically small populations (less than 30 potential breeding groups). Provision of nest boxes is a non-invasive technique that may help reduce effects of cavity kleptoparasitism (Loeb and Hooper 1997). Some evidence suggests that any effect of red-bellied woodpeckers (F. C. James, pers. comm.) and southern flying squirrels (Loeb and Hooper 1997) may increase with habitat degradation. In general, maintaining good quality nesting and foraging habitat (see 8F, 8I), providing sufficient numbers of suitable, unenlarged or restricted cavities (8E), and retaining snags in the landscape are the best management tools to reduce possible effects of occasional predation and cavity kleptoparasitism and to control the far more serious impacts from cavity enlargement.

G. The Role of Fire in Southern Pine Ecosystems

Fire is an integral component of the southern pine/bunchgrass ecosystems of the southeastern United States, and fire suppression is a principal factor in the decline of these ecosystems and characteristic species such as red-cockaded woodpeckers (see 1A). In this section, we review the history of fire in the region and the fire dependence of the species comprising southern pine ecosystems. In 3F, we discuss prescribed fire and red-cockaded woodpecker management, including description of ignition techniques, benefits to other species, and concerns about negative impacts. Guidelines for using prescribed fire in the management of red-cockaded woodpeckers are presented in 8K.

History of Fire in the Southeast

Fire is a natural ecosystem component that gained and lost importance in North America as the glaciers retreated and advanced. Pyrophytic vegetation in what is now the southeastern United States evolved in response to fires ignited by lightning long before the last glacial retreat roughly 10,000 years ago (Komarek 1968, 1974, Ware *et al.* 1993). Aboriginal people immigrated into the region during the last glacial period, and so the development and spread of fire-dependent ecosystems as the last glaciers retreated were influenced by both climate and the presence of Native Americans (Delcourt *et al.* 1993, Frost 1993, Ware *et al.* 1993). Modern plant assemblages have remained relatively stable for the past 6,000 years (Webb 1988, Frost 1998), despite some oscillations in fire frequency caused by minor changes in climate (Frost 1998). Thus, the ecosystems in place at the time of European exploration of North America had been in place for thousands of years (Frost 1998), and those in the southeastern region were shaped primarily by fire.

Prior to European colonization, there were few natural firebreaks in the southeast, and so fires burned for extended periods and over large regions. Return intervals for these natural fires were as frequent as 1 to 3 years in much of the Atlantic and Gulf Coastal Plains, and as frequent as 4 to 6 years in Upper Gulf Coastal Plains and the

Piedmont (Wahlenburg 1946, Frost 1998). Some areas, such as slopes with northern aspect and wetlands, may have burned at frequencies of 7 to 25 years (Frost 1998).

Fire intensity is intimately related to fire frequency, and together they are a primary determinant of ecosystem structure and species composition. Over much of the southeast, frequent fires were low in intensity, as evidenced by the species adaptations and structure of longleaf and shortleaf communities (below). In some regions, fires were less frequent and of stand-replacing intensity. Such areas support pines that are adapted to stand-replacing fires, such as sand, Table Mountain (*P. pungens*), pitch, and pond pines (Landers 1991). Only the latter two species are used by red-cockaded woodpeckers. Occasionally, some patches of longleaf and shortleaf communities may have undergone stand-replacing fires as a result of unusually long fire intervals. Thus, precolonial longleaf and shortleaf ecosystems were likely mosaics of mostly multi-aged woodlands with occasional even-aged stands (Landers 1991). Community species composition and tree density varied as functions of the fire regime, moisture gradient, and soil fertility.

The relative role of Native Americans in augmenting the lightning fire regime likely varied regionally, depending upon the frequency of lightning fire (Frost 1998). Native Americans may have shifted the seasonality of fire from the lightning season to include fires in fall and winter as well (Higgins 1986, Frost 1998). In general, however, it is not necessary to distinguish the exact contributions of anthropogenic and lightning fire to understand the role of fire in shaping and maintaining the ecosystems of the southeast. Native Americans were an integral component of these developing ecosystems for the 10,000 years of the Holocene.

Like the Native Americans, early European settlers also used fire as a tool, practicing slash and burn agriculture throughout the southeast during the 18th and 19th centuries. Farmers and ranchers continued to use fire to improve grazing quality for free ranging livestock into the first half of the 20th century, setting fires primarily in the early spring (Otto 1986, Frost 1993). As timber surpassed cattle in economic importance, however, fire was increasingly seen as the enemy of the woodland manager. Fire detection and suppression systems were instituted, and large fires became increasingly rare.

Much of the 20th century was a time of active, aggressive fire suppression. Increasing human-made firebreaks such as roads, fields, and power lines also reduced the extent of natural fires and fire frequency. Prescribed fire was recognized by some as an important tool to reduce the risk of catastrophic wildfire (Sachett 1975) and was occasionally used to improve game habitat (Stoddard 1935), but these fires were set in the winter months. Dormant season fires were not as effective as natural, intense, growing season fire in maintaining the open pine woodlands and savannahs that red-cockaded woodpeckers require. By the 1960's, fire suppression and exclusion threatened the existence of the species.

Fire Dependence and Adaptation

Many species of the southern pine-bunchgrass ecosystems show adaptations to frequent, low intensity fires, including red-cockaded woodpeckers. A fundamental adaptation of red-cockaded woodpeckers to fire is the excavation of roost and nest cavities in live pines, a behavior that may have evolved in response to the lack of snags and hardwoods in fire-maintained pine systems (Ligon 1970, Jackson *et al.* 1986). This ability to excavate cavities in live pines is not only important to red-cockaded woodpeckers but also to the many other species that use these cavities in the otherwise cavity poor environment (Brennan *et al.* 1995, Conner *et al.* 1997a; see 2F). Excavation of cavities in live pines has in turn led to the complex and unusual cooperative breeding system of red-cockaded woodpeckers (Walters 1990, Walters *et al.* 1992a; see 2B). A second adaptation of red-cockaded woodpeckers to fire is the abandonment of cavity clusters in the presence of substantial hardwood midstory. This may be a mechanism for avoiding the dangerous fires that will inevitably occur when the midstory is ignited. The severe impact and continuing threat of fire suppression to red-cockaded woodpeckers are discussed in 1A and 1B.

Plants of the southern pine ecosystems are well adapted to and require frequent burning. Many groundcover plants require growing season fires for flowering and fruit and seed production (Platt *et al.* 1988a, Streng *et al.* 1993, Walker 1993). Platt *et al.* (1988a) showed that herbaceous plants undergoing growing season fire not only increased flower production but also increased synchronicity of flowering, facilitating pollination and reducing risk of hybridization. Populations of these herbaceous plants, therefore, are regulated by fire. Ferguson (1998) recounted a typical example of a population of Florida skullcaps (*Scutelleria floridana*) reduced to three individuals which then swelled to over 100 individual plants following a growing season fire. Walker (1993) lists nearly 400 rare, mostly herbaceous plants of longleaf pine communities, of which over 90 percent are adapted to growing season fire. Diversity of herbaceous plants in longleaf systems place these among the most highly diverse ecosystems in North America (Walker and Peet 1983, Peet and Allard 1993). This diversity is maintained by frequent fire and severely threatened by fire suppression (Christensen 1981, Ware *et al.* 1993, Peet and Allard 1993, Glitzenstein *et al.* 1998b, Walker 1998). Over 120 species of plants associated with red-cockaded woodpecker habitats are currently on the regional list of proposed, endangered, threatened, and sensitive species (USFS 1995).

Pine trees in general are noted for being fire-adapted, but longleaf and south Florida slash pines in particular are extremely well adapted to fires of high frequency and low intensity (Landers 1991). Adaptations providing these two species with resistance to fire damage include the grass stage of seedlings, a large taproot, special bark characteristics, absence of branches below the crown, and the typical clumped arrangement of needles at the growing tips of branches (Wahlenburg 1946, Landers 1991). Longleaf and south Florida slash pine seedlings maximize taproot growth and minimize early height growth; the reverse is true of loblolly pine (Landers 1991). In addition, fire enhances seed germination and seedling establishment. Reproduction of longleaf and development of longleaf seedlings is especially enhanced by growing-season fire, as evidenced by long-term research into the reproduction of longleaf pine in the Escambia Experimental Forest, Alabama (W. D. Boyer, pers. comm.). Finally, both fire-adapted species facilitate the ignition and spread of fire by producing highly resinous, long needles and shedding them frequently (Platt *et al.* 1988b, 1991, Noss 1989, Landers 1991). This facilitation of fire maintains environmental conditions that are beneficial to these species but detrimental to competitors. Through its profound influence on the fire regime, longleaf pine is a key species in the longleaf pine communities (Platt *et al.* 1988b, 1991, Noss 1989, Landers 1991). Fire suppression and the resulting invasion of hardwoods have altered almost all longleaf pine ecosystems (Frost 1993).

Engstrom (1993) reported 36 species of mammals and 86 species of birds (35 permanent residents, 22 winter residents, and 29 breeders) characteristic of southeastern longleaf pine ecosystems. Many of these animals, and many more plant species, are threatened by fire suppression. USFS (1995) reported that 56 animal species associated with red-cockaded woodpecker habitats are currently on the regional list of proposed, endangered, threatened, and sensitive species. In addition, entire associations of species have been affected, such as the threatened gopher tortoise (*Gopherus polyphemus*) and the 13 listed and candidate species of animals that depend on gopher tortoise burrows (USFS 1995). Fire benefits shortleaf pine communities as well, although these have not received as much research attention as longleaf systems. Masters *et al.* (1998) reported that species richness and diversity of small mammals increased in relation to midstory reduction and prescribed fire, and no species was adversely affected by fire.

Guyer and Bailey (1993) reported 34 amphibian and 38 reptilian species that are closely associated with longleaf pine forests. Thirty-five percent of the amphibians and reptiles inhabiting longleaf pine forests, and 56 percent of the longleaf pine specialist species, were listed by at least one conservation agency as being of special concern. Fire suppression was identified as a primary cause of the decline of these species.

There is growing evidence that frequent fire may increase arthropod diversity and abundance (Folkerts *et al.* 1993, Collins 1998, Provencher *et al.* 1997, 2001). Groundcovers maintained by frequent fire may support more arthropods than areas with a hardwood midstory (Provencher *et al.* 1997, 2001, Collins 1998), although populations of some species, especially those in the leaf litter, may initially decline after burning. Provencher *et al.* (1997, 2001) suggest that invertebrate densities may increase following fire because resprouting plant tissue contains higher levels of nitrogen relative to carbon than older tissue (Christensen 1993), thus providing more palatable forage. It has been hypothesized that nutrient content of arthropods increases also, following the release by fire of nitrogen and other nutrients into the soil (James *et al.* 1997).

Implications for Management

Fire is an essential element of southern pine ecosystems, critical to the maintenance of habitat for red-cockaded woodpeckers and many other species. Frequent fire has helped to shape and maintain some of the most highly diverse ecosystems outside the tropics. However, natural fire can no longer maintain suitable habitat for red-cockaded woodpeckers and associated species, because the fragmentation of landscapes has reduced fire spread, duration, and therefore fire frequency. Thus, prescribed fire is a fundamental solution to the conservation of red-cockaded woodpeckers and their ecosystems. To maximize benefits, the frequency, intensity, and season of prescribed fire should mimic the historic natural fire regime as closely as possible (see 3F).

3. MANAGEMENT TECHNIQUES

A. POPULATION MONITORING

Population monitoring is a critical component of the conservation and recovery of red-cockaded woodpeckers. Effective monitoring begins with explicit identification of monitoring objectives, the appropriate metrics to be used in meeting objectives, and familiarity with necessary sampling and monitoring techniques. It is then up to managers and researchers to apply these standards in good faith. Finally, monitoring results must be compared to stated objectives. It is the responsibility of the Red-cockaded Woodpecker Coordinator to evaluate monitoring results within the framework of recovery objectives (1 – 6, below), using information reported annually by managers and researchers (Annual Reports, below). Fortunately, red-cockaded woodpeckers are more easily monitored than most species because of their conspicuous active cavity trees and the exceptional stability of territory locations.

Here we identify six objectives for population monitoring: (1) to determine population status and trend; (2) to qualify for and evaluate translocation; (3) to evaluate management techniques other than translocation, using an experimental approach (adaptive management); (4) to measure impacts of activities not related to species management; (5) to document success or failure of mitigation; and (6) to conduct research. Appropriate metrics, monitoring techniques, and other information for each of these objectives are given below. Guidelines for population monitoring are given in 8C. Guidelines for monitoring cavity availability are given in 8E, and banding protocol is presented in Appendix 2. Many activities conducted for monitoring purposes require federal permits (see Appendix 1) and may require state permits as well.

Population Size and Trend

Determination of population size and trend is a primary objective of monitoring red-cockaded woodpecker populations. Such determination is the foundation of assessing progress toward recovery goals. Critical thresholds of population sizes are described in Recovery Criteria (6). Recommended rate of population increase and critical values of population declines are identified and defined in 8A.

The two metrics most important to monitoring population size and trend are number of potential breeding groups and number of active clusters. We define and describe these two metrics below, along with associated variables. Together these two metrics give a reasonable assessment of population health. Monitoring group size and/or reproductive success is not necessary to determine population size and trend. We provide protocol for the monitoring of group size and reproductive success in Appendix 2, should managers and researchers choose to evaluate these parameters as well. Monitoring group size and reproductive success is strongly recommended for critically small populations (less than 30 potential breeding groups) on public lands, and required for those populations receiving translocated birds for population augmentation (below).

Number of Active Clusters

An active cluster is a cluster in which one or more of the cavity trees exhibit fresh resin as a result of red-cockaded woodpecker activity or in which one or more red-cockaded woodpeckers are observed. Number of active clusters is a traditional measure of population size, and is generally known exactly rather than estimated. However, because this metric gives no information as to the status of the group occupying each cluster (e.g., potential breeding group, solitary male, or captured cluster), it is best accompanied by estimates of number of potential breeding groups (below).

Counting the number of active clusters consists of two management actions: (1) evaluating the activity status of known clusters (cluster activity checks) and (2) surveying for new clusters. Here we give brief protocols for each.

Cluster Activity Checks.--Activity status of each known cluster is assessed during the breeding season or just prior to it (March – July), by one or more experienced red-cockaded woodpecker biologists. It is conducted during those months because populations are lowest then and because consistency in data collection is vital to accurately assessing and comparing population trends.

All potentially active clusters are checked for evidence of red-cockaded woodpecker activity. Potentially active clusters are all clusters active within the last 5 years and all inactive clusters, including recruitment clusters, that have undergone restoration of appropriate habitat structure and/or cavity installation within that time. Evidence of activity includes fresh resin on one or more cavity trees as a result of red-cockaded woodpecker activity or the presence of one or more birds. Within each cluster, all cavities that have been active within the last 5 years are evaluated until an active cavity is located or birds are observed. If all cavities are inactive in a cluster that is normally active, a thorough search for new cavity trees is conducted in suitable habitat within 0.4 km (0.25 mi) of the cluster center.

The accuracy of this metric, number of active clusters, can be compromised if cavity trees are inappropriately assigned into clusters. Cluster designation requires at least some intense monitoring initially (see Reed *et al.* 1988a).

Number of active clusters is to be counted in all red-cockaded woodpecker populations, but the recommended frequency of cluster activity checks varies with population size. These recommendations are given in management guidelines for population monitoring (8C). To save time and effort, other monitoring activities can be conducted at the time cluster activity checks are conducted. Chief among these are evaluating the availability of suitable cavities (8E) and estimating the number of potential breeding groups (below).

Surveys for New Cavity Trees and Clusters.--Comprehensive surveys for new cavity trees and clusters within occupied and potentially occupied habitat can be conducted at approximately 10-year intervals, by trained personnel following specific protocol. During these surveys, all clusters that have been inactive for more than five years are checked for activity also. In most habitat types, surveys are best conducted by foot, using transects spaced to allow overlapping visual coverage of all potential cavity trees (pines at least 60 years in age, in pine and pine-hardwood stands regardless of tree density). Proper spacing of transects varies with overstory density, midstory density and height, and terrain. Aerial surveys, by helicopter or small fixed wing aircraft, are useful in certain habitats such as pocosin or bays where access by foot is difficult. Such surveys, performed by experienced observers, can locate most clusters containing multiple cavity trees but rarely detect all cavity trees in a cluster or all clusters. In other words, aerial surveys document the presence of cavity trees but not their absence. Ground surveys are used to verify the results of aerial surveys and to locate all cavity trees in detected clusters.

Initial surveys for active cavity trees and clusters are a fundamental step in beginning management of red-cockaded woodpecker populations. However, repeated surveys for new clusters in previously unoccupied habitat are not recommended at this time. In recent years, this management action has yielded little return for substantial investment (R. Costa, pers. comm.), presumably because most forests are currently quite young and because pioneering by red-cockaded woodpeckers is rare (see 2B).

Number of Potential Breeding Groups

An active cluster may contain a potential breeding group, a solitary male, or be captured by a neighboring group. A potential breeding group is an adult female and adult male that occupy the same cluster, with or without one or more helpers, whether or not they attempt to nest or successfully fledge young. A solitary male is an adult male occupying a cluster without a mate. A captured cluster is one that does not support its own group, but is kept active by a member or members of a neighboring group. Increasing proportions of active clusters without potential breeding groups are early indicators of population decline. For this reason, number of potential breeding groups is a critically important metric. In small populations that are sampled completely, number of potential breeding groups is known exactly. In larger populations that are not sampled completely, number of potential breeding groups is estimated. Here we give directions on monitoring techniques to determine or estimate number of potential breeding groups, followed by a discussion of sampling methods.

Number of potential breeding groups is assessed during the breeding season by conducting (1) nest checks in active clusters until nesting is documented and (2) morning follows in active clusters in which no nesting is observed. Nest checks are periodic visits to active clusters during the breeding season, and consist of (1) lightly scraping on active cavity trees in an effort to flush incubating birds, (2) listening for nestlings begging for food, (3) inspecting potential nest cavities using a video probe or climbing equipment, and/or (4) watching for adults carrying food to a cavity. Nest checks are conducted every 7 to 11 days until a nest is detected. If nesting is documented, the cluster supports a potential breeding group and no further nest checks are required (unless reproductive success is being monitored, see below and Appendix 2). It is important that frequency of nest visits and the date of their initiation are consistent across years to allow accurate determination of population trend.

Morning follows are required for each active cluster in which no nest has been documented by the middle of the breeding season. Morning follows are roughly equivalent to "group checks" described by the U.S. Forest Service (USFS 1995). The target group is observed for a half an hour to an hour, immediately after the birds exit their cavities in the morning, to determine group status. Group status is classified as (1) potential breeding group, indicated by two or more birds that remain together and peacefully interact; (2) solitary male, indicated by a bird that remains solitary for the duration of the follow; or (3) captured cluster, indicated by no birds or a bird that roosted in the target cluster but joined a neighboring group. Care must be taken to accurately classify the group. Red-cockaded woodpeckers roosting extra-territorially in clusters occupied by one or more residents, captured clusters, and territorial conflicts can confuse the observer and result in erroneous status classifications. If doubt as to group status exists, the follow time is extended or the follow is repeated on another day. Two observers may be necessary if two clusters are located very close together or if cavity trees within a cluster are spread over a large area. If an extended follow or several follows fail to adequately yield the status of a group, managers may choose to color-band one or more adults to determine group status without doubt. Morning follows are preferable to evening roost checks because evening checks can miss group members that are roosting in unknown cavity trees or in neighboring clusters.

Currently, nest checks in combination with morning follows are considered sufficient to estimate number of potential breeding groups, and more intensive monitoring such as color-banding of adults and nestlings is considered unnecessary for this purpose. Of course, this approach must be implemented conscientiously if sound data are to be collected. If, in the future, it appears that nest checks and morning follows are not being implemented well, use of color-bands to estimate number of potential breeding groups may be recommended.

Sampling.--Recommended sample sizes for estimating number of potential breeding groups vary according to population size. These recommendations are given under Population Monitoring Guidelines (8C). Sample sizes may be adjusted in the future as more information concerning annual variation and sampling error is obtained. Currently, most estimates of solitary males and captured clusters are derived from populations that are color-banded, not monitored using the combination of nest checks and morning follows described above.

The best method of sampling to estimate number of potential breeding groups is to select a random sample annually, without replacement, from the set of all potentially active clusters (defined above). Stratified random sampling is to be used whenever it is suspected that some groups are consistently experiencing different conditions than others. Examples of consistently different conditions include differences in natural habitat type, past or present habitat management or silvicultural treatments, or human activities such as military training. Stratified random sampling is achieved by dividing the area to be sampled into homogeneous habitat types, habitat management history, or human activity levels. These strata are then sampled in proportion to the number of clusters that they contain, with the total combined sample equal to recommended sample size. Information concerning individual strata is limited if within-strata sample sizes are small, but accuracy of population-level parameters can be greatly increased in heterogeneous populations by using this method. Input from a wildlife statistician is strongly recommended.

Annual random sampling without replacement, stratified where appropriate, is our recommended sampling method to estimate number of potential breeding groups for populations that are not undergoing any banding. For populations in which some adults and nestlings are being banded, changing the sample annually is inefficient. For these populations, we recommend that a random sample without replacement be selected once every 5 years, and that this sample remain fixed for that 5-year period. Stratified random sampling at 5-year intervals should be used wherever appropriate. Again, consulting with a wildlife statistician is recommended.

Translocation

Translocation is described in 3D and guidelines for its use are given in section 8H and Appendix 3. There are several objectives for monitoring as part of a translocation program. First, a sample of groups is monitored to identify specific birds available for translocation. Second, eligibility status of the donor population must be evaluated and specific impacts of translocation must be assessed. Third, populations receiving translocated birds from donor populations are intensively monitored to qualify for the translocation program, to evaluate translocation success, and, potentially, to assess population-level benefits of this management technique. Similarly, in populations that are undergoing translocation of birds within the population, recipient clusters or target areas are monitored to evaluate translocation success and potentially to assess population-level benefits. We discuss each of these objectives in turn below.

Translocation of red-cockaded woodpeckers requires state and federal endangered species and bird banding permits (see Appendix 1). Specific protocols, available from the Red-cockaded Woodpecker Recovery Coordinator, are followed, and all translocation attempts are reported to the Recovery Coordinator through the Annual Report process.

Identification of Available Birds

Birds potentially available for translocation are identified by color-banding entire groups and determining group composition. This is required whether the bird is to be translocated within the population or to another population. Protocol for the banding of adults and nestlings are presented in Appendix 2. Group composition is determined by color-band observation throughout the breeding season and again by morning follows (described above) conducted just prior to the removal of birds to assess status of individuals and to determine whether the group in question meets the criteria for bird availability (see 8H). It is estimated that three to five groups will have to be banded to identify one bird available for translocation. All translocated birds are to be color-banded.

Assessing Impacts to the Donor Population

Ideally, impacts on the donor population of removing birds for translocation are assessed through the experimental approach of adaptive management (discussed in more detail below). Using this approach, donor populations are divided into one or more treatment blocks that undergo removal of birds, and one or more control areas from which no birds are removed. These assignments should be as free as possible of potentially confounding effects, such as systematic differences in habitat type or quality. Treatment and control areas are then randomly sampled at a sample size large enough to support statistical comparison. As a minimum, monitoring of samples consists of cluster activity checks and nest checks/morning follows, to derive number of active clusters and number of potential breeding groups. Preferably, all groups within the treatment and control areas are color-banded so that effects on group size and/or reproductive success (Appendix 2) can be estimated. Statistical comparisons can then be made of the proportion of clusters remaining active from one year to the next, the proportion of clusters retaining potential breeding groups from one year to the next, average group size, and/or reproductive success between treatment and control areas. Statistically significant differences in these variables will be important documentation of translocation impacts.

Currently, such experimental assessment of translocation impacts is strongly recommended but not required for participation in the translocation program. The minimum level of monitoring for donor populations is the same as that described for determining population size and trend above: monitoring number of active clusters and potential breeding groups through cluster activity checks, nest checks, and morning follows for a randomly selected sample of the size recommended in 8C, Table 11. Additionally, knowledge of group composition is required of the groups donating birds to determine bird availability (see above). If a negative change in population status is documented by this level of monitoring, such that the population no longer meets the criteria necessary to be a donor population as listed in 8H, the donor population may not contribute birds for translocation until the criteria are once again met. Without the experimental approach described above, it will not be known whether the change in population status is specifically due to removal of birds. However, regardless of the cause of the change, once a population no longer meets eligibility criteria no more birds can be removed until these criteria are once again met.

Monitoring Success of Translocations

Monitoring success of translocations is a critical aspect of the translocation program (3D, 8H). A translocation event is considered successful if the translocated bird obtains a breeding position in the target area, and the target area is defined according to the explicitly stated objective of each translocation. For more information on defining translocation success, see 3D and 8H. Once a translocated bird is released, no observations are required until the following breeding season. Observations of translocated birds should be minimized to reduce disturbance as much as possible.

Populations must be completely color-banded to qualify for population augmentation (receiving birds from donor populations). This requirement helps to ensure that recipient populations are managed at an intensity level appropriate to the great value inherent in the individual red-cockaded woodpeckers being translocated. This requirement also ensures that translocation success is accurately evaluated. Monitoring group size and reproductive success through complete color-banding (Appendix 2) yields knowledge of group composition necessary to accurately track status and location of translocated individuals.

For within-population translocations, monitoring requirements are less intensive. Groups within target areas should be banded to track success of the translocation. Donor groups have to be color-banded to identify available birds. Regular monitoring for size and trend is conducted as described above.

In addition to documenting the success or failure of an individual translocation event, monitoring can be used to better understand the benefits of translocation to recovering populations. Here the question is, how and how much does translocation contribute to population increases? Again, assessment of treatment effects is best achieved through the experimental approach of adaptive management. Such an approach consists of dividing the population into treatment areas receiving birds and control areas to which no birds are translocated. Treatment and control areas are best monitored by color-banding, which gives excellent estimates of group size, reproductive success, and change in proportions of active clusters and potential breeding groups. Statistically significant differences in these important metrics would provide important evidence of population-level benefits of translocation.

Such an approach may be difficult to use in populations undergoing population augmentation because only critically small populations (less than 30 potential breeding groups) are eligible to receive birds from donors. Thus, sample sizes of treatment and control areas would be low. Also, translocated birds may potentially appear anywhere within the population, and therefore treatment and controls may be difficult to delineate. Still, an experimental approach applied in any population undergoing translocation could potentially supply extremely valuable information on this management technique, whether the birds are sourced within or outside the population.

Evaluating other Management Actions

Population monitoring can be used to evaluate effects of other management actions as described for assessing population-level benefits of translocation, above. Such an approach is the foundation of adaptive management, in which management itself is conducted as an experiment and is responsive to new information gathered in this way. Delineated sections of populations receive treatment, and metrics such as group size and reproductive success (Appendix 2) or changes in proportions of active clusters and potential breeding groups (Population Size and Trend, above) are evaluated for statistically significant differences between treatments and controls. Some management activities that should be assessed in this way include restoration of site-appropriate pine species and pine thinning. Certain management activities, such as frequent prescribed burning, midstory reduction, and maintenance of suitable cavities, are to be applied in all clusters and therefore are not to be subjected to experiments.

Evaluating Impacts of Activities other than Species Management

Documentation of specific impacts of non-management activities on red-cockaded woodpeckers requires intensive monitoring. Examples of activities that may impact red-cockaded woodpeckers are development (e.g., roads, golf courses, housing areas), military training (e.g., impact areas, mechanized training, bivouacs, etc.), and timber management practices (e.g., thinnings, harvests). Monitoring is often required to document effects of the implementation of Reasonable and Prudent Alternatives and Reasonable and Prudent Measures pursuant to Section 7 of the Endangered Species Act.

Intensive monitoring of potential impacts consists of collecting data on cluster activity, group status, group size and composition, and reproductive success. Often, this intensive monitoring is restricted to affected clusters and sometimes neighboring clusters. This is usually done in assessing incidental take (see 4A) as related to a given activity, but such studies are often inadequate to provide definitive evidence of the cause of losses, especially since some losses may not manifest until years after the initial impact.

Impacts to woodpecker groups are best measured by an experimental approach in which treated clusters are paired with control clusters. We recommend these experiments be designed by biologists experienced with the study population, using input from a wildlife statistician. Simple monitoring of affected groups, as described above, can only document their continued existence. Experiments, however, may reveal impacts to group size or reproduction and can identify causes of effects as well.

Mitigation Monitoring

Monitoring may be required for implementation of Habitat Conservation Plans pursuant to Section 10 of the Endangered Species Act and for actions taken to offset violations of Section 9 of the Act. These cases generally require the use and documentation of specified monitoring actions. For further information concerning mitigation, see 4A.

Monitoring for mitigation includes (1) monitoring of clusters to be impacted and the neighboring clusters, and (2) monitoring of the population containing the mitigation site. The level of monitoring for impacted and neighboring clusters is determined on a case-by-case basis. Monitoring of the population containing the mitigation site is typically intensive, consisting of complete color-banding and assessment of cluster activity, potential breeding groups, group size, and reproductive success. Documentation of newly created groups requires comprehensive knowledge of the current distribution of woodpecker clusters and groups within the subject population.

This comprehensive knowledge of the population to contain the mitigation site is needed prior to the installation of artificial cavities. If artificial cavities are placed too close to another group (0.4 km [0.25 mi] or less), the provisioned site is likely to be captured by the adjacent group and no new group will be formed. If artificial cavities are placed too far from other groups (more than 1.6 to 3.2 km [1 to 2 mi]), the likelihood of woodpeckers finding the new site is reduced unless translocation is used.

Comprehensive knowledge of the mitigation site is also necessary for accurate determination of new group formation. Formation of a new group cannot be assumed from simply observing red-cockaded woodpeckers in the provisioned site unless the birds observed are known not to be part of a previously existing group. Birds from adjacent groups can be expected to routinely forage around and within the new site and may cross-roost in the new cluster. Mitigation is successful only when monitoring clearly demonstrates that a new group (of equivalent status to the group impacted, solitary male or potential breeding group) has been formed and that it represents a net gain of one group in the area occupied by the provisioned site and all immediately adjacent territories (within 3.2 km [2 mi]). The newly established group has to remain in the cluster for at least six months, including the breeding season, or there is evidence of nesting (i.e., one or more eggs are laid). Such determination is only possible through intensive monitoring including color-banding (Appendix 2).

Research Monitoring

Research monitoring is used to investigate all aspects of the biology of red-cockaded woodpeckers, including, but not limited to, demography, social behavior, and habitat use. Color-banding of red-cockaded woodpeckers is often conducted. Research monitoring that involves handling, banding, or disturbance of red-cockaded woodpeckers requires the appropriate state and federal endangered species and bird banding permits. Typically, but depending on the circumstances, a Section 7 consultation and/or Section 10 Scientific Research Permit may be required.

Annual Reporting of Monitoring Results

Managers are required to submit an Annual Red-cockaded Woodpecker Population Data Report (hereafter referred to as Annual Report) to the Red-cockaded Woodpecker Recovery Coordinator containing results of their annual monitoring efforts. Such reporting is a critical aspect of woodpecker management and recovery.

B. CAVITY MANAGEMENT: ARTIFICIAL CAVITIES AND RESTRICTOR PLATES

Loss of cavities and cavity trees was a primary cause of the decline of red-cockaded woodpeckers, and is a substantial threat currently (see 1A, 1B). Today's forests simply do not contain sufficient numbers of mature and old growth trees for populations to remain stable or increase in the absence of human intervention. Red-cockaded woodpeckers will abandon clusters if sufficient suitable cavities are not available. Cluster abandonment can lead directly to population extirpation (Costa and Escano 1989), because populations of red-cockaded woodpeckers are regulated by the number of potential breeding groups rather than by annual variation in reproduction and survival (Walters 1991; see 2B), and because natural formation of new clusters is very slow at least under current conditions of relatively young forests and small populations (see 2B). Therefore, cavity management through the use of artificial cavities and restrictor plates is absolutely critical to the conservation of most populations.

Cavity ecology, including reassons why the birds need mature and old growth trees, is discussed in 2D. Community ecology, including the use and enlargement of red-cockaded woodpecker cavities by other species, is discussed in 2F. In this section, we describe the various methods of artificial cavity installation and their respective advantages and disadvantages, and also show how restrictor plates are used. Guidelines for the use of artificial cavities and restrictor plates are presented in 8E.

Artificial Cavities

Artificial cavities for red-cockaded woodpeckers were developed in the late 1980's and early 1990's (Copeyon 1990, Copeyon *et al.* 1991, Allen 1991, Taylor and

Hooper 1991), and have since revolutionized management of red-cockaded woodpeckers. Prior to their development, biologists were unable to address the severe limitation in cavities impacting most populations, and therefore had little ability to slow, much less reverse, the decline of the species. With the advent of artificial cavity technology, cavities and entire clusters can be provided. In combination with aggressive habitat management, cavity management can stabilize and increase populations.

The power of the new technology to conserve and protect red-cockaded woodpeckers was illustrated soon after development, when Hurricane Hugo destroyed nearly 90 percent of the cavity trees on the Francis Marion National Forest in 1989. Rapid and extensive use of drilled cavities and cavity inserts following the devastation saved a large proportion of the population and allowed for population growth in subsequent years (Watson *et al.* 1995). During the 1990's, many other populations were stabilized, and some increased, through cavity provisioning in combination with prescribed burning. In addition, other recently developed conservation and management tools such as translocation, mitigation, and Habitat Conservation Plans are based to a large degree on the use of artificial cavities.

However, artificial cavities have not always been used effectively. Widespread and haphazard installation of artificial cavities can have negative impacts on red-cockaded woodpeckers and their potential cavity trees, and misdirects valuable management efforts and funds. Before artificial cavities are installed, managers should have a clear understanding of population dynamics in this species, especially the role of cavities and the effects of spatial structure on population growth or decline (see 2B, 2C). In addition, managers need to be well versed in the benefits and drawbacks of the various installation methods, so that they know what to expect of cavities already installed in their populations and can choose the appropriate method for additional cavities. Finally, proper maintenance of artificial cavities is essential (e.g., Montague et al. 1995).

There are basically four methods of constructing artificial cavities: Copeyon-drilled cavities and starts, cavity inserts, and modified drilled cavities. Copeyon-drilled cavities and starts were developed at North Carolina State University (Copeyon 1990). Cavity inserts were developed at the Southeastern Forest Experiment Station of the U.S. Forest Service, Clemson University (Allen 1991). Taylor and Hooper (1991) created the modified version of Copeyon's drilled cavity.

Basically, drilled cavities are constructed by drilling two tunnels: first, an entrance tunnel that the birds will use, and second, an access tunnel that is then used by the drill operator to ream out the cavity chamber. The access tunnel is plugged and sealed after the chamber is constructed. The two drilled methods, Copeyon and modified drilled, differ in the dimensions of the access tunnel and consequently in their durability. Drilled starts are drilled entrance tunnels with a widened interior. Cavity inserts are pre-fabricated nest boxes inserted into an opening in the tree created with a chainsaw. More detailed descriptions of these techniques are given below, followed by a comparison of their relative merits and applications.

Construction of Copeyon-drilled Cavities and Starts

The Copeyon-drilled method of cavity construction is illustrated in Figures 2 and 3. Candidate trees for Copeyon-drilled cavities must have at least 15.2 cm (6 in) of heartwood and no more than 8.9 cm (3.5 in) of sapwood, and less sapwood is preferred.

To construct the cavity, a gasoline-powered drill equipped with a wood-boring bit 5.1 cm (2 in) in diameter is used to excavate an entrance tunnel through the sapwood and into the heartwood, at a slightly upward angle. The same bit is used to begin a second tunnel 5.1 to 10.2 cm (2 to 4 in) above the entrance tunnel. This access tunnel is then continued at a downward angle of roughly 60 degrees, using a 4.2 cm (1.65 in) bit, until the back of the entrance tunnel is intersected and 7.5 to 10 cm (3 to 4 in) below the entrance tunnel have been opened to form a rudimentary chamber. The rudimentary chamber is then hollowed out, using the 4.2 cm (1.65 in) bit, to complete the cavity. The extent to which a cavity approaches the shape and dimensions of a naturally excavated cavity depends on the width of sapwood, the diameter of the heartwood core, and the skill of the drill operator. Care must be taken to avoid drilling into the sapwood at the front of the cavity chamber, by drilling at too steep an angle, or at the rear of the cavity, by drilling too deep.

The access tunnel is sealed with wood plugs and non-toxic wood putty. A thin, flexible wood veneer called “wiggle board” may be used to line the entrance tunnel instead of wood putty. A comprehensive maintenance schedule is required in the weeks immediately following construction, to inspect for resin leakage.

Upon completion of the cavity, resin wells are drilled with a 1.3 cm (0.5 in) twist bit or cut with a knife or chisel, and the area several feet above and below the cavity is scraped with a bark knife or hoe blade to give the tree the reddish appearance of an active red-cockaded woodpecker cavity tree. Non-toxic white or almond paint is sprayed below resin wells, above and below the cavity entrance, and completely around the tree bole in the vicinity of the cavity to simulate natural pine resin.

Drilled starts are constructed using the above method to create an entrance tunnel (Figure 3). The access tunnel and cavity chamber are not constructed. Instead, a 4.2 cm (1.65 in) bit is used to enlarge the rear of the entrance tunnel (within the heartwood) to give the red-cockaded woodpecker room to excavate the cavity chamber. Such an advanced start may be large enough for a red-cockaded woodpecker to roost within, and red-cockaded woodpeckers can complete a drilled start in several months to a year (J. Carter III, pers. comm., Harding 1997). Drilled starts can be placed in trees with too much sapwood and/or too little heartwood to accept a drilled cavity.

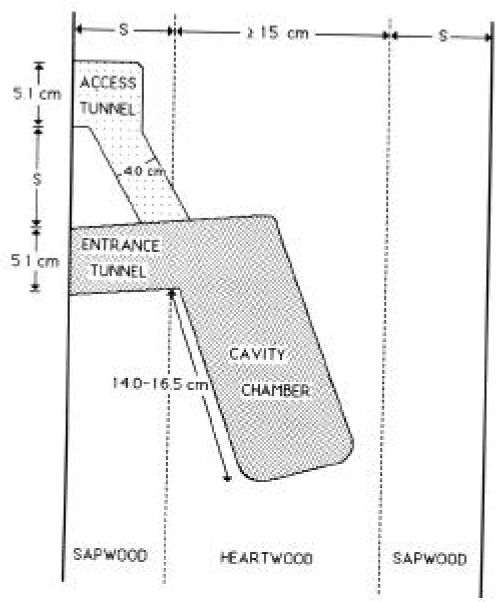


FIGURE 3. Diagram of Copeyon-drilled cavity (Copeyon 1990). Copyright Wildlife Society Bulletin; used with permission.

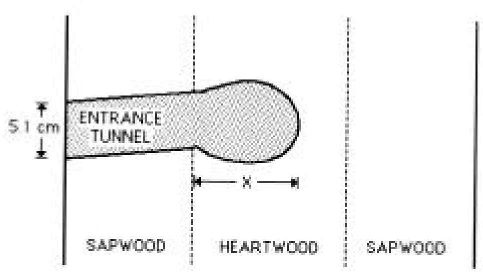


FIGURE 4. Diagram of Copeyon-drilled start (Copeyon 1990). Copyright Wildlife Society Bulletin; used with permission.

Construction of Modified Drilled Cavities

Taylor and Hooper's (1991) modification of Copeyon's drilled cavity technique differs from the original technique in that larger bits are used to begin the access tunnel (8.9 cm [3.5 in] bit) and to construct the vertical access tunnel and cavity chamber (7.6 cm [3 in] bit). Using this technique, most of the access tunnel and cavity chamber can be excavated at once. Resin wells are created and the trunk is painted to resemble a natural cavity tree just as described above.

Construction of Cavity Inserts

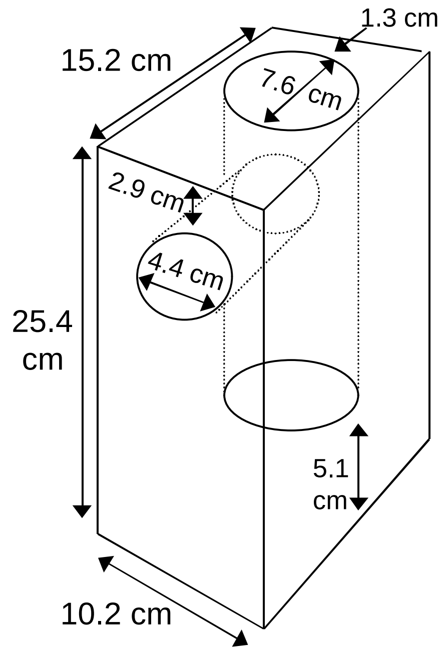
The cavity insert (Allen 1991) is a completely different approach to cavity construction. In this method, a chainsaw is used to cut a rectangular opening in a pine tree, and a wooden block with a pre-drilled cavity is inserted into the opening (Figure 4). The cavity insert is secured in the tree with wooden wedges and non-toxic wood putty. A full frontal restrictor plate is used to prevent damage by pileated woodpeckers. Because inserts may be placed in trees that are mostly sapwood, the insert must be heavily coated with a non-toxic waterproof sealant to prevent resin leakage through small, sometimes imperceptible, cracks into the cavity chamber. Cavity inserts are held primarily within the sapwood of the tree, and so can be placed in pines that have little heartwood. Trees of at least 38.1 cm (15 in) in diameter at cavity height are required. (If trees of this size are not available, use the drilled cavity or drilled start technique). Resin wells are created, and the trunk is scraped and painted to simulate a natural cavity tree.

Southern yellow pine (*Pinus* spp.) is the preferred wood to use in constructing inserts. In the past, western red cedar (*Thuja plicata*) was used, but we now suggest using southern yellow pine as it is a harder wood than western red cedar.

Comparison of Construction Methods

Preliminary work evaluating the four methods of cavity provisioning was conducted in the Francis Marion National Forest (Hooper *et al*., unpublished), an appropriate location for such an investigation because of the large-scale provisioning of all cavity types following Hurricane Hugo. Although the population increased rapidly following the devastation of Hugo (Watson *et al.* 1995), a declining trend has been present since 1996 (USFWS, unpublished). Aging of the artificial cavities is considered a potential contributing factor to recent declines, in addition to problems implementing the prescribed burning program.

FIGURE 5. Diagram of a cavity insert (adapted from Allen 1991). Full restrictor plate and non-toxic coating, both required on all inserts, are not illustrated here.



Hooper *et al.'s* (unpublished) data suggests that Copeyon-drilled cavities and starts remain in use for a remarkably long period. After an average of 8.5 years, more than two-thirds of Copeyon-drilled cavities remained in use, and one quarter of the remaining available Copeyon-drilled cavities were in use as nest cavities. Half of all the original drilled starts were in use as cavities 8.5 years later, and one quarter of the remaining available cavities that were originally drilled starts were in use as nest cavities. Cavity inserts did not exhibit the same durability. Just less than half of cavity inserts remained in use after 8.5 years, and none were used as nest cavities. However, cavity inserts were installed in clusters of consistently lower quality than those in which drilled cavities were placed (D. Allen, pers. comm.). Because clusters receiving inserts had suffered heavier hurricane damage and had virtually no old pines remaining after the storm, comparisons of durability between inserts and drilled cavities are biased by differential habitat quality. Modified drilled cavities showed the lowest durability of all cavity types, without the same systematic bias in habitat quality. Less than one third of modified drilled cavities were used an average of 7.3 years later, and none as nest cavities.

Differences in cavity survival did not appear to result from differential mortality of trees holding the various cavity types (Hooper *et al.*, unpublished). Less than 2 percent of pines with artificial cavities died from structural failure of the tree bole resulting from cavity installation, and this did not differ between trees containing inserts and those with drilled cavities. Cavity trees with inserts did not appear to suffer more damage from wind or physiological stress than other cavity trees, a conclusion also reached by Lowder (1995). Instead, lowered survival of inserts was due to higher rates of flooding and cavity enlargement. Inserts were not fitted with full restrictor plates (below), which would have reduced enlargement rates considerably. Almost half of all inserts had the interior altered by the birds to the point where the insert was breached and the tree itself was visible. Such expansion did not appear to affect the activity status of the inserts.

Lowered survival of modified drilled cavities was due to high rates of damage to the entrance tunnel and access plug. The larger access plug was far more likely to rot, and the septum between the access plug and entrance tunnel was more likely to be altered by decay or by other woodpeckers, than were those of Copeyon-drilled cavities. Enlargement of completed drilled starts was negligible.

Recommended Construction Methods

In light of the current value of cavity trees and potential cavity trees, we have formulated careful guidelines for the construction of artificial cavities (see 8E). Copeyon-drilled cavities are recommended for cavity provisioning if pines with sufficient heartwood are available. Managers may choose to drill starts instead of cavities if the cavities are not likely to be needed for a year or more. (Drilled starts over one year in age were found to be as useful to the birds as Copeyon-drilled cavities; Hooper *et al.*, unpublished.) Use of inserts is recommended when cavities are needed rapidly and there are no pines old enough to support a Copeyon-drilled cavity. Use of the modified drilled method of cavity construction is to be avoided.

Use of either method of artificial cavity installation, cavity inserts or drilled cavities, requires conscientious and careful application with special attention to potential problems specific to each method. Inserts require a full restrictor plate and heavy coating with a non-toxic waterproof sealant. All inserts must be inspected carefully for cracks prior to and following installation; any damaged inserts should be discarded. Flooding of inserts can be minimized by using restrictors, by constructing entrance tunnels at a slightly upward angle, and by drilling a drainage hole, 0.95 cm (0.375 in) in diameter from the lower front of the box to the bottom of the cavity chamber. Finally, red-cockaded woodpeckers have a tendency to breach the cavity chamber of inserts. This behavior has the potential to result in resin-related deaths, although it is likely that such breaching occurs slowly enough to allow resinosis (saturation of sapwood with hardened resin; see Conner and Rudolph 1995a), and that resin leaks into the cavity chamber are rare.

When Copeyon-drilled cavities and starts are used, it is imperative that they be screened for at least one month following installation and checked for resin leaks as described below. All artificial cavities and starts must be inspected and maintained as described below and in section 8E.

Cavity Screening, Resin Leakage, and Maintenance Checks

All drilled starts and drilled cavities must be screened with heavy wire mesh (0.64 by 0.64 cm [0.25 by 0.25 in]) to prevent access by red-cockaded woodpeckers for at least four weeks after installation to ensure that no resin is leaking into the cavity chamber. If leaks are detected, cavities must remain screened and additional checks conducted. Persistent resin leakage into entrance tunnels can be treated using repeated scraping, applications of wood putty, replacement of wooden veneer, or redrilling with a 5.1 cm (2 in) diameter bit. If the leak is severe, cavities should be blocked with a wooden plug at least 7.6 cm (3 in) long and replaced elsewhere. Artificial cavities and starts should be constructed during the non-growing season (except in emergencies) to reduce the likelihood of resin leakage.

All artificial cavities, including inserts, and drilled starts should be checked for latent resin leakage during the first growing season after installation. If this check is negative no further maintenance checks are required for drilled starts and cavities unless the entrance tunnel begins to heal over from lack of red-cockaded woodpecker use. If an entrance tunnel is redrilled or scraped, screen it again as described above. Inactive artificial starts and cavities require periodically redressing of resin wells and rescraping of bark to enhance the likelihood of discovery and occupation by red-cockaded woodpeckers.

Cavity Height, Orientation, and Location

In general, artificial cavities should be placed as high as the recipient trees will allow, within the range of natural cavity heights in the surrounding habitat. Height of drilled cavities may be limited by the amount of heartwood present, and height of inserts may be limited by tree diameter; both will vary according to local conditions. For example, sites with low site index such as sandhills will support only low cavities. Cavities should be oriented so that the entrance faces west, because natural cavities show a tendency to be oriented in this direction (Locke and Conner 1983).

Cavities should be constructed within 66 m (200 ft) of existing cavity trees to maintain the integrity of the cluster. Inserts should not be placed in pines less than 45 years old, because the growth of the tree could damage the insert and possibly result in a dangerous situation. Additionally, inserts are not to be placed in relicts, flat-tops, and very old pines; these extremely valuable trees should be left for natural excavation or, if absolutely necessary, used to support drilled cavities.

Number and Definition of Suitable Cavities

Carrie *et al.* (1998) found that group size of red-cockaded woodpeckers in Louisiana increased with the number of cavities provisioned, and recommended a minimum of three to four suitable cavities per cluster. Results of the study more clearly supported the use of four suitable cavities rather than three as a minimum. A minimum of four suitable cavities per cluster has also been the traditional policy of the U.S. Fish and Wildlife Service. We therefore recommend that each cluster contain at least four suitable cavities. This recommendation does not apply to populations that have met the population goals identified in delisting criteria or in site-specific management plans.

A suitable cavity has a single entrance, an entrance tunnel that is not enlarged, a cavity chamber that is not enlarged, a solid base, and is dry and free of debris. In addition, the cavity plate must not contain large amounts of dead wood (Carrie *et al.* 1998). Relict, enlarged, or any suspect cavities must not be considered suitable for use by red-cockaded woodpeckers.

Restrictor Plates

The cavity restrictor was developed at North Carolina State University in the mid-1980's (Carter *et al.* 1989), to prevent and repair the enlargement of red-cockaded woodpecker cavity entrances. Cavity restrictors are square or rectangular metal plates with an inverted U-shaped or circular opening, 3.8 to 4.4 cm (1.5 to 1.75 in) wide, in the center of the plate. Typically, they are made of approximately 22-gauge stainless steel, aluminum, or sheet metal; expanded metal and quarter-inch hardware cloth are also suitable. Restrictors range in size from 7.6 by 7.6 cm (3 by 3 in) to much larger. Smaller restrictors are used for starts and cavity entrances that show little damage, while the largest sizes are used for enlarged cavities and to cover the front of cavity inserts. Cavity inserts are now fitted with full restrictor plates prior to installation.

The inverted U-shape opening was the original design (Carter *et al.* 1989). The opening extends from the entrance hole to the bottom of the restrictor plate, allowing the birds' feet to contact the tree surface when entering and exiting the cavity. If restrictor plates with circular openings are used, the metal directly below the opening of the entrance tunnel must be removed to allow the birds a secure foothold. Care must be taken to ensure that this metal is not so rough or jagged as to cause injury to the birds' toes or feet. Smooth, slick metal below the entrance is a deterrent to red-cockaded woodpecker use and may completely prevent use of some cavities.

For natural and drilled cavities, restrictors are attached to the tree with nails or screws at all four corners placed in pre-bored holes. Wood screws (1.3 cm [0.5 in] long) are preferred over nails because they allow easy repositioning of the restrictor with minimal damage. Screws or nails longer than 2.54 cm (1 in) should not be used because the cavity chamber may be breached, creating a hazard for cavity occupants. Restrictors are often painted brown with a non-toxic paint in order to blend with the tree.

The primary use of restrictors is to repair or prevent enlargement of cavity entrances (see also 2F), usually done by pileated woodpeckers but occasionally by red-bellied and red-headed woodpeckers, northern flickers (*Colaptes auratus*), and gray squirrels (*Sciurus carolinensis*. Pileated woodpeckers can seriously damage cavities in just minutes, and can completely destroy cavities in less than an hour, but the reasons for this behavior remain unknown. Further, pileated woodpeckers may damage some cavities in a cluster, while leaving others unharmed. Some cavities, or entire clusters, can exist undamaged for years in areas frequented by pileated woodpeckers, then suffer a sudden onset of damage. In extreme circumstances, pileated woodpeckers can damage or destroy most or all cavities in a cluster, leading to cluster abandonment. Commonly, a cluster suffers chronic damage over several years, leading to cluster instability and eventual abandonment. Because of the critical importance of suitable cavities to red-cockaded woodpeckers, use of restrictors to prevent and repair damage is an essential element of management for many populations. The number of cavities restricted in a cluster will vary according to circumstances, and may range from none to all cavities present. Knowing when to use restrictors to prevent damage, and when their use is not necessary, is a skill gained from experience and good judgment.

Whereas pileated woodpeckers can destroy red-cockaded woodpecker cavities by doubling the diameter of the entrance tunnel and exposing the cavity chamber, red-bellied woodpeckers, red-headed woodpeckers, and flickers normally enlarge cavity entrance tunnels and cavity chambers only enough to allow access. Over several years, these species can modify a cavity so that red-cockaded woodpeckers will rarely, if ever, use it. Although some rate of loss of red-cockaded woodpecker cavities due to modification by other species is natural, red-cockaded woodpeckers cannot always tolerate such losses in today's forests. In small, declining, or isolated populations, any loss of suitable cavities may not be tolerable. It will usually be necessary to use restrictors to repair enlargement by these species in such populations.

In the past, restrictors were sometimes used to exclude some avian cavity kleptoparasites, such as red-bellied woodpeckers, red-headed woodpeckers, and European starlings (*Sturnus vulgaris*), from cavities with either enlarged or unenlarged entrance tunnels. Variation in diameter of natural entrance tunnels allows access of some individuals or species to some cavities. For instance, both male and female red-bellied woodpeckers can enter some natural, unenlarged entrance tunnels, while only the slightly smaller females can access others. Eastern bluebirds and southern flying squirrels can access all cavities. However, use of restrictors on unenlarged cavities to exclude cavity kleptoparasites is not recommended, because of danger to red-cockaded woodpeckers. The difference between excluding a starling and excluding or entrapping a red-cockaded woodpecker is a matter of millimeters. Several deaths of adult red-cockaded woodpeckers resulting from entrapment in restricted cavities have been documented in the North Carolina Sandhills (J. Carter III, pers. comm.). In many cases, the affected red-cockaded woodpecker had successfully entered the cavity, but could not exit. Given that population-level impacts of cavity kleptoparasitism have not been demonstrated (Kappes 1993, Conner *et al.* 1996, Mitchell *et al.* 1999; see 2F), there is little justification for use of restrictors to exclude kleptoparasites.

Restrictors must be inspected annually, because restrictors that have loosened or come out of place are a serious hazard to red-cockaded woodpeckers and have resulted in multiple deaths throughout their range (R. Costa, pers. comm.). Injury and death can result from feet, wings, or legs of birds being caught under the edges or corners of restrictors. In populations where annual monitoring can not be accomplished, restrictors will not be used. Restrictors may have subtle costs as well: examination of a limited number of adult red-cockaded woodpeckers using restricted cavities showed visual evidence of excessive bill wear (J. H. Carter III, pers. comm.). Raulston *et al.* (1996) concluded that restrictors did not affect woodpecker survival or bill wear, but this was a small, short study and further research is warranted. With proper inspection and maintenance, restrictors may help keep a cavity in use for many years (Wood *et al.* 2000).

In summary, restrictors are an important management tool, but they must be used in the appropriate situations only, installed by experienced personnel, and monitored annually. Widespread use of restrictors without specific need for them is not recommended, because they are potentially dangerous. Cavity restrictors are best used to prevent or repair enlargement of cavities by pileated woodpeckers. In small populations, their use against cavity damage by other species may also be necessary. Restrictors should not be used to prevent starlings and other woodpeckers from using the cavity, because red-cockaded woodpeckers can be entrapped as well.

C. PREDATOR AND CAVITY KLEPTOPARASITE CONTROL

Red-cockaded woodpecker populations that are healthy and of medium to large size require no predator control and few measures to combat cavity kleptoparasites. Predators and cavity kleptoparasites were not among the original causes of the decline of red-cockaded woodpeckers, and their removal or control will not result in population or species recovery. Critically small populations, however, may not be able to tolerate even occasional loss of nests or cavities. Managers of critically small populations (less than 30 potential breeding groups) may choose to use predator management techniques, but only in concert with aggressive management of foraging and nesting habitat.

But, managers should be aware that predator exclusion devices may have unexpected consequences, since indirect interactions among predators, kleptoparasites, and red-cockaded woodpeckers are not understood. For this reason, use of snake exclusion techniques is generally discouraged. Snake exclusion devices should only be considered for trees containing newly installed artificial cavities or on active trees with a minimal resin barrier that are likely to be used as nest sites. If predator management is conducted, use of an experimental approach with adequate controls is strongly encouraged.

Methods of predator and kleptoparasite control are described in this section, and guidelines for their use are presented in 8G. A general discussion of predation, cavity kleptoparasitism, and cavity enlargement is given in 2F, and use of restrictors to control cavity enlargement is described in 3B and 8E. Most control measures used in red-cockaded woodpecker populations have been designed for one of two taxa: flying squirrels and rat snakes. Methods vary from lethal measures to non-invasive techniques such as bark shaving (Saenz *et al.* 1999), provision of nest boxes (Loeb and Hooper 1997), and retention of snags (Kappes and Harris 1995). In general, the least invasive techniques are preferred.

Exclusion of Rat Snakes

Three artificial methods of excluding rat snakes from cavity trees have been explored: snake nets, snake excluder devices (SNEDs), and the bark-shaving technique. Snake nets were developed by Neal *et al.* (1993b, 1998), and consist of a folded nylon monofilament net stapled to cavity trees at roughly 1.5 m (5 ft) above the ground. Rat snakes attempting to climb cavity trees get entrapped in the nets and soon die from heat stress. Red-cockaded woodpeckers can also get caught in these nets. Samano *et al.* (1998) reported the death of four red-cockaded woodpeckers and the entrapment of a fifth (rescued by biologists) in snake nets in a single year. Because of the documented danger to red-cockaded woodpeckers and the lethal effects on snakes, use of snake nets is prohibited.

Snake excluder devices (SNEDs) were developed by Withgott *et al.* (1995), and consist of a strip of lightweight aluminum flashing attached to the trunk of the cavity tree at ground level or up to 1.5 m (5 ft) above the ground. Withgott *et al.* (1995) used a 60 cm (23.6 in) wide band of aluminum flashing that they wrapped around and stapled to the bole of cavity trees. Prior to stapling the flashing in place, the bark on the bole of the cavity tree was scraped to smooth the surface and permit a tighter fit. The bark was also scraped relatively smooth about 30 cm (1 ft) above and below each SNED after installation. SNEDs proved to be highly effective in preventing climbing by rat snakes, and did not appear to affect use of the tree by red-cockaded woodpeckers (Withgott *et al.* 1995). Neal *et al.* (1998) reported numerous over-climbs of SNEDs on red-cockaded woodpecker cavity trees in Arkansas and Mississippi that were fitted with narrow metal flashing (less than 0.9 m [3 ft]), whereas only one over-climb occurred on 92 cavity trees fitted with metal flashing greater than 0.9 m (3 ft) wide. Thus, SNEDs greater than 0.9 m (3 ft) wide appear to be an effective, non-lethal method to reduce rat snake predation on red-cockaded woodpecker nest cavities. SNEDs require adequate annual maintenance, to check for dangerous tears in the aluminum and to remove any resin accumulation.

Bark-shaving was recently developed by Saenz *et al.* (1999) as an effective means of deterring climbing by rat snakes. A very sharp draw knife is used to shave the bark around the circumference of the tree in a 1 m (3.3 ft) band, at breast height, to eliminate furrows and rough surfaces without cutting into the cambium (Saenz *et al.* 1999). Breast height was chosen for ease of execution. This technique proved to be nearly 100 percent effective in experimental trials, and the one over-climb event occurred 3 ½ months after shaving on a tree that had developed a rough surface again (Saenz *et al.* 1999). Reshaving prevented the snake from climbing this tree again. Thus, bark-shaving can be used at the start of the nesting season or upon installation of artificial cavities, to give roughly three months of additional protection. Care must be taken not to damage the cavity tree by cutting into xylem tissue. Also, resistance to fire may be decreased by bark-shaving (Saenz *et al.* 1999), and any cavity tree thus treated should be well protected against fire.

The resin barrier created by red-cockaded woodpeckers is an extremely effective means of excluding rat snakes from cavity trees, especially in highly resinous longleaf pines (Ligon 1970, Dennis 1971b, Jackson 1974, 1978a, Rudolph *et al.* 1990a). In longleaf pine habitats, no additional measures are needed to control rat snakes regardless of population size. For critically small populations (less than 30 potential breeding groups) in pine types other than longleaf, managers may choose to install snake excluder devices or use the bark-shaving technique on trees likely to be used as nest trees. Managers may also choose to use bark-shaving to provide short-term protection against snakes when installing artificial cavities. Bark-shaving may be especially useful just before the nesting season, to protect active artificial cavity trees that do not yet have a resin barrier.

In summary, use of snake exclusion techniques should be restricted to pines containing newly installed artificial cavities, or pines with minimal resin but likely to be used as nest sites, in critically small populations. Use of snake exclusion techniques in other situations is discouraged.

Exclusion of Southern Flying Squirrels

Southern flying squirrel excluder devices (SQEDs) were developed by Montague *et al.* (1995), and consist of sheets of aluminum flashing that are wrapped around the cavity tree above and below the cavity entrance. Small portions of the flashing extend perpendicular to the bole of the pine tree. If kept clean of hardened pine resin, the SQEDs serve as an effective barrier and deny squirrel access to red-cockaded woodpecker cavities when they climb up and down the bole of cavity trees (Montague *et al.* 1995, Loeb 1996). However, a "skilled" flying squirrel can fly directly to a cavity entrance if adjacent pines are sufficiently close to permit a glide path. SQEDs require inspection and maintenance at least yearly, to ensure no dangerous tears develop and to keep them free from resin. Again, use of SQEDs is not necessary in populations of 30 or more potential breeding groups.

Montague *et al.* (1995) recommended that cavities reclaimed from southern flying squirrels be vacuumed to remove chewed pine needles and squirrel feces that are typically present in cavities with squirrels. Cavity cleaning may increase the probability that red-cockaded woodpeckers will reoccupy the cavity.

Lethal vs. Non-lethal Methods of Control

Rat snakes, southern flying squirrels, and other predators and kleptoparasites are all important components of southern pine ecosystems. Measures to control these species should not be applied in all areas managed for red-cockaded woodpeckers. Large and medium-sized populations located in areas of quality habitat should have sufficient reproduction and population size to easily offset any losses caused by predation and kleptoparasitism.

However, in critically small populations (less than 30 potential breeding groups) where appropriate habitat is in the process of being restored, or where populations are being reintroduced, predator and kleptoparasite management may be applied. Retention of snags and creation of nest boxes are important management options (Harlow and Lennartz 1983, DeFazio *et al.* 1987, Kappes and Harris 1995, Loeb and Hooper 1997). Use of lethal devices and euthanasia to control predators and kleptoparasites is discouraged.

D. TRANSLOCATION

Translocation is the artificial movement of wild organisms between or within populations to achieve management objectives. It is an important tool for the management and recovery of red-cockaded woodpeckers, if used in the appropriate situations and in the appropriate manner. In this section, we describe the reasons for using translocation and give a brief review of its use and success in red-cockaded woodpecker management. Guidelines for its use are presented in 8H.

Translocation of red-cockaded woodpeckers has four specific applications for which it is best suited: (1) augmentation of a population in immediate danger of extirpation, (2) development of a better spatial arrangement of groups, to reduce isolation of groups or subpopulations, (3) reintroduction of birds to suitable habitat within their historic range, and (4) management of genetic resources. We refer to the first application as population augmentation. This consists of moving birds from a healthy donor population to a critically small recipient population (less than 30 potential breeding groups). We refer to the second application as strategic recruitment, which is achieved by moving birds from within or between populations to recruitment clusters strategically located to link groups and subpopulations. All translocations, including those intended to augment a population, should serve to develop better spatial arrangements of groups.

Population augmentation is a means of buffering at-risk recipient populations against effects of demographic and environmental stochasticity (see 2C), which can result in extirpation of critically small populations regardless of other management efforts. This management action also serves to counteract the inbreeding depression that can reduce the persistence of very small, isolated populations (Haig *et al.* 1993, Daniels *et al.* 2000). Augmentation is not necessary for larger populations because they are not so highly vulnerable to stochastic events (other than catastrophes).

Strategic recruitment is a means to develop the beneficial spatial arrangements that can dramatically increase persistence and health of red-cockaded woodpecker populations (Conner and Rudolph 1991b, Crowder *et al.* 1998, Letcher *et al.* 1998, Walters et al. 2002b). Linking isolated groups and subpopulations with newly established breeding groups in strategically located recruitment clusters may be a slow process, because each new cluster must be within helper dispersal distance of active clusters. However, over time strategic recruitment can optimize spatial arrangements of groups within populations.

Reintroduction is the establishment of new populations in restored habitat within the species historic range. Reintroduction is currently being used experimentally to establish a new population in northern Florida (Hagan and Costa 2001), but at this time it is not a management technique available for widespread use. Establishment of new populations is not a criterion for delisting the species. Still, reintroduction can have a critical role in restoration of historic communities and conservation of local species diversity.

For the purposes of population augmentation or strategic recruitment, a potential mate can be moved to a cluster inhabited by a solitary individual (mate provisioning), or potential pairs can be moved simultaneously to unoccupied clusters. Reintroduction of birds is best accomplished by simultaneously translocating multiple potential pairs to suitable habitat (Carrie *et al.* 1999, Hagan and Costa 2001). Another current application of translocation is its use for mitigation (see 4A). Future use of the technique may include the translocation of individuals among recovered populations and essential support populations to counteract species-wide genetic drift (see 2C).

Benefits and Drawbacks to Translocation

Translocation has its benefits and drawbacks. It can be an important method to counteract loss of genetic variation but may also serve to disrupt valuable local genetic resources (Haig *et al.* 1994a, Hedrick 1995). It is an especially useful tool in the management of red-cockaded woodpeckers, because population dynamics in this species are regulated by the number of potential breeding groups in a population, not the annual number of young produced (Walters 1991; see 2B). Therefore, some juvenile birds may be moved without affecting the overall population size or trend. However, impacts to the donor areas and populations must be carefully evaluated and controlled (Griffith *et al.* 1989, Haig *et al.* 1993). Most importantly, translocation must not be used as a substitute for habitat management and restoration, two more difficult but much more fundamental management tasks (e.g., Pitelka 1981, Meffe 1992). Causes of population decline should always be identified and removed before translocation is attempted (Short *et al.* 1992, Meffe 1992, Caughley 1994).

Translocation can potentially disrupt local adaptations and genetic coadaptation. Local adaptations to environmental conditions confer highest fitness to individuals remaining in a specific area, whereas genetic coadaptation gives highest fitness to those individuals retaining coadapted gene complexes. Coadapted gene complexes are sets of genes that evolved together and impart greater fitness than the sum of each individual gene's contribution. A coadapted gene's effect depends on the presence of one or more other genes (Templeton *et al.* 1986). In red-cockaded woodpeckers, there is no direct evidence of local adaptations or coadaptation, but researchers have documented some genetic structure across the species' range (Stangel *et al.* 1992, Haig *et al.* 1994a, 1996, Stangel and Dixon 1995). Restricting translocations to short geographic distances only is important to the conservation of local genetic resources (Haig *et al.* 1994a).

Translocation can also spread parasites. Fortunately, the prevalence of blood parasites in red-cockaded woodpeckers is low, and cavities are relatively free of blood-feeding insects (Pung *et al.* 2000).

Thus, in general, translocation of red-cockaded woodpeckers is a short-term tool to be used in specific crisis situations with utmost caution and only after habitat suitable in quality and quantity exists (Griffith *et al.* 1989, Kleiman 1989) and habitat management plans emphasizing frequent fire are fully implemented. In addition, translocation may have a long-term application among recovered populations to counteract species-wide genetic drift, if natural dispersal is deemed insufficient for adequate gene flow. Translocations for this purpose require careful planning to offset effects of genetic drift without affecting local genetic resources (see Hedrick 1995).

History of Translocation of Red-cockaded Woodpeckers

Prior to the development of artificial cavities (Copeyon 1990, Allen 1991) and translocation (DeFazio *et al.* 1987), many managers and biologists were pessimistic about the long-term persistence of red-cockaded woodpeckers (Ligon *et al.* 1986, Escano 1995). In particular, there was little hope of conserving and restoring the many small, declining populations. Recently, however, most populations have been stabilized and/or increased (Hooper *et al.* 1990, Richardson and Stockie 1995, Watson *et al.* 1995, Walters and Meekins 1997, Walters *et al.* 1997, USFWS unpublished). For some small populations, increases in population size were achieved through aggressive habitat management and cavity provisioning without resorting to translocation (Richardson and Stockie 1995, Watson *et al.* 1995, Walters and Meekins 1997, Walters *et al.* 1997, USFWS unpublished). However, the stabilization and increase of other critically small populations has required the use of translocation in concert with intensive habitat and cavity management (DeFazio *et al.* 1987, Allen *et al.* 1993, USFWS unpublished).

Initially, translocations were performed as emergency efforts to rescue individual birds from military construction impacts (e.g., Odom *et al.* 1982) or loss of habitat to timber harvests (e.g., Reinman 1984). These early efforts met with very little success, and several authors criticized the use of translocation especially as mitigation for destruction of occupied clusters (Cely 1983, Jackson *et al.* 1983). Odom (1983) concluded, “red-cockaded woodpecker relocation is not recommended as a management tool at this time”, but also noted its potential and called for further research. Following these initial attempts in the early 1980's, experiments were performed in the late 1980's and early 1990's to test translocation methods and its usefulness as a recovery tool (Allen *et al.* 1993, Costa and Kennedy 1994).

Perhaps the best known of these experiments in translocation was the extremely intensive effort to conserve and restore the critically endangered red-cockaded woodpecker population in the Savannah River Site in South Carolina (Allen *et al.* 1993, Gaines *et al.* 1995, Franzreb 1999). By late 1985, this population was reduced to one breeding pair and two solitary males (DeFazio *et al.* 1987) and aggressive management was begun, including habitat management, cavity installation, and translocation (Gaines *et al.* 1995). From 1986 to 1995, 54 red-cockaded woodpeckers were translocated, including 21 translocated from four donor populations outside the study area and 33 from within the population (Franzreb 1999). By 2000, the Savannah River Site population consisted of 31 potential breeding groups (P. Johnston, pers. comm.). Clearly, translocation was an important part of the dramatic change in this population’s status.

Following the success of the Savannah River Site translocation attempts (Allen *et al.* 1993), the Southern Region of the U.S. Forest Service decided to implement red-cockaded woodpecker translocations as a management tool in 1989 (Escano 1988). Because the Apalachicola National Forest in Florida contained the largest and only recovered red-cockaded woodpecker population, it was chosen as the primary donor population. From 1989 to 1992, 18 red-cockaded woodpeckers were translocated from the Apalachicola NF to seven other national forest units (Hess and Costa 1995).

Recently, translocation has been used with great success in the reintroduction of one population and to augment several extremely small populations. Reintroduction of red-cockaded woodpeckers into Avalon Plantation in Florida, beginning in 1998, has resulted in a population of 7 potential breeding groups in 2001 (Hagan and Costa 2001). The population at the Joseph W. Jones Ecological Research Center was increased, using translocation, from a solitary male in 1998 to 5 breeding pairs in 2001, and Southlands Experimental Forest increased from three males in 1997 to 8 potential breeding groups in 2001. Other recent examples of the successful use of translocation to augment critically small populations include increases in the Chickasawhay National Forest and Fort Jackson. Currently, translocation remains an important crisis management tool to be used with caution in appropriate circumstances.

Translocation Success

Efforts to measure the success of translocation as a management technique have been hampered by inconsistent data collection and differing definitions of success (Costa and Kennedy 1994). Definitions of success have varied, ranging from the individual being present soon after release to the fledging of offspring the following breeding season (Costa and Kennedy 1994). To further confuse the issue, definitions of success must change depending upon the objective of the translocation: for augmentation of a critically small population, reproduction of a translocated bird anywhere in the population is considered successful; however, if the objective is strategic recruitment of a new group by translocating birds from within the population to a specific area, then reproduction of those individuals in an area other than the target area is not considered a success.

Currently, the average estimated success rate for translocation is roughly 50 to 60 percent, for various meaningful definitions of success including presence in the recipient cluster in the following breeding season (Hess and Costa 1995), evidence of breeding in the following season or of pair-bonding just prior to the breeding season (Costa and Kennedy 1994), and remaining at or near the release site for 30 days (Franzreb 1999). Similarly, Franzreb (1999) reported that roughly half of adults and subadults (25 of 49) translocated to and within the Savannah River Site reproduced somewhere within that population. Higher success has been reported for simultaneous movement of multiple pairs (50 to over 70 percent present in the following breeding season; Carrie *et al.* 1999, Hagan and Costa 2001, USFWS unpublished), an encouraging development in translocation methods for red-cockaded woodpeckers and one which has been emphasized for other species as well (Griffith *et al.* 1989). Reproduction specifically at the recipient cluster is currently estimated to have occurred in 27 percent of translocations conducted between 1989 and 1995 (48 of 178, Edwards and Costa, in review).

Success of translocations has increased as methods have improved. Information is slowly accumulating on the effects of age, sex, and other factors such as distance, habitat condition, and the number of birds released on the likelihood of successful translocation. This research has been invaluable in formulating both a regional translocation strategy and specific guidelines for the movement of birds. Researchers agree that moving females to territories with solitary males, and moving potential pairs simultaneously, are the most successful types of movements (Rudolph *et al.* 1992, Allen *et al.* 1993, Costa and Kennedy 1994, Hess and Costa 1995, Hagan and Costa 2001, Edwards and Costa, in review). Birds are less likely to return to their original cluster if moved more than roughly 19.3 km (12 mi; Allen *et al.* 1993, Franzreb 1999). Other factors, such as insufficient number or poor condition of recipient cavities, problems in transport, and problems at the time of release, reduce success of translocations (Hess and Costa 1995). Finally, Rudolph *et al.* (1992) suggested that simultaneous movement of multiple pairs (5-10) might increase success. Again, this method has yielded encouraging results. Carrie *et al.* (1999) reported a success rate, defined as birds present in the following breeding season, of over 70 percent (12 of 17) after releasing multiple potential pairs in the Sabine National Forest. Other translocations of multiple pairs have shown success rates from 50 to over 70 percent as well (USFWS unpublished); for example, of 13 individuals translocated to the Joseph W. Jones Ecological Research Center in Georgia between 1999 and 2001, 10 remained in the beginning of the 2001 breeding season (J. Stober, pers. comm.).

In summary, it is apparent that translocation has an important but very specific role in the conservation and recovery of red-cockaded woodpeckers. It is not to be used as a substitute for more fundamental management actions that provide good quality foraging and nesting habitat. In the presence of good quality foraging and nesting habitat, translocation can be an effective short-term tool to counteract effects of demographic and environmental stochasticity and a useful measure over the long-term to reduce loss of genetic variation in isolated populations. Translocation is best performed by moving multiple pairs of juvenile red-cockaded woodpeckers, simultaneously, to recruitment clusters that are strategically located to improve the spatial structure of the population.

E. SILVICULTURE

Silviculture is the theory and practice of controlling the establishment, composition, structure, and growth of forests to achieve management objectives (Smith 1986). It was developed primarily for the purpose of timber production, but can be used for other purposes including biological conservation (Smith 1986, Thompson *et al.* 1995). Silviculture is an important tool for the management of red-cockaded woodpeckers with or without the additional goal of timber production. Today's forests differ substantially in structure and species composition from the precolonial forests that supported red-cockaded woodpeckers in abundance (Conner and Rudolph 1989, Foti and Glenn 1991, Ware *et al.* 1993, Masters *et al.* 1995, Noel *et al.* 1998). Second growth forests can be dense, can contain many small young trees and few large old trees, and often have a complex vertical structure. Proper silviculture can restore and maintain the open, two-layered habitat required by red-cockaded woodpeckers. In this section, we discuss the compatibility and usefulness of silvicultural methods to management and recovery of red-cockaded woodpeckers. We give guidelines for the use of silviculture in 8J.

Conservation and recovery of red-cockaded woodpeckers are compatible with timber production within certain constraints (Rudolph and Conner 1996, Engstrom *et al.* 1996, James *et al.* 1997, 2001, Hedrick *et al.* 1998). Suitable forest structure and function must be retained to support red-cockaded woodpecker populations. Suitable forest structure includes a substantial amount of large pines, low densities of small and medium sized pines, sparse or absent hardwood midstory, and abundant diverse herbaceous groundcovers (Hardesty *et al.* 1997, James *et al.* 1997, 2001, Hedrick *et al.* 1998, Walters *et al.* 2000, 2002a). Foremost among important functions of southern pine forests is the ability to carry frequent growing season fires (Platt *et al.* 1988b, Engstrom *et al.* 1996).

Silvicultural methods can be divided into three systems: even-aged, two-aged, and uneven-aged management. Two-aged is sometimes included within even-aged management. Each system has several possible methods of regeneration, the simultaneous harvest and establishment of tree reproduction (Thompson *et al.* 1995). Even-aged management includes clearcutting, standard seed tree, and standard shelterwood methods. Two-aged management includes modified seed tree and irregular shelterwood methods, and uneven-aged management includes single tree selection and group selection methods. Several researchers have assessed the compatibility of these methods with restoration and maintenance of habitat for red-cockaded woodpeckers (USFWS 1985, Lennartz 1988, Walker and Escano 1992, Walker 1995, USFS 1995, Rudolph and Conner 1996, Engstrom *et al.* 1996, Hedrick *et al.* 1998). The suitability of each method varies with forest type, silvicultural history, ownership, and management objectives. Silvicultural systems also differ in how production of habitat is sustained over time. It is critical to sustain habitat in perpetuity for recovery of red-cockaded woodpeckers.

Silvicultural Systems

Even-aged Management

Even-aged management is the culture of trees of one age class in a given stand (Helms 1998). The forest is regulated at the landscape level, with equal areas in each age class. Regeneration methods of even-aged management differ in the amount of residual trees remaining after harvest. Clearcutting is the removal of all commercially valuable trees on site. In standard seed tree and shelterwood methods, residual trees are left standing as seed sources after the initial harvest and are removed following the establishment of reproduction. Regardless of regeneration method, intermediate thinnings are made to improve growth and health of trees by reducing tree density (Smith 1986, Walker 1995). Modified seed tree and irregular shelterwood are not included as even-aged management in this document (see Two-aged Management below).

Clearcutting, standard seed tree, and standard shelterwood methods are not generally compatible with management to recover red-cockaded woodpeckers, except when used to restore native, site-appropriate pines. The U.S. Forest Service now discourages use of clearcutting (USFS 1995). Even-aged silviculture results in fragmented habitat, and red-cockaded woodpeckers are especially sensitive to negative impacts of habitat fragmentation because of their cooperative breeding system (see 2B). Even-aged silviculture renders stands unsuitable as nesting or foraging habitat for decades. Even with long rotations, even-aged silviculture results in stand-level removal of the large old trees most important to red-cockaded woodpeckers. Even-aged silviculture can be useful in the removal of off-site pine species to restore native pines (see 3G). If within occupied habitat, such restoration is best limited to small areas (Ferral 1998).

Two-aged Management

Two-aged management is a modification of even-aged management in which two age classes exist in a given stand (Smith 1986, Rudolph and Conner 1996). Two-aged stands are created by modified seed tree and irregular shelterwood methods, which are similar to corresponding standard methods except that residual trees are never harvested. In two-aged management, 15 to 25 pines/ha (6 to 10 pines/ac) or more are left as residual trees. The forest is regulated in the same way as in even-aged management. Intermediate thinnings are important to reduce stand density and open the forest structure.

Modified seed tree and irregular shelterwood methods are compatible with management of red-cockaded woodpeckers (Conner *et al.* 1991b, Rudolph and Conner 1996, Hedrick *et al.* 1998). Two-aged silviculture promotes the growth of old and even very old trees in every stand, and older trees are important to both nesting and foraging (see 2D, 2E). Prescribed burning can be conducted throughout much of the forest without fear of damaging young pines, because pine reproduction is concentrated in limited areas. This is a strong advantage in forests of loblolly and/or shortleaf pines which are sensitive to fire when young (Farrar 1996, Hedrick *et al.* 1998). Finally, two-aged silviculture can open up the forest and establish lower pine densities preferred by red-cockaded woodpeckers (Conner *et al.* 1991b). Irregular shelterwood and modified seed tree methods are the cornerstone of restoration of the shortleaf pine/bluestem grass (*Andropogon* and *Schizachyrium* spp.) ecosystem on the Ouachita National Forest in Arkansas (USFS 1996).

Modified seed tree and irregular shelterwood methods have some drawbacks in their application for red-cockaded woodpecker management. The older residual pines are subject to increased windthrow, especially the more shallow rooted pine species (Smith 1986), and increased lightning strikes. In longleaf stands, however, mortality of residual pines is not likely to be greater than that of similarly aged pines in other stands (Boyer 1979). A second drawback to modified seedtree/shelterwood silviculture is that reduction in canopy cover may reduce needle litter, an important fuel (Engstrom *et al.* 1996). Also, an excessive pine midstory can develop, with detrimental effects on cluster occupancy (see 2D) and suitability of the stand for foraging (see 2E). Dense pine regeneration, even under residual pines, renders the stand unsuitable for foraging and such stands are not considered foraging habitat until the pine regeneration can be thinned considerably (see 8I and 8J for specific description of the pine size class distributions that are considered foraging habitat). Frequent prescribed burning can be an important tool to control density of pine regeneration.

Finally, modified seed tree and irregular shelterwood methods may not retain sufficient densities of large trees for newly regenerated stands to qualify as foraging habitat (see 8J). When using these methods in the presence of red-cockaded woodpeckers, long rotations or a greater number of residual pines are necessary to provide suitable foraging habitat.

Uneven-aged Management

Uneven-aged management results in stands with at least three age classes (Smith 1986, Helms 1998). Reproduction occurs throughout the forest in gaps created by the harvest of single trees or groups of trees (regeneration by single tree and group selection, respectively). If group selection is used, patches of trees removed are generally below 0.8 ha (2 ac) in size. The forest is regulated at the stand level, usually by either timber volume or stand structure. The forest can be regulated using one of several methods, including regulating by timber volume using the volume/guiding diameter limit (V-GDL) method (Reynolds 1959, Baker *et al.* 1996, Farrar 1996, Guldin and Baker 1998) or by stand structure using the BDq method (Marquis 1978, Baker *et al.* 1996, Farrar 1996, Guldin and Baker 1998). Another method of uneven-aged silvicultural management is the Stoddard-Neel approach (Mitchell *et al.* 2000).

The V-GDL method uses periodic inventories to measure tree growth, which is then established as the allowable harvest. The guiding diameter limit is the size above which the volume of trees meets the allowable cut. All trees above the guiding diameter limit are not necessarily cut; for every tree above the limit retained, an equal volume of trees below the limit are harvested (Farrar 1996, Guldin and Baker 1998). According to Guldin and Baker (1998), the classic marking rule for this method is to “cut the worst trees and leave the best”. In general, the V-GDL method of regulation is somewhat subjective and therefore can be difficult to apply (Farrar 1996, Guldin and Baker 1998).

The BDq method uses three parameters to describe the target after-cut stand structure: residual basal area (B), maximum diameter retained (D), and the ratio of number of stems in a given size class to those in the next larger class (q). The priority of these parameters is in the order given, so that trees above the maximum diameter are retained if residual basal area cannot be met without them (Baker *et al.* 1996, Farrar 1996, Guldin and Baker 1998). If the structure of the residual stand closely corresponds to q, the stand has a negative exponential (inverse-J) size distribution and is said to be well-balanced (Guldin and Baker 1998). Both q and D can be adjusted to increase the presence of large old trees to meet management objectives (Farrar 1996). The BDq method is preferred over the V-GDL method for most uses because it provides an objective means of monitoring the smaller size classes (Farrar 1996, Guldin and Baker 1998).

The Stoddard-Neel approach is a subjective method that has not been specifically quantified, but has the following characteristics (Mitchell *et al.* 2000). Perpetuation of the forest ecosystem as a whole is the overriding goal of management. Each tree is individually assessed according to its contributions to the ecosystem and the surrounding landscape. Harvest is considered only after it can be conducted without compromising conservation goals, and after that point, only harvesting a portion of the annual incremental growth is allowed. Specific harvest limits are set and reviewed every 10 years. Criteria for individual tree retention include pines with old growth characteristics, older canopy dominants, and longleaf pines in mixed pine stands. Criteria for individual tree selection include some defective trees, those with low crown vigor, and the promotion of an open, multi-aged canopy structure. Openings vary in size ranging from 0.1 ha to 0.2 ha (0.25 ac to 0.5 ac). Salvage logging of dead trees is allowed only if applied toward the allowable cut, and some dead and downed trees are maintained throughout the forest.

Uneven-aged management is compatible with restoration and maintenance of red-cockaded woodpecker habitat (Engstrom *et al.* 1996, James *et al.* 2001). Uneven-aged management can provide large old trees throughout the landscape. Densities of small and medium sized pines can be controlled to avoid detrimental effects on red-cockaded woodpeckers. Frequent prescribed burns can be used to control hardwoods and maintain herbaceous groundcovers in longleaf forest types. For loblolly and shortleaf forests, it is harder to use prescribed fire in uneven-aged stands because of fire sensitivity of young pines and the presence of young pines throughout the landscape (Rudolph and Conner 1996, Hedrick *et al.* 1998). However, prescribed burning at intervals of variable length may be used successfully in these forest types (Cain 1993, Farrar 1996, 1998, Cain *et al.* 1998). Annual and biennial fires interspersed with periods of up to 5 years without fire may effectively control midstory and encourage herbaceous groundcovers while allowing for reproduction of loblolly and shortleaf pines (Cain 1993, Cain *et al.* 1998). The Red Hills region of south Georgia and north Florida supports a large population of red-cockaded woodpeckers in longleaf systems effectively managed with a combination of single tree and group selection methods (Engstrom and Baker 1995, Engstrom *et al.* 1996). Finally, uneven-aged management has been used successfully to remove off-site pine species and restore native site-appropriate pines (e.g. McWhorter 1996).

There are several drawbacks in the application of uneven-aged silviculture to the management of red-cockaded woodpeckers. The number of harvests, and consequently habitat disturbance, can be greater than that of two-aged management (Rudolph and Conner 1996) although this is not necessarily so (Engstrom *et al.* 1996, Farrar 1996, W. D. Boyer, pers. comm.). In fact, W. D. Boyer (pers. comm.) states that the number of entries in longleaf stands under uneven-aged management can be fewer than in stands under even-aged management.

Application of prescribed fire is difficult or at least somewhat complex in uneven-aged stands of loblolly and shortleaf pines, and therefore hardwoods may become a problem (Rudolph and Conner 1996, Hedrick *et al.* 1998). Finally, selection systems, just like even-aged management, can result in the harvest of the old, large trees most valuable to red-cockaded woodpeckers. With careful application these drawbacks can be minimized.

Low Intensity Management

Some woodpecker populations exist in forests that are not managed for timber production. Low-intensity management for the primary purpose of biological conservation uses frequent growing season burns to control hardwoods, prepare the site for pine reproduction, and encourage beneficial native, site-appropriate groundcovers. Natural disturbances such as wind-throw and lightning strikes establish gaps in the canopy for reproduction and recruitment to occur. Hurricanes may occasionally create larger openings. Longleaf, shortleaf, and other pines on native sites are suited for low intensity management.

Some forests may require restoration prior to the application of this silvicultural method. Hardwood midstories and/or overstories may need reduction or removal. Herbaceous groundcovers may need to be restored, and dense pine stands will require thinning to densities suitable for red-cockaded woodpeckers.

Low intensity management is advantageous for red-cockaded woodpeckers because conservation is the primary goal. Low-intensity management offers aesthetic and recreational benefits as well, because the low tree density and healthy herbaceous layer are generally appealing to the public. Low-intensity management does not have the monetary benefits of timber production.

Pine Density

Pine densities generally recommended for timber production by uneven-aged management are 10.3 to 17.1 m^2 basal area per ha (45 to 75 ft^2/ac) in longleaf systems and somewhat higher for shortleaf and/or loblolly (Farrar 1996). Pine density before and after selection cutting generally remains within this range. Even-aged and two-aged management typically result in pine densities of 18.3 to 27.4 m^2/ha basal area (80 to 120 ft^2/ac) or more (Farrar 1996), and after cutting densities are often reduced to below 2.6

m^2/ha (20 ft^2/ac). In addition, second-growth forests are generally more dense than old growth woodlands (Ware *et al.* 1993, Masters *et al.* 1995, Noel *et al.* 1998).

For management of red-cockaded woodpeckers, it is important that densities of small and intermediate-sized pines (<35 cm, or 14 in dbh) be reduced, and the largest trees protected (Walters *et al.* 2000, 2002a, James *et al.* 2001). Two recent studies of foraging ecology in longleaf ecosystems documented increases in fitness of woodpeckers in more open habitat and at lower pine densities (Walters *et al.* 2000, 2002a, James *et al.* 2001). Thinning suppressed pines opens the forest structure, promotes desired herbaceous groundcovers, and increases effects of prescribed burning. However, further experimental research on silvicultural treatments, with adequate controls, is urgently needed to better understand the appropriate habitat structure to support healthy red-cockaded woodpecker populations (F. C. James, pers. comm.).

Further research is also necessary to assess effects of pine densities on foraging ecology of woodpeckers in shortleaf and loblolly systems. For shortleaf and loblolly forest types, pine densities below 18.4 m^2/ha (80 ft^2/ac), or an average spacing of at least 7.6 m (25 ft) between pines in mature stands, are very important in reducing risks of southern pine beetle infestations (Thatcher *et al.* 1980, Nebeker and Hodges 1985, Hicks *et al.* 1987, Belanger *et al.* 1988, Mitchell *et al.* 1991).

Priority for Leave Trees

Leave trees are those that remain standing after thinnings and harvests. Benefits to red-cockaded woodpeckers can be increased by preferentially leaving trees important to them. These important trees include old and very old pines (relict and remnant pines and flat-tops), potential cavity trees (pines over 60 years in age), and pines scarred by turpentine harvest or lightning.

Site Preparation

Regardless of the silvicultural system used, some form of site preparation is necessary to establish pine reproduction. Site preparation removes vegetation and other organic material to expose the mineral soil required for seed germination. Prescribed burning is the preferred method of site preparation, because it mimics natural processes, minimizes disturbance to the soil, and promotes native, site-appropriate herbaceous groundcovers beneficial to red-cockaded woodpeckers (see 2E). Prescribed burning during the growing season induces flowering of many native herbaceous plants (Platt *et al.* 1988a; see 2G) and enhances reproduction of longleaf pines much more so than winter burning (W. D. Boyer, pers. comm.).

Prescribed burning within one year of a good pine seed crop is generally the only site preparation needed, if hardwoods are well under control. If prescribed burning cannot be used, the Bracke scarifier-mounder or a roller drum chopper has fewer impacts on soil profiles and plant communities than do discing, root raking, windrowing, and bedding. Bracke-mounding is a relatively non-invasive technique by which small mounds rather than plow lines are created to expose the mineral soil. Chemical treatments are sometimes used for site preparation as well, but effects of herbicides on native groundcovers are largely unknown (Litt *et al.* 2000, 2001). Any method of site preparation that disturbs the soil will favor ruderal, disturbance-tolerant grasses and forbs over desired species such as wiregrass (Provencher *et al.* 1998, 1999, 2001b), and recovery of groundcovers can be exceedingly slow. For example, Provencher *et al.* (1997, 1998) estimated that recovery of groundcovers following selective harvest of longleaf pine can take 50 years in deep sandy soils.

F. Prescribed Burning

Because of fundamental changes in the landscape and natural fire regime of the southeast, prescribed burning is and will continue to be the primary means of restoring and maintaining fire in southern pine ecosystems (Frost 1998). Prescribed burning provides benefits for a suite of species characteristic of southern pine ecosystems, and is an essential management tool for the conservation and recovery of red-cockaded woodpeckers (Robbins and Myers 1992, Costa 1995a). By reducing dangerous fuel loads, prescribed burning is also a vitally important component in the protection of human life and property from extreme wildfire.

Red-cockaded woodpeckers are rightly termed an umbrella or flagship species, because their protection and management provides for the conservation of entire ecosystems and the hosts of associated species within. It is especially prescribed burning, but also retention of old growth and mature trees, that provides critical support for associated species. To maximize these benefits, the frequency, intensity, season, and variability of prescribed fire should mimic the historic natural fire regime as closely as possible (Masters *et al.* 1996).

In this section, we briefly review the benefits of prescribed burning to red-cockaded woodpeckers and other species of southern pine ecosystems, and then address concerns about possible negative effects on some animals. We also review the application of prescribed fire to the landscape and its use in habitat restoration. A general discussion of the history and role of fire in southern pine ecosystems is given in 2G. Guidelines for the use of prescribed burning are given in 8K.

Benefits of Prescribed Burning

Benefits to Red-cockaded Woodpeckers

Red-cockaded woodpeckers require open woodlands for nesting and roosting cavities. Hardwood encroachment eventually results in the abandonment of clusters and severe population decline or extirpation (Beckett 1971, Hopkins and Lynn 1971, Van

Balen and Doerr 1978, Locke *et al.* 1983, Hovis and Labisky 1985, Conner and Rudolph 1989, Costa and Escano 1989, Loeb *et al.* 1992, Masters *et al.* 1995). Encroachment of hardwoods and woody shrubs also degrades the quality of foraging habitat (James *et al.* 1997, Walters *et al.* 2000, 2002a). Prescribed burning, especially during the growing season, is a highly effective means of controlling such hardwood and shrub encroachment. Prescribed burning can effectively control hardwoods and shrubs without damaging the herbaceous layer and soils, and can be much less expensive than other restoration methods (Provencher *et al.* 2001b). Prescribed fire also has direct benefits to herbaceous plants in southern pine communities by initiating flowering (Platt *et al.* 1988a). Fire helps maintain a healthy native plant community, which in turn leads to increased fitness of red-cockaded woodpeckers (Hardesty *et al.* 1997, James *et al.* 1997, 2001). The mechanism for increased fitness of red-cockaded woodpeckers in the presence of abundant herbaceous groundcovers has not been documented, but one proposal for such a mechanism is increased abundance and/or nutrient content of prey (James *et al.* 1997).

Benefits to Associated Species

Many plants and animals associated with southeastern pine communities are threatened by loss of habitat through fire suppression and conversion to other land uses. Management for red-cockaded woodpeckers directly supports these sensitive, threatened, and endangered species. Currently, over 120 species of plants and 56 animal species associated with red-cockaded woodpecker habitats are on the regional list of proposed, endangered, threatened, and sensitive species (USFS 1995). Many more herbaceous plants of longleaf communities are rare in today's landscape (Walker 1993), nearly all of which are adapted to growing season fire. Thirty-five percent of the amphibians and reptiles inhabiting longleaf pine forests, and 56 percent of the longleaf pine specialist species, were listed by at least one conservation agency as being of special concern (Guyer and Bailey 1993). Fire suppression was identified as a primary cause of the decline of these species.

Fire benefits shortleaf pine communities as well, although these have not received as much research attention as longleaf systems. Masters *et al.* (1998) reported that species richness and diversity of small mammals increased in relation to midstory reduction and prescribed fire, and no species was adversely affected by fire. Similarly, King (1982) reported increased abundance and diversity of small mammals in loblolly/shortleaf pine forests of the Georgia Piedmont in response to frequent prescribed fires.

Prescribed burning directly benefits bird species associated with open pine woodlands such as Bachman's sparrows (*Aimophila aestivalis*), brown-headed nuthatches (*Sitta pusilla*), pine warblers (*Dendroica pinus*), prairie warblers (*D. discolor*), and red-headed woodpeckers (Engstrom *et al.* 1984, Jackson 1988, Wilson *et al.* 1995, Conner and Dickson 1997, Allen 2001). Bachman's sparrows, in particular, are in decline throughout most of their range and respond strongly to management for red-cockaded woodpeckers (Dunning and Watts 1990, Gobris 1992, Plentovich *et al.* 1998). Bird species associated with riparian habitats within open pine woodlands, such as Carolina wrens (*Thryothorus ludovicianus*), white-eyed vireos (*Vireo griseus*), common yellowthroats (*Geopthlypis thrichas*), and hooded warblers (*Wilsonia citrina*), can benefit from prescribed burning as well (Engstrom *et al.* 1984, Conner and Dickson 1997, Allen 2001). Riparian habitats within open pine forests, when frequently burned, support increased density and diversity of shrubs, a likely cause of increased abundance of associated bird species (Allen 2001). Additionally, many songbird species of southeastern pine communities prefer burned over unburned forests for nesting sites (White *et al.* 1999).

Concerns about Negative Effects

Increasing use of prescribed fire has prompted concern among some land managers, researchers, and the general public. A common anxiety is that prescribed burning during the growing-season may have detrimental effects on non-target species. Managers perceive negative impacts on game species, including losses of nests of ground-nesting birds such as northern bobwhites (*Colinus virginianus*) and wild turkeys (*Meleagris gallopavo*), and reduction of hard mast forage for game birds, white-tailed deer (*Odocoileus virginianus*), and black bear (*Ursus americanus*) among others. However, these concerns have not been substantiated. In fact, increases in abundance of bobwhites and wild turkeys after the introduction of growing season burns have been reported in many areas (Landers *et al.* 1995, Palmer and Hurst 1998). Prescribed burning and pine thinning benefit white-tailed deer by increasing the production of available forage and preferred woody browse to more than four times that of untreated areas (Masters *et al.* 1996).

One immediate effect of growing season fire is the destruction of nests, and this has caused some concern. However, for species associated with southeastern pine habitats, the benefits of prescribed burning far outweigh the occasional loss of nests. Improved habitat quality enables higher population densities, whereas fire suppression substantially lowers the abundance of these bird species (Allen 2001). Saving some nests through fire suppression can serve no purpose if the birds have no habitat in which to exist. In addition, many birds adapted to southeastern pine habitats, such as Bachman's sparrows, pine warblers, prairie warblers, and others, readily renest upon loss of a nest. Game birds such as wild turkeys and northern bobwhites also readily renest (Vangilder and Kurzejeski 1995, Harper and Exum 1999). This behavior acts to minimize any negative effect that fire can have.

There also has been some concern about possible effects of management for red-cockaded woodpeckers on neotropical-nearctic migratory birds. Some species of neotropical-nearctic migrants have experienced declines in recent decades (Robbins *et al.* 1989, Sauer and Droege 1992, Peterjohn and Sauer 1994). In response, conservation biologists and land managers have focused on these species. However, in the southeastern coastal plains, neotropical migrants of greatest management concern are largely associated with bottomland riparian forests (Hunter *et al.* 1994), whereas resident bird species of concern are associated with mature open pine forests and benefit from woodpecker management (Dunning and Watts 1990, Hunter *et al.* 1994, Wilson *et al.* 1995, Tucker *et al.* 1996). A study of the response of breeding bird communities to red-cockaded woodpecker management in southern Mississippi reported that 7 of the 9 bird species that benefited from woodpecker management were pine-grassland species under regional or national decline, whereas all 4 species benefiting from fire suppression were relatively common forest interior species exhibiting stable or increasing trends (Burger *et al.* 1998). In addition, almost all species of birds that increase abundance under fire suppression, such as red-eyed vireos (*V. olivaceous*), black-and-white warblers (*Mniotilta varia*), and Acadian flycatchers (*Empidonax virescens*), also use frequently burned riparian habitats within open pine ecosystems (Allen 2001). Finally, even species that are considered interior forest species may benefit from management for red-cockaded woodpeckers that includes prescribed fire. For example, Powell *et al.* (2000) reported increased abundance of wood thrushes (*Hylocichla mustelina*) on plots treated with pine thinning and prescribed fire relative to control plots in the Georgia Piedmont. The authors went on to suggest that such management contributed to the stability of the study population and recommended its use to stabilize other declining populations in the state.

Thus, management for red-cockaded woodpeckers benefits other resident bird species of concern without impacting those neotropical migrants that are in decline. Managers should not hesitate to conduct prescribed burns for fear of impacts to neotropical migratory birds. Neotropical-nearctic migrant species of concern will best be conserved not by fire suppression but by the protection of habitats most important to them, such as southeastern bottomland hardwoods and northeastern boreal forests.

Close proximity of human development to forests supporting red-cockaded woodpecker populations presents significant risks of natural fire to human property and human lives. Frequent prescribed burning is a critically important technique to reduce risk of extreme natural fire and increase human safety. Risks associated with prescribed burning can be reduced through careful application and other techniques (e.g., Feary and Neuenschwander 1998), and if properly planned and implemented prescribed burns can be safely used to manage natural habitats and protect human life and property. Benefits to human safety and to the entire ecosystem far outweigh risks, if fires are planned and conducted with caution and guidelines are followed (see 8K).

Season of Prescribed Burning

As stated above, the frequency, intensity, season, and variability of prescribed fire should mimic the historic natural fire regime as closely as possible (Masters *et al.* 1996). Growing season fire is emphasized throughout this document because it is commonly believed that most historic fires occurred during the lightning season. Early to mid growing season fire typically has stronger benefits for native, site-appropriate groundcovers than dormant season fire. Late growing season fire may have detrimental impacts on overstory pines and is not as effective in reducing midstory root stock and promoting native groundcovers (Sparks *et al.* 1998, 1999). Sparks *et al.* (1998, 1999) found late dormant season burns more effective than late growing season burns in reducing hardwoods and restoring herbaceous groundcovers in the Ouachita Highlands. Spring burns had much higher reproduction of longleaf pines and development of longleaf pine seedlings than did summer or winter burns in the Escambia Experimental Forest of Alabama, and hardwood development was virtually non-existent in stands undergoing spring burns (W. D. Boyer, pers. comm.). Season of prescribed burns may vary according to specific management objectives (e.g., initial fuel reduction), but the overriding goal of prescribed burning programs in southeastern pine ecosystems should be the institution of a fire regime that best recovers and maintains an abundant, diverse, native, and site-appropriate herbaceous layer to the ecosystem in question.

Application of Fire to the Landscape

Aerial and ground ignition are the two most common methods used to apply fire to the landscape. Ground ignition is the more common of the two because it requires less financial resources and training. However, aerial ignition is becoming increasingly popular because more area can be burned per unit time, and the smoke dispersal is improved.

Ground ignition is accomplished by one or more techniques. Hand-held drip torches are most common, either used alone or in combination with other techniques such as mechanical torches mounted to all-terrain vehicles (ATVs). Using all-terrain vehicles increases the efficiency of ground burning operations, but entails greater safety risks than hand held torches. Caution must be exercised when using ATVs in forest stands with excessive midstory, hidden stumps, or large amounts of downed timber, and operators should be trained in vehicle use. Recently, several safety improvements have been made to ATV-mounted torches, and managers considering their use should contact state and federal agencies to learn more about these improvements. Use of ATVs in areas supporting gopher tortoises may negatively impact that species.

Aerial ignition can be a very efficient method of burning large areas in a few hours. One example of a successful prescribed burning program using aerial ignition is that of the Carolina Sandhills National Wildlife Refuge (Ingram and Robinson 1998). Aerial ignition is generally accomplished through the use of a helicopter equipped with a helitorch or a plastic sphere dispenser (PSD). The helitorch uses a gel-like substance (alumi-gel) which is ignited and dispensed from a torch suspended from the helicopter. The PSD uses an apparatus mounted inside the helicopter that disperses individual spheres about 3.8 cm (1.5 in) in diameter; these spheres ignite in a few seconds once on the ground. The use of the PSD method requires a second person, other than the pilot, to operate the PSD machine. Over a thousand hectares (several thousand acres) can be burned per hour using either technique. Each technique has advantages and disadvantages; local experts should be contacted to discuss their use in various regions of the woodpecker’s range.

Aerial ignition requires considerably greater protection of cavity trees than does ground ignition, because aerially ignited fires vary much more in fire intensity. If raking or mowing is used as a method of securing red-cockaded woodpecker cavity trees within an aerial-ignition burn unit, this should be done for a distance of 6.1 m (20 ft) or more from the cavity trees. Even greater distances may be required if the area has not already undergone frequent burning and the habitat requires restoration. In this case, all clusters should be burned using ground ignition before aerial ignition of the larger burning unit.

Restoration Burning and the Reintroduction of Fire

Restoring seriously degraded habitat is perhaps the most challenging application of prescribed fire in the management of red-cockaded woodpeckers, but it can be highly successful if performed with commitment and cooperation. Wade *et al.* (1998) describe four cases in which fire has been successfully reintroduced under seemingly insurmountable circumstances: (1) reintroduction of fire to an area that was not burned for over 50 years; (2) intentional use of a high-intensity stand replacement fire; (3) burning following a major hurricane, and (4) burning within a residential subdivision. Similarly, fuel reduction and restoration of plant communities has been accomplished in many state parks in Florida (Stevenson 1998).

Restoration burns are commonly used to reduce or remove dense hardwood midstories. These burns are usually more intense than other controlled burns, and it is especially important that adequate fire suppression equipment be on site in these instances. Clusters on deep, sandy soils, with a dense hardwood midstory and a sparse accumulation of ground fuels, can be effectively treated with a restoration burn during the growing season. Key to success of this management action is a thorough understanding of fire behavior in those fuel types under a variety of weather conditions. The use of fire for restoration purposes often requires burning under very specific weather parameters including those conditions identified as extreme fire weather conditions. Typically, these parameters include modest to high wind speeds, a low relative humidity, and low fuel moistures. Use of prescribed burns under these conditions requires extensive experience in the application of growing season fire and should only be attempted by experienced burners.

G. HABITAT RESTORATION

Ecological restoration is the process of returning ecosystem properties such as composition, structure, function, and dynamics to altered ecosystems. These properties are restored to within their estimated unaltered natural range of variation or, alternatively, to within ranges of variation that are capable of sustaining desired ecosystem components and processes. Thus, ecosystem restoration is rooted in the understanding and representation of natural variation in communities, ecosystems, and landscapes (White and Walker 1997). Identification of ecosystem composition, structure, function, and dynamics to be restored is achieved through the selection of appropriate reference criteria

(White and Walker 1997). A variety of reference information can be derived from existing reference sites, historical data, and on-site evidence (Meffe and Carroll 1997, White and Walker 1997). However, spatial scale is important in considering natural variation. Restoration should be performed with both regional and local variation under consideration.

For red-cockaded woodpeckers, restoration of good quality habitat is vital to the recovery of the species. Loss of habitat was primary among the original causes of decline (see 1A), and the widespread increases necessary for recovery cannot be achieved without large-scale restoration of habitat. Habitat loss was caused by removal of the original old growth forest, fire suppression, reproductive failure of longleaf pine, and conversion of longleaf and other native, site-appropriate pine species to plantations of off-site species. Methods of site preparation have also substantially altered native groundcovers in woodpecker habitats.

Reintroduction of a fire regime patterned after historic fires is central to the restoration of native southeastern pine ecosystems—that is, habitat for red-cockaded woodpeckers. Prescribed fire should mimic the frequency, intensity, seasonality, and variability of natural historic fire in order to maximize benefits to the fire-adapted species of southeastern pine communities. Restoration of fire to the landscape aids in restoring appropriate habitat structure and species composition. Prescribed fire facilitates the reproduction, growth, and maintenance of longleaf, shortleaf, and other native, site-appropriate pine species, and can reestablish highly diverse native groundcovers. The restoration of these species, in turn, facilitates frequent fire—an important function—in the system. Other important management tools in habitat restoration include thinning to restore historic pine densities; protecting, planting and seeding native, site-appropriate pines and groundcovers; and the use of site preparation methods that minimize soil disturbance.

One problem in specifying desired components and structure for ecosystem restoration is lack of information concerning historic communities and alteration of existing reference sites (White and Walker 1997, Walker 1998). Longleaf pine woodlands have been reduced to less than 5 percent of their original area, and longleaf ecosystems with intact groundcovers are even more rare (Frost 1993). Species lists and structural analyses of remnant longleaf pine ecosystems (e.g. Peet and Allard 1993, Noel *et al.* 1998) are critical. Other ecosystem types supporting red-cockaded woodpeckers, such as shortleaf and native slash pine communities, require further research attention as well. Despite these difficulties, researchers have assembled a body of information that can be used to identify general desired future conditions for southern pine ecosystems supporting red-cockaded woodpeckers. Key components of these conditions include: (1) native, site-appropriate canopy pine species, (2) old growth pines, (3) lower density of canopy pines than in most second and third-growth forests, and (4) healthy forb and bunchgrass groundcovers.

Restoration of Native Canopy Pines

Loss of native pines, especially longleaf but also shortleaf pine, has occurred throughout the range of red-cockaded woodpeckers. Loblolly and slash pines are native to the southeastern United States, but were restricted primarily to mesic sites and were rarely dominant in precolonial forests (White 1984, Christensen 2000). Restoration of native, site-appropriate pines is an important component of red-cockaded woodpecker management and recovery, primarily because these pines provide superior habitat and facilitate critical, frequent fire (Platt *et al.* 1988b). Restoration of native pine communities is a crucial aspect of ecosystem management also (see 3H). Restoration of longleaf pine has been identified as a high priority in the management of national forests. Over 40,000 ha (100,000 ac) of national forests were restored to longleaf pine between 1988 and 1997, a 20 percent increase over 1988 levels (McMahon *et al.* 1998). An additional 140,000 ha (350,000 ac) are to be restored over the next 90 years, representing a future increase of 60 percent over 1988 levels (McMahon *et al.* 1998). Expanded use of growing-season fire is an important part of this restoration program (McMahon *et al.* 1998).

Size of Restoration Areas

An important consideration in the restoration of native, site-appropriate pine species is the size of the area to be restored. Restoration work should not result in impacts to red-cockaded woodpeckers, either through direct loss of habitat or habitat fragmentation (Ferral 1998, F. James, pers. comm.). Clearcuts near active red-cockaded woodpecker clusters or recruitment clusters that are performed for this purpose should be no larger than 16 ha (40 ac), and use of smaller patches are recommended. Clearcuts as large as 32 ha (80 ac) are acceptable if they are at least 1.6 km (1 mi) from active or recruitment clusters.

Restoration Methods

General information about longleaf restoration is presented in Hermann (1993) and Kush (1998), and further details can be obtained from the Longleaf Alliance (Rt. 7, Box 171, Andalusia, AL, 36420; Gjerstad *et al.* 1998). In addition, the USDA Forest Service offers information and incentives to state managers and private landowners considering the restoration of native, site-appropriate pine species through the State and Private Forestry Programs (McMahon *et al.* 1998).

The first step in the restoration of site-appropriate pines to an area currently supporting off-site species is the removal of the off-site pines (typically loblolly and slash, but also Virginia and sand pines) through small clearcuts or group selection. Site preparation (preferably prescribed burning) rids the area of non-merchantable pines and undesirable hardwoods while establishing proper conditions for planting (see below and 8J for further discussions of site preparation). Seedlings or seeds to be planted in the site should be from an appropriate source for the local area to maintain genetic integrity and to enhance the likelihood of success (Schmidtling *et al.* 1998).

Restoration of Historic Pine Densities

Many of today's forests are densely stocked (Boyer and Farrar 1981, Landers *et al.* 1990, Noel *et al.* 1998). Density of pines in historic forests was substantially lower, as estimated from old survey data, travelers' accounts, and current old growth remnants (Foti and Glenn 1991, Masters *et al.* 1995, Noel *et al.* 1998). For example, precolonial densities for shortleaf pine forests in the Ouachita Mountains have been estimated at roughly 8 m^2 per ha (35 ft^2/ac) pine basal area and 6 m^2/ha (25 ft^2/ac) of hardwood basal area (Foti and Glenn 1991, Masters *et al.* 1995). Some old growth forests in rich sites may have carried pine basal areas near 23 m^2/ha (100 ft^2/ac) or more, but the overall structure was open because the individual pines were so large. Not only are second-growth stands more dense than old growth forests, but they typically have lower variability in density across the stand (Noel *et al.* 1998).

In the absence of active management, second-growth forests may not shift toward an old growth structure for decades or even centuries (Noel *et al.* 1998). Second-growth longleaf forests studied by Noel *et al.* (1998) contained an overrepresentation of pines 20.3 to 40.6 cm (8 to 16 in) in dbh, and trees of these sizes were characterized by extremely low mortality and very slow growth. Thus, change in habitat structure was unlikely to occur naturally in the near future. However, researchers and managers are not always sure of the best method or methods to restore appropriate pine densities. Selective removal of small groups of trees is recommended for xeric longleaf forests, but flatwoods longleaf may require more research to develop restoration methods (Noel *et al.* 1998). Prescribed burning, patterned after the historic fire regime, can contribute to long-term restoration of appropriate pine (and hardwood) densities (Noel *et al.* 1998).

Restoration of Native Groundcovers

Longleaf pine ecosystems are famous for their highly diverse groundcovers (Walker and Peet 1983, Simberloff 1993, Peet and Allard 1993, Glitzenstein *et al.* 1998b, Walker 1998). These fire-dependent ecosystems contain nearly one quarter of all the plant species in North America, including high numbers of endemic species (Mitchell *et al.* 2000). Restoring and maintaining this diversity is a primary goal of ecological restoration in the southeast. Native, site-appropriate groundcovers have important benefits to red-cockaded woodpeckers: native grasses are pyrogenic (Platt *et al.* 1988b, Noss 1989), and native groundcovers may support more diverse and abundant arthropods than encroaching hardwoods (Provencher *et al.* 1997, 1998, Collins 1998). Also, an ecosystem approach to managing red-cockaded woodpeckers and their habitat emphasizes the conservation of native, site-appropriate diversity.

Vegetation native to longleaf and shortleaf pine ecosystems may be best restored and maintained through the use of frequent growing season fire. Loss of groundcover diversity in the absence of fire is well documented (Christensen 1981, Ware *et al.* 1993, Peet and Allard 1993, Glitzenstein *et al.* 1998b, Walker 1998), and single fires are not sufficient to restore species diversity (Glitzenstein *et al.* 1998b). Prescribed fire is necessary to remove decades of litter accumulation and expose the mineral soil for seedling germination and early seedling growth (Walker 1998). In addition, prescribed fire opens the forest floor to sunlight, by reducing off-site hardwoods and shrubs and reducing the density and stature of on-site hardwoods and shrubs. Growing season fire stimulates flowering and fruit production of native groundcover plants (Platt *et al.* 1988a, Streng *et al.* 1993). Finally, benefits of fire may be increased by restoring natural variability in the fire regime (Walker 1998).

Hardwood Control

Key to restoration of native groundcovers is the initial control of existing hardwoods. Prescribed burning during early to mid-growing seasons may be the most cost-effective method of reducing hardwoods (Provencher *et al.* 2001b). In situations requiring rapid midstory removal, such as in clusters recently abandoned or supporting only a solitary male because of excessive hardwoods, mechanical and/or chemical methods of hardwood reduction may be in order (Conner 1989, Conner *et al.* 1995, Provencher *et al.* 2001b). However, such methods should be used with extreme caution to minimize disturbance to soils, pine tree roots, and desired native herbaceous species. If chemical and/or mechanical means of midstory reduction are used for rapid hardwood reduction, the area in question should soon be included in a prescribed fire program to restore and maintain appropriate herbaceous groundcovers.

Both herbicides and mechanical methods can result in increased abundance of disturbance-tolerant, ruderal species such as broom sedge (Provencher *et al.* 1998, 1999, 2001). In a study at Eglin Air Force Base, researchers compared three hardwood reduction treatments, including the commonly used herbicide, hexazinone, in a well-replicated large-scale experiment. They found that herbicide use increased disturbance-tolerant species while causing significant declines in common important species such as gopher apple (*Licania michauxii*), dwarf huckleberry (*Gaylussacia dumosa*), little bluestem (*Schizachyrium* spp.) and various legumes (e.g., Florida milk-pea, *Galactica floridana*). Some of these effects still persisted after four years and following the application of growing season fire (Provencher *et al.* 1999). Moreover, effects of herbicides on rare plant species are not known (Litt *et al.* 2000, 2001). In a recent review of all available studies on the impacts of herbicides on vegetation, only two, including Provencher *et al.* (1999), comprehensively documented the effects of herbicides across all species, including rare species (Litt *et al.* 2000, 2001). Litt *et al.* (2000, 2001) concluded that herbicide effects on plant species of management concern generally cannot be evaluated at this time. Use of herbicides to control hardwoods is also discussed in USFS (1989).

Handtools such as chainsaws or brushhooks will have minimal impacts on native species, but excessive use of heavy machinery should be avoided. In one study, repeated passes with a double drum chopper to remove scrub oaks (*Quercus* spp.) killed 50 percent of the existing wiregrass (Outcalt and Lewis 1990). In this same study, single passes with a light single drum chopper had little effect on groundcovers. Roller choppers may have increased effects on mesic sites (Glitzenstein *et al.* 1993). Use of heavy-duty mowers or grinders mounted on rubber-tired tractors may have fewer negative impacts than roller chopping.

With sufficient expertise, prescribed fire can be used to control even serious hardwood problems. Effects of fire vary with its intensity, frequency, and season, and although restoration of the historic fire regime is the desired goal, initial control of hardwoods may require manipulation of fire frequency, intensity, and season beyond those of historic fire (Robbins and Myers 1992). For example, Masters *et al.* (1995), in their recommendations for the reintroduction of fire into the shortleaf pine forests of the McCurtain County Wilderness Area in Oklahoma, called for initial use of dormant season burns to acclimate the old growth pines to fire. These were to be followed by high frequency growing season fires to remove small stems, and then by large-scale fires initiated after longer burn intervals to hasten return to precolonial conditions. Sparks *et al.* (1998, 1999) found late dormant season burns preferable to late growing season burns in reducing hardwood root stock and promoting grasses and forbs. To use fire successfully, managers must have solid understanding of the frequency, intensity, variability, and season of fire necessary to achieve management objectives, and specifically identify these in the planning of a prescribed burning program.

Site Preparation

As mentioned above, mechanical and/or chemical methods of site preparation can have detrimental effects on native groundcover plants (discussed in Glitzenstein *et al.* 1993, Provencher *et al.* 1999). Effects of site preparation methods can vary depending on characteristics of the specific site, especially soil moisture content. In general, mechanical and chemical site preparation increase weedy species, and repeated use can reduce or eliminate native species. Site preparation that leads to soil disturbance will favor more ruderal, weedy, disturbance-tolerant species at the cost of sensitive species (Provencher *et al.* 1998, 1999), and recovery rates for native groundcovers may approach 50 years in xeric soils (Provencher *et al.* 1997, 1998). Windrows and other methods that create piles are among the most destructive of mechanical site preparation methods. Roller chopping may have minimal impacts on xeric sites, especially if light machines are used (described above, Outcalt and Lewis 1990), but may be more damaging on wetter sites. Bracke-mounding has lower impacts than roller chopping. Bracke-mounding is a relatively non-invasive technique by which small mounds rather than plow lines are created to expose the mineral soil. Use of heavy-duty mowers or grinders mounted on rubber-tired tractors may also have lower impacts on soils and tree roots than roller chopping. However, site preparation is best performed using prescribed fire in order to minimize disturbance.

Direct Seeding and Planting

Not all of the desired plant species may return through the use of prescribed fire alone, depending on the degree of habitat alteration and the availability of natural seed sources. Progress has been made in the restoration of specific species using direct seeding and planting. For example, Hattenbach *et al.* (1998) reported successful use of direct seeding of wiregrass and several other groundcover species in the restoration of the Apalachian Bluffs and Ravines Preserve in Florida. Other examples of successful restoration of desired groundcover plants are described by Glitzenstein *et al.* (1998a, 1998b) and Bissett (1998). Researchers stress the need for frequent fire prior to and during restoration efforts to create required conditions for germination and to promote flowering. Direct seeding and planting is a labor-intensive technique conducted at very small scales. Thus, protection of existing native groundcovers should always be the first option.

H. ECOSYSTEM MANAGEMENT

Ecosystem management has been defined in many ways (reviewed by Meffe and Carroll 1997), but its various definitions contain common themes. In general, ecosystem management is an expansion of single-species or traditional management methods to include broader ecological, socioeconomic, and institutional perspectives. Meffe and Carroll (1997), in their review of ecosystem management, have developed the following composite definition:

> Ecosystem management is an approach to maintaining or restoring the composition, structure, and function of natural and modified ecosystems for the goal of long-term sustainability. It is based on a collaboratively developed vision of desired future conditions that integrates ecological, socioeconomic, and institutional perspectives, applied within a geographic framework defined primarily by natural ecological boundaries.

This definition summarizes important aspects of ecosystem management common to various definitions (e.g., Grumbine 1994, Christensen *et al.* 1996), including:

1. *Conservation of biological diversity and ecological integrity.* Targets of conservation include all natural levels of organization, from genes through landscapes; the complex interactions among these levels; natural disturbance regimes; and ecosystem functions. Both natural and modified landscapes have these conservation targets.

2. *Long-term sustainability.* Sustainability, over generations and centuries, is of overwhelming importance. It should always be a clearly identified objective that is incorporated into management planning.

3. *Collaboration.* Successful ecosystem management requires cooperation among federal, state, and local agencies, tribal governments, corporations, and individuals.

4. *Desired future conditions.* Desired future conditions are determined based on historical, ecological, and cultural considerations. This vision should be specifically identified and incorporated into management planning.

5. *Ecological perspective.* Excellent science is a foundation of ecosystem management.

6. *Socioeconomic perspective.* Ecosystem management recognizes that humans are a fundamental component of the natural world, and that conservation must protect human rights as well as biological diversity. Local and indigenous people should be involved in decision-making at the outset and throughout the management process, and impacts of management actions on people must always be evaluated. Excellent social science, therefore, is also a foundation of ecosystem management.

7. *Institutional perspective.* Institutions must be flexible, to respond to changing needs and new information. Flexible administration and legislation that properly reflects human values is the third foundation of ecosystem management.

8. *Natural ecological boundaries.* Precise definitions of ecosystems are not required for ecosystem management; rather, boundaries should reflect some natural border of interest (such as a watershed or mountain range, Meffe and Carroll 1997). Therefore, ecosystem management is generally conducted at larger geographic scales than traditional management. Also, management across political boundaries can be conducted only through cooperative efforts.

9. *Adaptive management.* An important component of ecosystem management not specifically identified in Meffe and Carroll's (1997) definition is its ability to adapt to changing environmental conditions and new information. The fundamental basis of adaptive management is experimental research, complete with adequate reference sites and controls. Adaptive management requires feedback from consistent and intensive biological monitoring, and indicator species must be carefully chosen to reflect management goals.

Ecosystem Management and Red-cockaded Woodpeckers

Current management for red-cockaded woodpeckers is, in many ways, an ecosystem approach. Long-term sustainability is the primary objective of management recommended in this recovery plan, and desired future conditions that will support long-term sustainability are identified herein. Cooperation among federal agencies (specifically, the U.S. Fish and Wildlife Service, the U.S. Forest Service, the U.S. Departments of Defense and Energy, and the National Park Service) is required in the management of core and essential support recovery populations. Cooperation of federal, state, and local agencies, corporations, and individuals is being fostered for the management of red-cockaded woodpeckers on state and private lands. Finally, ecological borders are used for recovery units and form the basis of the translocation strategy.

Moreover, management for red-cockaded woodpeckers provides strong benefits for entire ecosystems. Such benefits are mainly the result of broad-scale prescribed burning programs and broad-scale silviculture that restores open conditions and retains old trees throughout the landscape. In addition, cavities created by red-cockaded woodpeckers or supplied to them through management are used by a host of secondary cavity species. Ecologically, single-species management of red-cockaded woodpeckers merges with ecosystem management for three main reasons: (1) red-cockaded woodpeckers are an indicator species whose population trends can mark the health of southern pine ecosystems (Provencher *et al.* 2001a); (2) red-cockaded woodpeckers are an umbrella species, whose protection provides simultaneous protection for many associated species; and (3) red-cockaded woodpeckers are a keystone species whose presence influences the presence and/or abundance of other species (secondary cavity users) in the community.

However, some aspects of current woodpecker management have not yet been expanded to the level of the ecosystem. One example of current management that is not consistent with an ecosystem approach is management of predation and cavity kleptoparasitism. Managers of several red-cockaded populations have instituted predator and kleptoparasite control programs, but no research has assessed management impacts on these other species or on indirect interactions among community members. Ecosystem management protects viable populations of all native species in the region. More information concerning the population dynamics of predators and cavity kleptoparasites, and their impacts on red-cockaded woodpeckers in general, is required before methods of control can be considered part of an adaptive, ecosystem-based strategy. At present, the U.S. Fish and Wildlife Service is recommending that methods of control be non-lethal, and used only in critically small populations of red-cockaded woodpeckers (see 8G).

The primary example of current management that is not consistent with an ecosystem approach is the continued focus of most management actions, especially prescribed burning and retention of old trees, within the cluster rather than throughout the landscape. Burning and retaining old trees only in small patches provides only limited benefits to other members of southern pine communities. Moreover, such patch-based management has had detrimental effects on red-cockaded woodpeckers as well, including decreased value of foraging habitat (James *et al.* 1997, Walters *et al.* 2000, 2002a), increased cavity damage by pileated woodpeckers (Saenz *et al.* 1998), and increased mortality of cavity trees due to pests such as southern pine beetles (Conner *et al.* 1997a). Fundamental change in the scale of prescribed burning and beneficial silvicultural practices is required for both ecosystem management and the recovery of red-cockaded woodpeckers.

Some management actions must continue to be applied at the level of individual territories or aggregations of territories rather than at a landscape scale. That is, some aspects of single-species management continue to be critical to the recovery of red-cockaded woodpeckers. Chief among these are cavity management (see 8E), establishment of strategically placed recruitment clusters (8B), and translocation (8H). Predator and cavity kleptoparasite control is a single-species management technique also, but it differs from those listed above in that it can potentially disrupt natural ecosystem processes and impact other native species.

Thus, at present red-cockaded woodpeckers are best managed with a combination of single-species and ecosystem management. In addition, other members of southern pine communities benefit substantially from such management. Once red-cockaded woodpeckers attain recovery, single-species methods may not be required. Currently, we hope that ecosystem management by itself, including continued monitoring of red-cockaded woodpeckers, will provide long-term sustainability for all members of southern pine communities. However, at this time we simply do not know what management will be needed after delisting. Our understanding of future management needs will increase as the species recovers.

4. CURRENT STATUS AND CONSERVATION INITIATIVES

A. PRIVATE LANDS

Conservation of red-cockaded woodpeckers on privately owned lands is an important part of species recovery (Costa 1995b, 1997, Bonnie and Bean 1996, Bonnie 1997), although primary support for recovery is provided by federal properties (4C). Red-cockaded woodpeckers on private lands have inherent ecological, cultural, and historical value. Groups and populations of red-cockaded woodpeckers on private lands also have substantial value as reservoirs of genetic resources, sources of immigration for other populations, and as stepping stones to facilitate dispersal between other populations. In addition, prior to species recovery, many populations on private lands will have a key role in translocation programs, as either donors or recipients of red-cockaded woodpeckers. Currently, 23 percent of all red-cockaded woodpecker groups are located on private lands. However, other than the prohibition against take (below), nothing in the Endangered Species Act requires private landowners to participate in active conservation. Thus the role of private landowners in species recovery is important but voluntary.

The voluntary nature of active conservation on the part of private landowners has some benefits. Private lands conservation arising from local participants can be more meaningful and longer lasting than attempts at regulating private land use by federal authorities. The most successful conservation programs are those that strike a balance between voluntary participation and federal control. For endangered species, private landowners require a mechanism for resolving land use conflicts; however, mitigation to help offset adverse impacts to listed species must be adequate and federally supervised (Bean and Wilcove 1997). Flexibility, with appropriate boundaries, can foster genuine conservation interest on the part of local landowners and reduce the resentment that is a common result of enforcement of federal regulations (Bean and Wilcove 1997, Bonnie 1997). For example, volunteer participants in Safe Harbor programs (below) have shown increased concern for red-cockaded woodpeckers on their lands (Bonnie 1997). Raising awareness, incentives, and the removal of disincentives are key factors facilitating the rise of conservation among private individuals (USFWS 1979, 1985, Bonnie and Bean 1996, Kennedy *et al.* 1996).

These benefits of voluntary conservation were recognized, encouraged, and incorporated into a private lands conservation strategy by the U.S. Fish and Wildlife Service during the 1990's (Costa 1995b; described below). Some early efforts may have fallen short of conservation goals (Bonnie 1997), but with continual improvements the private lands conservation strategy of the U.S. Fish and Wildlife Service has shown remarkable success.

The Endangered Species Act and Private Landowners

Federal law does not require private landowners to participate in the recovery of threatened and endangered species but does prohibit their 'take' (Section 9a of the Act). The term, take, means to "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct" (Section 3.18 of the Act). Habitat destruction and alteration may be considered forms of take where they are the proximate and foreseeable cause of death or injury to members of the species, following a Supreme Court ruling on this issue (Sweet Home vs. Babbitt). The Endangered Species Act does provide a mechanism for take of endangered species on private lands if that take is "incidental to, and not the purpose of, the carrying out of an otherwise lawful activity" (Section 10a of the Act). Incidental take may be permitted by the U.S. Fish and Wildlife Service only after the applicant submits a detailed Habitat Conservation Plan (HCP) that includes steps to be taken to minimize and mitigate impacts from the proposed actions (Section 10a). Thus, the U.S. Fish and Wildlife Service has formulated guidelines for mitigation of impacts to red-cockaded woodpecker groups (below). Still, incidental take permits are issued rarely, because generally alternatives to incidental take exist, and the Act requires the evaluation of alternatives and their use if appropriate (Section 10a). Federal properties are not involved in the incidental take permitting process, but rather must consult with the U.S. Fish and Wildlife Service on proposed actions that may have the potential to result in incidental take (Section 7a of the Act).

Recent Trends and Current Status

Despite continued protection under the Endangered Species Act, the decline and local extirpation of red-cockaded woodpeckers on private lands has been well documented across their range. Reports from North Carolina (Carter 1974, 1990, Carter *et al.* 1983, 1995), South Carolina (Cely and Ferral 1995), Georgia (Baker 1981, 1995), Arkansas (James and Neal 1989), Texas (Ortego and Lay 1988), Florida (Baker 1983), and range wide (Thompson 1976, Ligon *et al.* 1986, James 1995) show declines and local extirpations into the early 1990's. These losses are the result of a variety of factors including loss and fragmentation of habitat, fire suppression and resultant changes in habitat structure, and vulnerability to environmental and demographic stochasticity because of small population size. Currently, there are 1296 known active clusters on private lands in 11 states (Costa and Walker 1995, USFWS unpublished), and the existence of up to 280 additional groups is considered likely.

The Private Lands Conservation Strategy

The private lands conservation strategy was developed by the U.S. Fish and Wildlife Service in response to the realization that red-cockaded woodpeckers on private lands were important to the recovery of the species, and that their loss was a significant biological problem (Costa 1995b, 1997). Moreover, the U.S. Fish and Wildlife Service recognized that conservation of red-cockaded woodpeckers on private lands would require a multi-faceted approach based on conservation science and innovative conservation partnerships (Costa 1995b, 1997). The strategy has been aggressively implemented, modified as necessary based on new scientific findings, and regularly evaluated to ensure goals are being achieved. Five primary objectives of the private lands strategy are to (1) increase the acreage of private land under management for red-cockaded woodpeckers; (2) maintain or increase the larger populations on private lands, (3) establish healthy, spatially aggregated, and protected groups of woodpeckers to offset losses, (4) foster and develop corporate partnerships between and among federal, state, and private parties responsible for and interested in red-cockaded woodpecker recovery and (5) increase, via translocation, the size of populations on state and federal lands (Costa 1995b). This last objective does not imply that federal properties are appropriate mitigation sites, but private lands do occasionally contribute birds to public properties as part of the regional translocation strategy.

The implementation of the private lands strategy between the U.S. Fish and Wildlife Service and private land conservation partners since 1992 has helped to slow, stabilize, and in some cases reverse population declines among woodpeckers on privately owned lands. It has resulted in significantly increased protection for many woodpecker groups and their habitat on privately owned lands, and raised the possibility that such protection can become the normal standard rather than the exception. Finally, the private lands strategy has resulted in the creation of strong and effective partnerships with a multitude of diverse partners. Currently, 509 red-cockaded woodpecker groups on 140,608 ha (347,439 ac) of private lands are protected, in agreements involving 139 private landowners. These agreements provide protection for 40 percent of the known red-cockaded woodpeckers on private lands. Additionally, several landowners in signed and pending agreements have agreed to increase their existing populations. These increases could result in 71 additional groups.

The development of the private lands strategy began in the early 1990’s, with initial attempts to protect woodpeckers on forest industry lands (Costa 1995b). In 1992, the first Memorandum of Agreement (below) was signed with an industrial forest landowner in an effort to protect approximately 90 groups in Arkansas and Louisiana (Wood and Kleinhofs 1995). Seven other Memoranda of Agreement followed (Costa 1997). These are 'no-take' agreements under which a corporation agrees to protect occupied habitat and conduct some habitat management (Bonnie 1997, Costa 1997). Since 1995, the U.S. Fish and Wildlife Service has shifted from Memoranda of Agreement to Habitat Conservation Plans (HCPs; Bonnie 1997, Costa 1997), in which incidental take of existing and/or future woodpecker groups is permitted in exchange for management of occupied and unoccupied habitat. Habitat Conservation Plans, authorized under Section 10 of the Endangered Species Act, can involve a variety of landowners, including timber and other corporations, private citizens, and developers. Two forms of HCPs currently exist: individual plans and statewide plans. More recently, Safe Harbor agreements have become the primary tool for conservation of red-cockaded woodpeckers on private lands (Bonnie 1997, Costa and Kennedy 1997, Costa 1999, Costa *et al.* in press).

Memoranda of Agreement

Memoranda of Agreement (MOAs) are legal conservation agreements between the U.S. Fish and Wildlife Service and corporate landowners. The agreement outlines management actions by which the corporation can satisfy responsibilities under the Endangered Species Act and the U.S. Fish and Wildlife Service's guidelines for habitat management, and meet corporate objectives for land management. These management actions typically include population monitoring, management and retention of current and future nesting habitat, maintenance of adequate foraging habitat, and research and educational initiatives. Several MOAs also include state or other federal agencies as cooperators. Motivation to enter into such agreements includes reduced risk of litigation, prestige and satisfaction associated with conservation efforts, and consolidation of populations and responsibility (Costa and Edwards 1997). Currently, over 12,990 ha (32,100 ac) of habitat and 83 active woodpecker clusters are managed under Memoranda of Agreement.

Individual Habitat Conservation Plans

Individual Habitat Conservation Plans allow the 'incidental take' of red-cockaded woodpecker groups with mitigation, as authorized under the Endangered Species Act. Both the plan and the associated mitigation are funded by the landowner. Early HCPs for individual landowners were criticized because the mitigation required was not considered sufficient to offset the permitted loss of groups (Bonnie 1997). These critics correctly identified two major faults of early mitigation efforts. First, occupation of the newly established clusters was not assured. Second, the creation of clusters on federal properties did not truly mitigate damage to privately owned clusters, because federal agencies are already required to conserve (recover) their populations. In response to these criticisms, the current policies governing the use of mitigation (below) require that one occupied cluster be established for each active cluster harmed or removed. In addition, new groups are established on private lands when possible (below).

TABLE 5. Number of active red-cockaded woodpecker clusters (ACT, 2000) on private properties that harbor or are capable of harboring ten or more active clusters and are currently under partnerships with the U.S. Fish and Wildlife Service. These properties are all designated significant support populations (see 7). Also listed are the property owners, property population goal, and type of agreement.

Property (State)	**Owner**	**ACT 2000**	**Goal**	**Type[1]**
Arcadia Plantation (SC)	Private Landowner	11	11	SH
Avalon Plantation (FL)	Turner Endangered Species Fund	7	25+	MOA
Bates Hill Plantation (SC)	Private Landowner	12	12	SH
Brookgreen Gardens (SC)	Brookgreen Gardens	6	10	SH[2]
Brosnan Forest (SC)	Norfolk Southern Railroad	75	100	SH
Brushy Creek (TX)	International Paper	3	20	SH
Calloway Tract (NC)	The Nature Conservancy	5	10	SH
Crossett Forest (AR/LA)	Plum Creek Timber Company	82	92	MOA
Curtis H. Stanton Energy Center (FL)	Orlando Utilities	7	10	----
Friendfield Plantation (SC)	Private Landowner	10	14	SH
Good Hope Plantation (SC)	Private Landowner	12	12	SH
Hobcaw Barony (SC)	B. W. Baruch Foundation	23	23	SH
J. W. Jones Ecological Research Center (GA)	Ichauway, Inc.	6	10+	SH
Medway Plantation (SC)	Private Landowner	14	14	SH
Palmetto-Peartree Preserve (NC)	Conservation Fund	25	25+	CE
Piney Grove Preserve (VA)	The Nature Conservancy	3	10+	SH
Plum Creek Conservation Area (AR)	Plum Creek Timber Company	26	30	HCP
Potlach Corporation Lands (AR)	Potlach Corporation	20	30	HCP
Prince George (SC)	Prince George Foundation	3	10	SH
Red Hills (GA/FL)	Various Landowners	180	180	SH[3]
Scrappin' Valley (TX)	Temple Inland Corporation	8	14	SH
Southern Pines/Pinehurst (NC)	Various Landowners	47	47	SH
Southlands Experimental Forest (GA)	International Paper	8	30	HCP
TOTAL: 22 Properties in 8 States		**588**	**729**	

[1]Safe Harbor (SH), Memorandum of Agreement (MOA), Conservation Easement (CE), or Habitat Conservation Plan (HCP). See text for more detail.

[2] Pending.

[3] Over 30 landowners harbor 180 active clusters, some of which are enrolled in Safe Harbor, some are pending enrollment, and more enrollments are anticipated.

Since 1995, the U.S. Fish and Wildlife Service has authorized ten incidental take permits for non-industrial forest landowners. Under these permits, 27 groups of red-cockaded woodpeckers may be impacted or removed, pending completion of mitigation. Mitigation for these groups includes the probable establishment of 52 new groups through creation of recruitment clusters and/or translocation of juveniles to unoccupied clusters (Costa 1997).

The U.S. Fish and Wildlife Service has also issued three individual HCPs for industrial forest landowners. These plans provide current protection for 64 groups and potential long-term protection for 90 groups of red-cockaded woodpeckers.

Statewide Habitat Conservation Plans

Currently, statewide Habitat Conservation Plans (not including statewide Safe Harbor, below) permit the incidental take of demographically isolated groups only. Defining demographic isolation for this purpose is not an easy task. It is known that isolation of red-cockaded woodpecker groups results in decreased likelihood of group survival. However, research into the isolation of groups has been designed to identify spatial arrangements that increase population persistence, not to identify a statewide standard for incidental take (Bonnie 1997). Establishing a threshold measure of isolation above which groups would be available for statewide incidental take is a matter of some debate, and requires further research attention.

Safe Harbor

The Safe Harbor program has been an immense success for both landowners and red-cockaded woodpeckers (Bonnie 1997, Costa 1997, 1999, Costa *et al.* in press). Red-cockaded woodpecker Safe Harbor permits have been issued for the sates of Texas, South Carolina, and Georgia, the six-county Sandhills region of North Carolina, and a Nature Conservancy preserve in Virginia (Lohr 2000, Costa *et al.* in press). Louisiana and Alabama have draft plans, Florida has initiated the plan development process, and two individual landowners in Florida and Mississippi are working on agreements with the U.S. Fish and Wildlife Service (Costa *et al.*, in press). Under a Safe Harbor agreement, a landowner agrees to actively manage nesting and foraging habitat (i.e., a safe harbor) for the number of active red-cockaded woodpecker clusters equal to those present when the agreement is initiated (i.e., the baseline). Landowners must also agree to enhance existing habitat and/or improve additional potential woodpecker habitat, typically through the use of prescribed fire and cavity management. In turn, the landowner receives an incidental take permit, authorizing a land use change, for any additional woodpecker groups that may occupy the property in the future as a result of beneficial management practices. Thus, private landowners are free to manage their properties with prescribed fire, thinnings, lengthened timber rotations, or other actions that may benefit red-cockaded woodpeckers without fear of additional land-use restrictions.

Eligible landowners enrolled in Safe Harbor agreements may choose to enter into mitigation banking (below), and increase their baseline in exchange for a mitigation fee. This can be a powerful incentive for private landowners to join a Safe Harbor program and aggressively manage their lands for red-cockaded woodpeckers (Bonnie and Bean 1996, Kennedy *et al.* 1996, Costa and Kennedy 1997). Mitigation banks can be established only by following the guidelines presented below.

As of 2001, 191 groups, 48 landowners, and 58,005 ha (143,272 ac) in South Carolina, 50 groups, 53 landowners, and 14,354 ha (35,455 ac) in North Carolina, 17 groups, 19 landowners, and 6,029 ha (14,891 ac) in Texas, 8 groups, 3 landowners, and 13,142 ha (32,461 ac) in Georgia, and 3 groups, 2 landowners, and 734 ha (1,812 ac) in Virginia were enrolled in Safe Harbor agreements (Costa *et al*. in press). Many of these groups provide important support for nearby recovery populations.

Mitigation

No Net Loss of Groups

The philosophy guiding mitigation policy is that there be no net loss of red-cockaded woodpecker groups, and a primary objective is to assure that the status of the species as a whole is better following mitigation than before. Mitigation of impacts to red-cockaded woodpeckers is generally achieved through the establishment of a woodpecker group in another location, for every group that is affected by the proposed action. In general, the minimum required ratio of newly established to impacted groups is one to one. For the ten HCP permits issued to date, this ratio has been two to one (Costa 1997). Preservation credits, discussed below, are an exception to the required one to one ratio.

Mitigation Site

The location in which new groups are established is known as the mitigation site. This term refers to both the actual recruitment clusters and the population that contains the newly established groups. Four factors are important to the choice of mitigation sites: geographic location, ownership class (i.e., prior commitment to recovery), degree of protection in place, and amount of available habitat (i.e., maximum future population size). Mitigation within the recovery unit is preferred, to serve ecological goals and reduce costs. However, the Fish and Wildlife Service may approve mitigation outside recovery units on a case-by-case basis.

The first priority for ownership class of mitigation sites is private and state lands. When all opportunities to mitigate on private and state lands within the above geographic restrictions have been exhausted, federal lands shall be considered. Mitigation on federal properties will be conducted only if it is the sole appropriate option within the recovery unit. In general, the use of federal properties as mitigation sites for impacts on private lands is strongly discouraged. Additionally, the U.S. Fish and Wildlife Service prefers that mitigation sites have a degree of protection greater than that of impacted groups.

Mitigation sites must have sufficient habitat to support at least 10 groups of red-cockaded woodpeckers in territories that are aggregated, not isolated, in space. Only with a highly aggregated spatial structure do populations of 10 woodpecker groups have any reasonable chance of persisting over periods of 20 years or more (Crowder *et al.* 1998, Walters et al. 2002b). Mitigation sites may consist of multiple, adjacent properties under private or state ownership. Potential mitigation sites directly adjacent to red-cockaded woodpecker populations on federally owned lands may qualify even if the site has a capacity of less than 10 groups, providing the site and federally owned population has a combined capacity of 10 or more groups.

Mitigation Groups

Mitigation groups are those newly established in exchange for permission to impact groups, on a one-to-one basis as discussed above. Mitigation groups must have equivalent breeding status as impacted groups. In other words, if an impacted group consists of a solitary male, then only a solitary male needs to be established for mitigation, but if an impacted group consists of a potential breeding group, then a potential breeding group must be established as the mitigation group. Helpers do not need to be "replaced".

Mitigation groups are typically established prior to the impact on existing groups. However, incidental take may occur prior to successful mitigation if legally binding implementation agreements and performance bonds are in place. A mitigation group is considered established if evidence of breeding is detected or if the same potential breeding group or solitary male remain in the mitigation cluster for six months including a breeding season (April – July).

Mitigation Credits, Mitigation Banks, and Preservation Credits

Several tools to facilitate mitigation exist, including mitigation credits, mitigation banks, and preservation credits. A mitigation credit is earned once a mitigation group has been established (one credit is equal to one group), and is used by impacting an existing group. A mitigation credit can be used immediately after earning or stored in a mitigation bank to be used in the future. Mitigation credits stored in a bank can also be made available for sale to third parties requesting a permit to impact an existing group or groups. A mitigation bank is the mitigation site in which new groups are established. Guidelines for mitigation sites (above) apply to mitigation banks. Mitigation banks may be owned by a single or multiple landowners, but must have approved habitat management plans including regular prescribed burning and cavity management in place.

Finally, a preservation credit is earned by increasing the protection of one to three existing groups in exchange for the incidental take of one group. Increased protection may take the form of private land conservation easements, direct land acquisition, and subsequent transfer to protected/managed public land agencies or other conservation programs that ensure protection, but must be in place for perpetuity. In addition, preservation groups must benefit from population monitoring and habitat management, including frequent prescribed burning (8K), cavity and cluster management (8E, 8F), and provision of foraging habitat that meets the recovery standard (8I). Perpetual protection of one to three groups in excellent habitat in exchange for the loss of one group is considered an improvement in the conditions faced by red-cockaded woodpeckers as a whole, in agreement with the overall objective of mitigation policy.

The specific ratio for preservation credits is determined on a case-by-case basis. Variables used to calculate this ratio include location, population size, trend, viability, and ownership, forest type, breeding status, and available foraging habitat. The final ratio is based on a careful comparison of the status of these variables for both the impacted population and the mitigation site. These variables are used to ensure that the biological value of the group being impacted is replaced or improved upon by the mitigation group.

Funding for Mitigation

Mitigation is funded by the landowner performing the action that will impact woodpecker groups. Mitigation costs include a management endowment sufficient to cover habitat management, such as prescribed burning, for the mitigation groups for 5 years (one full generation for red-cockaded woodpeckers). Other costs include the initial provisioning of cavities and initial midstory control in the recipient cluster as well as the costs of translocating juvenile birds to create mitigation groups and translocating resident adults from affected clusters upon successful mitigation.

Other Incentive Programs

Several programs other than Safe Harbor Agreements are available to assist private landowners in management of their lands, but unlike Safe Harbor these are not designed directly for red-cockaded woodpeckers. However, programs that could potentially benefit woodpeckers are available through the Farm Services Agency, Natural Resources Conservation Service, U.S. Fish and Wildlife Service, and state forestry and wildlife agencies. Local offices of the administering agency or organization should be contacted for information about future sign-ups and eligibility requirements.

Farm Service Agency

The Conservation Reserve Program offers annual rental payments and cost-share assistance to plant permanent areas of grass and trees on land that is subject to erosion, and to improve soil, water, and wildlife resources. Assistance for up to 50 percent of costs is available for the 10 to 15 year contracts. This program is most applicable to agricultural lands. However, some management practices implemented under these programs could benefit red-cockaded woodpeckers.

Natural Resources Conservation Service

Landowners who participate in the Wetlands Reserve Program may sell a conservation easement or enter into a cost-share restoration agreement to restore and protect wetlands. Landowners receive financial incentives to enhance wetlands in exchange for retiring marginal agricultural land. In addition to farmland, eligible lands include production forestland where hydrology has been altered, riparian areas that link protected wetlands, and lands adjacent to protected wetlands that contribute significantly to wetland functions and values. The program offers landowners three options: permanent easements, 30-year easements, and restoration cost-share agreements of at minimum 10-year duration. Landowners continue to control access to the land—and may lease the land—for hunting, fishing, and other recreational activities requiring no development.

The Wildlife Habitat Incentives Program is designed to help private landowners develop and improve wildlife habitat on their lands. Participating landowners work with the Natural Resources Conservation Service to prepare a wildlife habitat development plan in consultation with the local conservation district. The plan describes the landowner’s goals for improving wildlife habitat, a list of practices, a schedule for installing them, and steps necessary to maintain the habitat for the life of the agreement. The participant enters into a cost-share agreement usually lasting at least 10 years. The landowner agrees to maintain the cost-shared practices and allows monitoring to judge the effectiveness of the practice. The U.S. Department of Agriculture agrees to provide technical assistance and pay up to 75 percent of the cost of identified practices.

The Environmental Quality Incentives Program is for farmers and ranchers who face serious threats to soil, water, and related natural resources. The program offers financial, educational, and technical help to install or implement structural, vegetative, and management practices called for in 5 to 10-year contracts. Eligible lands include cropland, rangeland, pasture, forestland, and other farm or ranch lands where the program is delivered. Cost-sharing may provide up to 75 percent of the funds for certain conservation practices.

The Forestry Incentives Program is intended to assure the nation's ability to meet future demand for sawtimber, pulpwood, and quality hardwoods. The program pays cost sharing of up to 65 percent (with a limit of $10,000 per person per year) for tree planting, timber stand improvement, and site preparation for natural regeneration. The state forester provides technical advice in developing a management plan and helps find approved vendors, if needed, for completing the work. Private, non-industrial landowners who own less than 4,047 ha (1,000 ac) are eligible to participate in the program. However, this program is available only in selected counties.

U.S. Fish and Wildlife Service

The Partners for Wildlife Program provides technical and financial assistance to private landowners that are restoring and enhancing fish and wildlife habitat. Program emphasis is on restoration of historic vegetation and hydrology. Seventy percent of the project area must reflect the historic vegetation and hydrology while 30 percent may consist of wildlife enhancement activities. Landowners must sign a minimum of 10-year agreement for some projects, and a 25-year agreement for restoration projects.

State Forestry Agencies

The Forestry Stewardship Program is intended to stimulate management of non-industrial, private forestland using multiple-use concepts. This technical assistance program provides management recommendations to fit the landowner's objectives for forest management. Wildlife habitat, water quality, and soil protection are examples of objectives that can be incorporated into the landowner's management plan. The Stewardship Incentives Program is intended to reimburse landowners for 75 percent of the cost of certain forest management practices, including those intended to improve habitat for endangered species. However, cost-share funding through the Stewardship Incentives Program is currently unavailable in many states.

State incentive programs administered by the respective state forestry agencies often emphasize reforestation. Through reforestation, however, other objectives of the landowner, such as creation or enhancement of habitat for red-cockaded woodpeckers, can be addressed. Some state wildlife agencies also administer incentive programs. Examples include Kentucky's Habitat Improvement Program and Arkansas' Acres for Wildlife Program. Not all state forestry or wildlife agencies within the range of the red-cockaded woodpecker offer incentive programs.

B. STATE LANDS

Status and Distribution

As of 2000, there were an estimated 631 active clusters of red-cockaded woodpeckers on 44 state-owned properties in 7 states (USFWS, unpublished; Table 6). Largest concentrations of woodpeckers on state lands occur in Florida, North Carolina, and South Carolina.

During the 1970's, Jackson (1978b) found that approximately 300 clusters, or 8.6 percent of all reported clusters, were located on lands owned by state or local governments. These clusters were distributed across ten states, with the largest concentrations occurring in Florida and South Carolina. Seven of the remaining eight states had less than 12 clusters on state or local lands. Costa and Walker (1995) estimated that 384 active clusters occurred on state lands in 8 states. Although it is clear that several states have, by 2000, lost all woodpeckers on state lands, comparison of current population sizes with those from the 1970's is hampered by inconsistent survey techniques and increasing survey effort across time (Cely and Ferral 1995, Ortego *et al.* 1995, J. Cely, pers. comm.).

Conservation of woodpeckers on state lands is improving, but much progress remains to be made. Habitat management plans, including population goals, have not yet been established for all state lands. Through interviews with state land managers and biologists, J. Hovis (pers. comm.) found that most state agencies have implemented a prescribed burning regime on their lands inhabited by red cockaded woodpeckers. Beyond this, however, the level of management and population monitoring varies considerably both within and among states. For example, some state lands have never been surveyed completely for cavity trees, whereas others have been surveyed but the demography of the resident red-cockaded woodpecker population is unknown. Today, only a few populations on state lands have been intensively managed and/or monitored on a long-term basis. These include the McCurtain County Wilderness Area in Oklahoma (M. Howery, pers. comm.), the Sandhills Game Lands in North Carolina (Walters *et al.* 1988a), and the Sand Hills State Forest in South Carolina (Ferral 1998).

Recovery Role

State lands can contribute to the recovery of the red-cockaded woodpecker in numerous ways. Some state lands will contribute by being part of a designated recovery population. For example, in North Carolina the Holly Shelter Game Lands is part of a primary core population and the Sandhills Game Lands is part of an essential support population. In South Carolina, the Sand Hills State Forest is part of a secondary core population. Several state properties in South/Central Florida are designated essential support populations (see 7). Other state lands throughout the range of red-cockaded woodpeckers contribute to the conservation and recovery of the species as significant and important support populations (see 7).

Finally, state lands can contribute to recovery as mitigation sites (see 4A). Through the mitigation process, red-cockaded woodpecker populations on state lands could be enhanced or restored. Establishing state lands as mitigation sites, however, would require a commitment from the state agencies involved to monitor and manage their woodpecker populations on a long-term basis. Unfortunately, many state agencies have neither the personnel nor funds required to fill such a commitment. Although mitigation monies could be used to finance some management and monitoring activities,

TABLE 6. Number of active red-cockaded woodpecker clusters (ACT, 2000) on state properties, by state. Also listed is estimated potential size (number of active clusters). Except where noted, potential size is based on an agency estimate or property goal identified in a draft or approved red-cockaded woodpecker management plan, or submitted in an Annual Report (2000).

State	Property Full Name	ACT 2000	Potential Size[2]
Arkansas	Pine City Natural Area	1	2[1]
	subtotal	1	2
Florida	Babcock/Webb Wildlife Management Area	27	240[1]
	Blackwater River State Forest	26	≥45
	Camp Blanding Training Site	14	25
	Central Florida Reception Center – South Unit	1	1[1]
	Goethe State Forest	30	150
	Hal Scott Preserve	7	15[1]
	J. W. Corbett/Dupuis Wildlife Management Area	13	90[1]
	Kicco Wildlife Management Area	1	1[1]
	Ochlockonee River State Park	3	3[1]
	Picayune Strand State Forest	3	25[1]
	Platt Branch Mitigation Park	4	7[1]
	St. Sebastian River State Buffer Preserve	8	25
	Tate's Hell State Forest	29	400[1]
	Three Lakes Wildlife Management Area	51	125[1]
	Withlacoochee State Forest - Citrus Tract	46	100
	Withlacoochee State Forest - Croom Tract	5	30
	subtotal	268	1282
Louisiana	Alexander State Forest	5	5
	subtotal	5	5
North Carolina	Bladen Lakes State Forest	3	3[1]
	Holly Shelter Game Lands	38	38
	Johnston Community College	1	1
	Jones Lake State Park	1	4
	McCain Tract	5	7
	Sandhills Game Lands	134	160
	Singletary Lake State Park	4	6
	Weymouth Woods State Nature Preserve	7	13
	subtotal	193	232
Oklahoma	McCurtain County Wilderness Area	12	44
	subtotal	12	44

Table continued next page.

TABLE 6 (cont.). Number of active red-cockaded woodpecker clusters on state properties.

State	Property Full Name	ACT 2000	Potential Size[2]
South Carolina	Cheraw State Fish Hatchery	1	1
	Cheraw State Park	7	25
	Hampton Plantation State Park	1	1[1]
	Lewis Ocean Bay Heritage Preserve	2	10[1]
	Longleaf Pine Heritage Preserve	2	4[1]
	Manchester State Forest	3	3[1]
	Persanti Island	3	3[1]
	Sand Hills State Forest	51	~143[1]
	Sandy Island	32	35[1]
	Santee Coastal Reserve	8	16
	Santee State Park	1	7[1]
	Webb Wildlife Center	12	30[1]
	Wedge Plantation	2	2[1]
	Yawkey Wildlife Center	8	15[1]
	subtotal	133	295
Texas	Huntsville State Fish Hatchery	1	1[1]
	I. D. Fairchild State Forest	4	7
	W. G. Jones State Forest	14	14
	subtotal	19	22
	TOTAL	**631**	**1882**

[1]Potential size based on U.S. Fish and Wildlife Service or responsible agency's estimate derived by dividing the area of currently or potentially suitable upland pine on the property by 81 ha (200 ac) per cluster.

[2] Except for those potential sizes identified as goals in approved agency management plans, all other potential population sizes are non-binding and subject to change pending approval of site-specific management plans.

long-term programs on state lands will require additional funding. Accordingly, state agencies should be encouraged to seek Section 6 funds through the U.S. Fish and Wildlife Service to initiate or enhance their activities on state lands with red-cockaded woodpeckers.

Conservation of Biodiversity within States

Whereas recovery of red-cockaded woodpeckers as a species is founded on distribution of large populations throughout the species range, biologists and managers working at the state level must set priorities for conservation of biodiversity based on political (state) boundaries. We emphasize that small populations with a minor designated role in species recovery may be critical in conserving biodiversity at the state level.

C. FEDERAL LANDS

Conservation of red-cockaded woodpeckers as a species depends primarily on the conservation of populations on federal lands, for several reasons. First, the vast majority of red-cockaded woodpeckers in existence today are on federal lands (Costa and Walker 1995, James 1995; see Table 7). Second, federal properties contain most of the land that can reasonably be viewed as potential habitat for red-cockaded woodpeckers (USFWS 1985). Third, existing legislation, especially the Endangered Species Act (Section 7) but also the National Forest Management Act and others, require that federal agencies conserve listed species and maintain biodiversity within their lands. In the Endangered Species Act (Section 3), conservation is defined as "the use of all methods and procedures necessary to bring an endangered species or threatened species to the point at which the measures provided pursuant to this act are no longer necessary." Thus, to the extent that legislation reflects public perception, it is the public's view that recovery of endangered species and conservation of biodiversity is a responsibility of the federal government to be conducted primarily on publicly owned lands under federal control. This is a difficult task, as it requires the protection of biodiversity at or near precolonial levels on minute remnants of the habitat base. Private landowners can contribute substantially to conservation, but such contributions above the required protection against direct harm (take) are voluntary (see 4A).

Federal properties supporting populations of red-cockaded woodpeckers include national forests, military installations, national wildlife refuges, a national preserve, and a Department of Energy property. As of 2000, there were an estimated 3698 active clusters of red-cockaded woodpeckers on 55 federally owned properties in 9 states (USFWS, unpublished; see Table 7). National forests support the majority of core woodpecker populations required for delisting and therefore have a uniquely important role in the recovery of red-cockaded woodpeckers. Second to national forests in recovery importance are the military installations. National wildlife refuges have a smaller but important role in woodpecker recovery, as do the remaining occupied federal properties.

National Forests

Current Status and Trends

Currently, there are 24 populations of red-cockaded woodpeckers partly or wholly supported by national forests (see map insert and Table 7), ranging in size from 6 active clusters (Shoal Creek Ranger District of the Talladega National Forest) to 486 active clusters (Apalachicola Ranger District, Apalachicola National Forest). An additional national forest property, the Talladega Ranger District of the Talladega National Forest, currently harbors no active clusters but red-cockaded woodpeckers will soon be re-established there. The Apalachicola Ranger District, together with the Wakulla Ranger District and other adjoining properties, supports the largest woodpecker population in existence (665 active clusters; see 7, Table 8).

Numbers of active clusters on national forest properties over the past three years are presented in Table 7. Most populations on national forests appear to be stable or increasing, and a few are in decline. In contrast, most populations on national forests were declining until the mid 1980's, and a few were stable (Costa and Escano 1989). Management efforts during the past decade, especially prescribed burning and cavity management, have stabilized most of these populations and led to increases in many. It is very encouraging that the widespread declines have been stabilized. Our challenge now is to increase the populations to sizes necessary for species recovery.

Recent declines have occurred on four national forest properties. On the Talladega Ranger District, the Kisatchie Ranger District, and the Francis Marion National Forest, poor habitat resulting from lack of fire and suitable cavities is considered the primary factor in these recent declines (R. Costa, pers. comm.). The decline in the Vernon Unit, Calcasieu Ranger District is surprising, given the apparent health of the population and its habitat. The reason for this decline is not presently known, but may be the result of differences in field survey and census methods over time, and/or record keeping. Each of these populations has a substantial role in recovery (below, Table 7; see also 7, Table 8) and these declining trends must be reversed.

Role in Recovery

National forests have a vital role in recovery of red-cockaded woodpeckers, because most core populations within recovery units (see 7) are located in national forests. National forests (or ranger districts) containing all or part of a primary core population are the Angelina, Apalachicola (Apalachicola and Wakulla Ranger Districts), Bienville, Croatan, Francis Marion, Kisatchie (Vernon Unit of the Calcasieu Ranger District), Osceola, Sabine, and Sam Houston. Each of these national forests (or ranger districts) will support a population of at least 350 potential breeding groups at the time and after the species is recovered. National forests (or ranger districts) containing all or part of a secondary core population are the Catahoula, Conecuh, Davy Crockett, DeSoto (Chickasawhay and DeSoto Ranger Districts, separately), Homochitto, Oconee, Ouachita, and Talladega (Oakmulgee Ranger District). Each of these national forests (or ranger districts) will support a population of at least 250 potential breeding groups at the time and after the species is recovered. Two national forests—the Ocala in South/Central Florida and the Talladega (Shoal Creek/Talladega Ranger Districts) in the Cumberlands—harbor a support population designated essential to recovery of the species because of the importance of conserving red-cockaded woodpeckers in those regions. Populations on all other national forests, not designated as primary core, secondary core, or essential support populations, are designated significant support populations (see 7). As federally managed support populations, they are required to be increasing at least until the species is recovered. These populations are valuable because they protect against demographic, environmental, and catastrophic events, contain important genetic resources, and facilitate natural dispersal among populations. Because of these contributions, support populations are necessary to bring the species to recovery but will not be required for species viability once core populations reach population goals identified in delisting criteria (see 6A).

Military Installations

Current Status and Trends

At present there are 15 military installations harboring red-cockaded woodpeckers (see map insert and Table 7), ranging from 1 active cluster on Charleston Naval Weapons Station to 301 active clusters on Eglin Air Force Base and 350 active clusters on Fort Bragg. All of these populations appear to be stable or increasing, with the exception of Dare County Bombing Range. Like the populations on national forests, widespread declines among populations on military installations have been stabilized, but substantial increases in population sizes are still required for recovery. In general, the military is managing red-cockaded woodpeckers very effectively. Rates of increase reported from Marine Corps Base Camp Lejeune and Fort Stewart during the 1990's are among the highest yet documented (in the absence of translocation), an encouraging result of intensive, well-planned, and well-executed management.

Role in Recovery

Military installations have a substantial role in recovery and continuing conservation of red-cockaded woodpeckers. Six military installations contain all or part of six primary core populations: Eglin Air Force Base, Fort Benning, Fort Bragg, Fort Polk, Fort Stewart, and Marine Corps Base Camp Lejeune. These primary core populations will contain at least 350 potential breeding groups at the time of and after the species is delisted. Avon Park Air Force Range is a designated essential support population because it supports one of the largest remaining populations in the ecologically unique South/Central Florida Recovery Unit (see 7). Dare County Bombing Range and Camp Mackall are likewise part of essential support populations because of unique or important habitat types. Seven other military installations contain significant support populations, whose increases are important to bringing the species to recovery for reasons described above; however, population goals for these populations are not included in delisting criteria.

National Wildlife Refuges

Current Status and Trends

There are currently 13 populations of red-cockaded woodpeckers partially or wholly contained on national wildlife refuges (see map insert and Table 7), ranging in size from 1 active cluster (Upper Ouachita, Pee Dee, and Black Bayou National Wildlife Refuges) to 116 active clusters (Carolina Sandhills National Wildlife Refuge). Most appear to be stable; several appear to be declining, including Carolina Sandhills, D'Arbonne, and Pocosin Lakes. Substantial increases are required for recovery.

Role in Recovery

National wildlife refuges have a small but important role in recovery of red-cockaded woodpeckers. One refuge (Okefenokee National Wildlife Refuge) contains part of a primary core population, and two refuges contain part of two secondary core populations (Carolina Sandhills and Piedmont National Wildlife Refuges). In addition, two refuges in northeastern North Carolina (Alligator River and Pocosin Lakes National Wildlife Refuges) contain part of a support population designated essential to recovery because of the importance of conserving red-cockaded woodpeckers in the unique habitat type there. The remaining populations partially or wholly on refuge lands are important or significant support populations (see 7) and should be managed for increasing populations. Big Branch Marsh National Wildlife Refuge, containing 15 active clusters at the present time, is notable among support populations on refuge lands because of its location in an ecoregion (Gulf Coast Prairies and Marshes) that currently contains no other woodpeckers.

Other Federal Lands

Two populations of red-cockaded woodpeckers occur on federal lands other than national forests, military installations, and national wildlife refuges. Big Cypress National Preserve harbors a population of 42 active clusters in the ecologically unique native hydric slash pine habitat of south Florida (see map insert and Table 7). Because of its unique habitat, this population is designated an essential support population. The Savannah River Site, controlled by the Department of Energy, contains an increasing population of 34 active clusters and is a secondary core population (see map insert and Table 7). This population will hold at least 250 potential breeding groups at the time of and after delisting.

TABLE 7. Number of active red-cockaded woodpecker clusters (ACT) on federal and tribal properties in 1998, 1999, and 2000, by responsible agency. Also indicated is property goal based on habitat designated for red-cockaded woodpeckers [usually 81 ha (200 ac) per cluster] in agency or site-specific management plans.

		ACT			
Federal Agency	**Property Full Name**	**1998**	**1999**	**2000**	**Goal**
National Park Service	Big Cypress National Preserve	40	41	42	42
	subtotal	40	41	42	42
U.S. Air Force	Avon Park Air Force Range	21	21	21	68
	Dare County Bombing Range	6	9	3	46
	Eglin Air Force Base	280	295	301	500
	Poinsett Weapons Range	5	6	6	30
	subtotal	312	331	331	644
U.S. Army	Camp Mackall	9	11	11	11
	Fort Benning	187	186	219	450
	Fort Bragg	309	350	350	436
	Fort Gordon	2	3	5	25
	Fort Jackson	13	21	24	126
	Fort Polk	45	44	46	179
	Fort Stewart	189	198	212	500
	Military Ocean Terminal Sunny Point	6	6	9	17
	Peason Ridge	25	25	23	120
	subtotal	785	844	899	1864
U.S. Dept of Energy	Savannah River Site	29	31	34	418
	subtotal	29	31	34	418
U.S. Forest Service	Angelina NF	30	30	29	252
	Apalachicola Ranger District, Apalachicola NF	505	486	486	500
	Bienville NF	106	106	104	500
	Catahoula Ranger District, Kisatchie NF	29	31	32	317
	Chickasawhay Ranger District, DeSoto NF	10	13	15	502
	Conecuh NF	13	14	18	309
	Croatan NF	60	58	62	169
	Davy Crockett NF	48	51	53	330
	DeSoto Ranger District, DeSoto NF	6	6	7	368
	Evangeline Unit, Calcasieu Ranger District, Kisatchie NF	68	70	72	231
	Francis Marion NF	368	334	344	453
	Homochitto NF	67	45	51	254
	Kisatchie Ranger District, Kisatchie NF	56	57	29	292
	Oakmulgee Ranger District, Talladega NF	123	115	110	394

Table continued next page.

TABLE 7 (cont.). Number of active red-cockaded woodpecker clusters on federal and tribal properties in 1998, 1999, and 2000.

		ACT			
Federal Agency	**Property Full Name**	**1998**	**1999**	**2000**	**Goal**
U.S. Forest Service (cont.)	Ocala NF	13	18	22	179
	Oconee NF	17	18	20	250
	Osceola NF	54	63	63	462
	Ouachita NF	15	16	21	400
	Sabine NF	22	25	28	262
	Sam Houston NF	168	168	168	541
	Shoal Creek Ranger District, Talladega NF	2		6	~125
	Talladega Ranger District, Talladega NF	1	5	0	~110
	Vernon Unit, Calcasieu Ranger District, Kisatchie NF	196	146	152	302
	Wakulla Ranger District, Apalachicola NF	125	125	138	506
	Winn Ranger District, Kisatchie NF	14	16	18	263
	subtotal	2116	2016	2048	8271
U.S. Fish and Wildlife Service	Alligator River NWR	2	2	3	~20+
	Big Branch Marsh NWR	8	9	15	20
	Black Bayou NWR			1	1
	Carolina Sandhills NWR	125	118	116	193
	D'Arbonne NWR	5	4	2	5
	Felsenthal NWR	15	15	15	34
	Noxubee NWR	37	38	44	88
	Okefenokee NWR	26	29	37	86
	Pee Dee NWR	1	1	1	10
	Piedmont NWR	35	37	39	96
	Pocosin Lakes NWR	4	1	1	50
	St. Marks NWR	6	6	9	71
	Upper Ouachita NWR	1	1	1	1
	subtotal	265	261	284	675
U.S. Marine Corps	Marine Corps Base Camp Lejeune	47	49	59	173
	subtotal	47	49	59	173
U.S. Navy	Charleston Naval Weapons Station	2	2	1	12
	subtotal	2	2	1	12
	TOTAL, FEDERAL PROPERTIES	**3596**	**3575**	**3698**	**12099**
Tribe					
Alabama-Coushatta	Alabama-Coushatta Tribe of Texas			2	2
	TOTAL, FEDERAL AND TRIBAL PROPERTIES			**3700**	**13101**

In summary, federal lands have a fundamental role in the recovery of red-cockaded woodpeckers. Advances in management of red-cockaded woodpeckers on federal lands have led to stabilization of most populations and increases in many. A few populations are still declining. For most populations designated as primary core, secondary core, or essential support populations, substantial increases are required before recovery population goals are reached.

D. NATIVE AMERICAN TRIBAL TRUST LANDS

Currently, there is one Native American Tribe with lands supporting active clusters of red-cockaded woodpeckers. Lands belonging to the Alabama-Coushatta Tribe of Texas presently support two active clusters, and the Alabama-Coushatta Tribal Forestry Department is actively managing for red-cockaded woodpeckers. Native American Tribes have no specifically designated role in recovery of red-cockaded woodpeckers, but are encouraged to participate in recovery efforts to the fullest possible extent.

PART II. RECOVERY

5. RECOVERY GOAL

The ultimate recovery goal is species viability. This goal is represented by delisting. Once delisting criteria are met, it is believed that the size, number, and distribution of red-cockaded woodpecker populations will be sufficient to counteract threats from demographic, environmental, genetic, and catastrophic stochasticity. Therefore, upon delisting the species will be viable over the long-term, at least under the current understanding of these stochastic processes. An interim goal is downlisting from endangered to threatened status.

6. RECOVERY CRITERIA

Population sizes identified in recovery criteria are measured in the number of potential breeding groups. A potential breeding group is an adult female and adult male that occupy the same cluster, with or without one or more helpers, whether or not they attempt to nest or successfully fledge young. A traditional measure of population size has been number of active clusters. Potential breeding groups is a better measure of population status, because this is the basis of population dynamics in this species, and number of active clusters can include varying proportions of solitary males and captured clusters. Estimates of all three parameters—number of active clusters, proportion of solitary males, and proportion of captured clusters—are required to support estimates of potential breeding groups.

To assist in the transition between these two measures, we have provided a range of numbers of active clusters considered the likely equivalents of the required number of potential breeding groups. Estimated number of active clusters is likely to be at least 1.1 times the number of potential breeding groups, but it is unlikely to be more than 1.4 times this number. Thus, an estimated 400 to 500 active clusters will be necessary to contain 350 potential breeding groups, depending on the proportions of solitary males and captured clusters and also on the estimated error of the sampling scheme. It is expected that all recovery populations will have sampling in place that is adequate to judge potential breeding groups. If this is not the case, only the highest number of active clusters in the range given can be substituted to meet the required population size.

A. DELISTING

Delisting shall occur when each of the following criteria is met. A brief rationale for each criterion is given immediately following this list, and a detailed discussion of species and population viability is presented in 2C. Discussion of the five listing factors identified in the Endangered Species Act (Section 4(a)(1)), and how they are related to red-cockaded woodpecker recovery, is also presented in this section. Definitions and descriptions of terms used in delisting criteria, such as recovery units, primary and secondary core populations, and essential support populations, are given in the next section (7). See Table 8 for population designation. All properties identified as part or all of a recovery population (Table 8) should be managed for maximum size that the habitat designated for red-cockaded woodpeckers will allow. (Maximum size is generally based on 200 ac [81 ha] per group).

Criterion 1. There are 10 populations of red-cockaded woodpeckers that each contain at least 350 potential breeding groups (400 to 500 active clusters), and 1 population that contains at least 1000 potential breeding groups (1100 to 1400 active clusters), from among 13 designated primary core populations, and each of these 11 populations is not dependent on continuing installation of artificial cavities to remain at or above this population size.

Criterion 2. There are 9 populations of red-cockaded woodpeckers that each contain at least 250 potential breeding groups (275 to 350 active clusters), from among 10 designated secondary core populations, and each of these 9 populations is not dependent on continuing installation of artificial cavities to remain at or above this population size.

Criterion 3. There are at least 250 potential breeding groups (275 to 350 active clusters) distributed among designated essential support populations in the South/Central Florida Recovery Unit, and six of these populations (including at least two of the following: Avon Park, Big Cypress, and Ocala) exhibit a minimum population size of 40 potential breeding groups that is independent of continuing artificial cavity installation.

Criterion 4. There is one stable or increasing population containing at least 100 potential breeding groups (110 to 140 active clusters) in northeastern North Carolina and southeastern Virginia, the Cumberlands/Ridge and Valley recovery unit, and the Sandhills recovery unit, and these populations are not dependent on continuing artificial cavity installation to remain at or above this population size.

Criterion 5. For each of the populations meeting the above size criteria, responsible management agencies shall provide (1) a habitat management plan that is adequate to sustain the population and emphasizes frequent prescribed burning, and (2) a plan for continued population monitoring.

Rationale for Delisting Criteria

Criterion 1. A population size of 350 potential breeding groups is considered highly robust to threats from environmental stochasticity as well as inbreeding and demographic stochasticity. It is the lowest current estimate of the minimum size necessary to offset losses of genetic variation through genetic drift. One primary core population has the potential to harbor 1000 potential breeding groups within the near future; this criterion is included because such a large population may well be resistant to loss of genetic variation through drift. Eleven of 13 primary core populations are required for delisting because it is recognized that at any given time, one or two may be suffering hurricane impacts. Thirteen primary core populations are designated because of available habitat and because this number, together with 10 secondary core populations (below), may serve to facilitate natural dispersal among populations and maximize retention of genetic variability. Primary and secondary core populations provide for the conservation of the species within each major physiographic unit in which it currently exists, with the exception of South/Central Florida. This unit is represented by several, smaller, essential support populations (below). Populations that depend on continuing artificial cavity installation to maintain stable or increasing trends are barred from meeting delisting criteria because this management technique is considered appropriate for short-term management only.

Criterion 2. A population size of 250 potential breeding groups is the minimum size considered robust to environmental stochasticity, and is well above the size necessary to withstand inbreeding and demographic stochasticity. Nine of 10 designated secondary core populations are required for delisting to allow for hurricane impacts.

Criterion 3. This unique habitat type is represented to the extent that available habitat allows. Unique genetic resources are conserved as much as reasonably possible. Because of small size, some of these populations will remain vulnerable to extinction threats and may eventually be lost. The likelihood of extirpation of small populations is minimized by enhancing the spatial arrangement of territories so that they are highly aggregated.

Criterion 4. These unique habitats, and genetic resources contained within this population, will be represented at the time of delisting. This population size is midway in estimates of sizes necessary to withstand threats from inbreeding depression and is considered robust to demographic stochasticity if territories are moderately aggregated in space.

Criterion 5. Continued habitat management and population monitoring are necessary to ensure that the species does not again fall to threatened or endangered status.

Delisting Criteria and Listing Factors Identified in the Endangered Species Act

The Endangered Species Act (Section 4(a)(1)) identified five factors that threaten or endanger a species, any one of which is justification for listing. At delisting, therefore, none of these factors can exist. We discuss each of these factors below and describe the means by which, if this recovery plan is fully implemented, these factors will not threaten red-cockaded woodpeckers at time of delisting.

Listing Factor A: *the present or threatened destruction, modification, or curtailment of a species' habitat or range*. Red-cockaded woodpeckers are vulnerable to habitat loss and habitat degradation. Habitat loss and degradation were primary factors in the species' original decline (see 1A); these factors resulted from direct conversion of habitat to other land uses, fire suppression, and loss of mature pines within pine woodlands. Direct conversion of habitat no longer occurs on public lands, which form the basis of recovery for red-cockaded woodpeckers. However, currently, lack of frequent fire and mature pines continue to threaten the species on public and private lands (1B). Red-cockaded woodpeckers are most vulnerable to loss and degradation of nesting habitat (2D), but are also vulnerable to loss and degradation of foraging habitat (2E). Addressing these threats is a primary objective of this recovery plan.

Management actions such as artificial cavity installation, prescribed burning, and silviculture that protects old pines are powerful tools critical to restoration of habitat and recovery of the species. As such, these actions are heavily emphasized in management guidelines (8E, 8K, 8J), recovery tasks (9), and throughout the document. Moreover, these critical actions are represented in delisting criteria: a prescribed burning program is explicitly required as part of habitat management plans that must be in place for delisting (criterion 6), whereas a stable or increasing population trend, independent from continuing artificial cavity installation, is required for populations to meet their size requirements (criteria 1-5). A stable or increasing trend independent of continuing artificial cavity installation can only be achieved once large old pines are available in abundance.

Listing Factor B: *overutilization for commercial, recreational, scientific, or educational purposes.* Overutilization was not a factor in the original decline of red-cockaded woodpeckers and it is not currently a threat to species recovery.

Listing Factor C: *disease or predation.* Disease and predation were not factors in the original decline of red-cockaded woodpeckers and neither is currently a threat to species recovery.

Listing Factor D: *inadequacy of existing regulatory mechanisms*. Existing regulatory mechanisms, specifically the Endangered Species Act and the National Forest Management Act, are adequate to ensure the recovery of red-cockaded woodpeckers, assuming this recovery plan is fully implemented.

Listing Factor E: *other natural or manmade factors affecting its continued existence.* Other natural or manmade factors affecting the continued existence of red-cockaded woodpeckers include habitat fragmentation and the threats to viability inherent to small populations. Addressing these threats is a primary objective of this recovery plan.

Habitat fragmentation can result in loss of population viability through disrupted dispersal. Further fragmentation of habitat is safeguarded against by appropriate silvicultural methods (3E, 8J). In addition, management guidelines emphasize maintaining or developing beneficial arrangements of red-cockaded woodpecker groups in space, to enhance dispersal within populations (8B, 8H). Translocation (8H) and installation of recruitment clusters (8B) are important management actions used to create such beneficial spatial arrangements. Threats to viability inherent to small populations are discussed in detail in section 2C. Resistance to these threats is the fundamental basis for target population sizes identified in delisting criteria (1 – 5). The set of populations that will exist at delisting will not be vulnerable to effects of habitat fragmentation nor to stochastic events that threaten small populations. Once delisting criteria have been met, the species will be viable to the fullest degree possible given current scientific understanding.

B. DOWNLISTING

Downlisting shall occur when each of the following criteria is met. Rationale for each criterion is presented immediately following this list. See Table 8 for population designation. All populations identified in downlisting criteria should be managed for maximum size that the habitat designated for red-cockaded woodpeckers will allow. (Maximum size is generally based on 200 ac [81 ha] per group).

Criterion 1. There is one stable or increasing population of 350 potential breeding groups (400 to 500 active clusters) in the Central Florida Panhandle.

Criterion 2. There is at least one stable or increasing population containing at least 250 potential breeding groups (275 to 350 active clusters) in each of the following recovery units: Sandhills, Mid-Atlantic Coastal Plain, South Atlantic Coastal Plain, West Gulf Coastal Plain, Upper West Gulf Coastal Plain, and Upper East Gulf Coastal Plain.

Criterion 3. There is at least one stable or increasing population containing at least 100 potential breeding groups (110 to 140 active clusters) in each of the following recovery units: Mid-Atlantic Coastal Plain, Sandhills, South Atlantic Coastal Plain, and East Gulf Coastal Plain.

Criterion 4. There is at least one stable or increasing population containing at least 70 potential breeding groups (75 to 100 active clusters) in each of four recovery units, Cumberlands/Ridge and Valley, Ouachita Mountains, Piedmont, and Sandhills. In addition, the Northeast North Carolina/Southeast Virginia Essential Support Population is stable or increasing and contains at least 70 potential breeding groups (75 to 100 active clusters).

Criterion 5. There are at least four populations each containing at least 40 potential breeding groups (45 to 60 active clusters) on state and/or federal lands in the South/Central Florida Recovery Unit.

Criterion 6. There are habitat management plans in place in each of the above populations identifying management actions sufficient to increase the populations to recovery levels, with special emphasis on frequent prescribed burning during the growing season.

Rationale for Downlisting Criteria

Criterion 1. A population size of 350 potential breeding groups is considered highly robust to threats from environmental stochasticity as well as inbreeding and demographic stochasticity. It is the lowest current estimate of the minimum size necessary to offset losses of genetic variation through genetic drift.

Criterion 2. This population size, 250 potential breeding groups, is sufficient to withstand extinction threats from environmental uncertainty, demographic uncertainty, and inbreeding depression. These 6 populations, in combination with the single population identified in criterion (1), will represent each major recovery unit.

Criterion 3. A second population in these coastal recovery units will decrease the species' vulnerability to hurricanes. The West Gulf Coastal Plain is excluded because there are no candidate populations there. The lower size, 100 potential breeding groups, is considered sufficient to withstand threats from demographic uncertainty and inbreeding depression, and is much more quickly attained than 250 potential breeding groups thought necessary to withstand environmental stochasticity.

Criterion 4. These special habitats will be represented at the time of downlisting. This population size is midway in estimates of sizes necessary to withstand threats from inbreeding depression and is considered robust to demographic stochasticity if territories are moderately aggregated in space.

Criterion 5. This unique region will be represented at the time of downlisting. Forty potential breeding groups is at the lower end of estimates of sizes necessary to withstand inbreeding depression and are considered robust to demographic stochasticity if territories are highly aggregated in space.

Criterion 6. These habitat management plans are necessary to ensure progress toward delisting.

7. RECOVERY UNITS

Recovery units are geographic or otherwise identifiable subunits of the listed entity that individually are necessary to conserve genetic robustness, demographic robustness, important life history stages, or some feature necessary for long-term sustainability of the overall listed entity. The recovery units established for red-cockaded woodpeckers are a surrogate for likely genetic variation and adaptation to local environments, because they are based on changing environmental conditions, i.e., they are geographic areas delineated according to ecoregions (physiographic provinces; see discussion below and map insert). Substantial genetic variation has been documented in red-cockaded woodpeckers across their range, although distinct boundaries for this variation have not been identified. Red-cockaded woodpeckers exhibit a correlation between genetic variation and geographic distance, meaning the farther apart populations are geographically, the greater the genetic variation between or among them. This has been documented using both randomly amplified polymorphic DNA (used as a genetic marker; Haig et al. 1994a, 1996) and allozyme data (Stangel et al. 1992, Stangel and Dixon 1995). As molecular markers gain resolution, we may be able to identify more distinct genetic boundaries, but the correlation between genetic variation and geographic distance is a classic characteristic of species that were once distributed primarily as a continuous population.

Names of recovery units are the same as their respective ecoregion, with one exception (South/Central Florida). There are eleven designated recovery units for red-cockaded woodpeckers. All but two recovery units contain one or more core recovery populations and one or multiple support populations (map insert). The remaining two recovery units contain support populations only. Core populations are classified as primary or secondary based on available habitat and population size required for delisting. In addition to primary and secondary core populations, several support populations are considered essential to species recovery and as such are identified in delisting and downlisting criteria. These essential support populations are not designated primary or secondary cores because of habitat limitations. All other support populations (below) are necessary to protect and maximize genetic and demographic health until the species is delisted.

Maintaining viable populations within each recovery unit is essential to the survival and recovery of red-cockaded woodpeckers as a species, across their range. Conservation of populations in all habitats, forest types, and ecoregions, represented within and by recovery units is critical to species survival and recovery because these varied populations have crucial ecological and genetic values. The loss, or reduction of the likelihood of survival and recovery, of core and essential support populations within one or more of the designated recovery units could not only jeopardize the recovery goals for the individual recovery unit(s), but also jeopardize the recovery of the entire species in several ways.

First, without immigration, no red-cockaded woodpecker population (with the possible exception of the Central Florida Panhandle population) will be large enough to avoid loss of genetic variability through genetic drift. Loss of genetic variation may reduce a species' ability to adapt and persist in a changing environment (ecoregion), and thereby reduce its viability over long time periods. One practical way to reduce the threat of genetic drift is to promote immigration, both natural (dispersal) and artificial (via translocation). Multiple recovery units, harboring all of the habitat types and representing all ecoregions in which red-cockaded woodpeckers currently exist, provide the means to ensure that natural and artificial immigration can occur and be managed.

Second, the vast majority of red-cockaded woodpecker populations are threatened today by demographic stochasticity and will remain so for the foreseeable future. Therefore, the short-term survival of many individual populations in most recovery units is dependent on translocated birds from other recovery units. Because donor populations for many small (less than 30 potential breeding groups), at-risk populations are in adjacent recovery units, actions adversely affecting donor populations in one recovery unit can jeopardize the survival and recovery of populations in other recovery units, thereby jeopardizing the entire species.

A third and significant threat to red-cockaded woodpecker populations are catastrophes, including hurricanes and outbreaks of southern pine beetles, which point to several reasons for identifying and conserving multiple recovery units. First, red-cockaded woodpecker populations in similar habitats/forest types and with more closely related genetic resources may occur in recovery units adjacent to those impacted by the catastrophic event, thus helping ensure that the ability of the species to adapt to these ecological conditions of habitat and forest type would be protected. Second, by maintaining a number of recovery units, with their associated populations, that are broadly spaced geographically, and including as many inland populations as possible, the threat from catastrophic loss is substantially reduced. Additionally, when losses do occur in one recovery unit, other recovery units can be relied upon to supply birds for population restoration programs, thereby ensuring the continued likelihood of survival and recovery of the species.

To achieve and maintain species viability, we must maintain a network of interacting populations within and between recovery units. This strategy will promote natural immigration from support and core populations, over the long-term, within and between recovery units, thereby reducing species' susceptibility to loss of genetic variability through genetic drift. If, in the future, natural immigration rates are determined to be inadequate to reach or maintain genetic variability, artificial immigration (via translocation) within and between recovery units will be necessary to ensure the survival and recovery of red-cockaded woodpeckers. Similarly, the recovery unit system provides the means today and into the future to overcome the threats of demographic stochasticity through translocation. Additionally, the recovery unit system provides the opportunity to respond aggressively to stabilize and restore recovery units and populations impacted by catastrophic events. Thus, the system of recovery units, with respective primary core, secondary core, and support populations, provides the foundation of the strategy to recover red-cockaded woodpeckers.

Recovery Units as the Basis for Jeopardy Analysis in Interagency Consultation

In the past, exceptions from applying the jeopardy standard to an entire species were granted by a U.S. Fish and Wildlife Service Director's memorandum, dated March 3, 1986, for specific populations of a species. Since the mid-1980's, in compliance with the Director's memorandum, we conducted jeopardy analyses for red-cockaded woodpeckers at the level of the population.

Our guidance on this topic changed with the release of our Consultation Handbook in 1998 (USFWS 1998). The Handbook states that when determining whether an action jeopardizes the continued existence of the species, we are to analyze the total impacts of the proposed project on the entire species. However, the Handbook acknowledges that for some wide-ranging species, this analysis can be facilitated by the establishment of recovery units in a final recovery plan. The Consultation Handbook notes that species' recovery plans provide the best available scientific information relative to the areas and environmental elements needed for the species to recover, and may even describe recovery units essential to recovering the species. Given that actions that appreciably impair or preclude the capability of such a recovery unit from providing the survival and recovery functions identified for it in a recovery plan may therefore represent jeopardy to the species, the Consultation Handbook indicates the jeopardy standard may be applied to individual recovery units identified as necessary for survival and recovery of the species in an approved final recovery plan. Thus, the designation of recovery units in recovery plans facilitates recovery both by focusing the species' recovery program on the need to conserve the geographic, demographic, and genetic features of the recovery unit for its contribution to the whole species, and by facilitating the evaluation of potential jeopardy to the species when the survival and recovery of an individual recovery unit is in question.

Ecoregions

Ecoregions (physiographic provinces; Bailey 1983, Bailey *et al.* 1994) are a system of classification based on physiography, the study of the natural features of the earth’s surface. Important to physiography and the designation of ecoregions are characteristics of land formation, climate, air and sea currents, and distribution of flora and fauna. Ecoregions are a more finely grained system of classification than the world biome system (Clements and Shelford 1939), for example, but not as fine as classifications according to ecosystems or communities. Although the natural boundaries of ecoregions are generally gradual rather than distinct, for the purposes of classification distinct boundaries have been delineated.

Ecoregions can be used to represent varying climatic and edaphic factors that have likely influenced species evolution over time. For red-cockaded woodpeckers, ecoregions reflect broad areas within which local adaptations and genetic coadaptation have likely occurred. (Genetic coadaptation is the evolution of gene complexes that together impart greater fitness than the sum of each individual gene’s contribution. A coadapted gene’s effect depends on the presence of one or more other genes; Templeton *et al.* 1986). Thus, major objectives in the use of ecoregions as a basis for recovery units are to identify likely genetic variation and to assure that this variation is conserved to the fullest extent possible.

Translocation

Translocations between populations (see 3D) will be conducted within recovery units and between adjacent recovery units except in rare cases. These rare exceptions include (1) previous agreements between the U.S. Fish and Wildlife Service, private landowners, and state and federal agencies, and (2) no donor population available in the same or adjacent recovery unit. This guideline applies to all translocations, including those intended for population augmentation (3D) and mitigation (4A). The primary objectives, and major benefits, of this guideline are the retention of genetic integrity and the protection of each unit's progress toward recovery. Translocation and/or mitigation must not result in genetic pollution or cause a net loss of groups within any given recovery unit. In addition, controlling maximum distances for translocation will minimize cost, logistical difficulties, and the stress on the birds from transport.

Primary and Secondary Core Populations

Primary Core Populations

Primary core populations are those that will harbor at least 350 potential breeding groups at the time of and after delisting. Populations of this size are above the minimum size considered necessary to withstand threats of extirpation from demographic stochasticity, environmental stochasticity, and inbreeding depression (2C). Populations of this size may not be capable of retaining sufficient genetic variability for long-term viability in the absence of immigration (Lande 1995; 2C), but because retention of genetic variability is a direct function of population size, these primary core populations will retain more variation than secondary core and support populations. Conservation of within-population genetic diversity is a major function of primary core populations.

One primary core population (Central Florida Panhandle) will harbor 1000 potential breeding groups at delisting. This population size may well be resistant to loss of genetic variation through genetic drift.

Although a minimum population size of primary core populations is necessarily identified in delisting criteria, primary core populations should expand to the maximum sizes the habitat designated for red-cockaded woodpeckers will allow, to retain as much genetic variation within the populations as possible (2C). (Maximum size is generally based on 200 ac [81 ha] per group). At downlisting, primary core populations may not necessarily contain 350 potential breeding groups.

There are 12 designated primary core populations, located on federal lands including national forests, military installations, and one national wildlife refuge (see map insert). Some state properties, such as Holly Shelter Game Lands in North Carolina, support important segments of primary core populations.

Secondary Core Populations

Secondary core populations are those that will hold at least 250 potential breeding groups at the time of and after delisting. This population size is the minimum estimate considered necessary to withstand threats of extirpation from environmental stochasticity, and is considered highly robust to threats from demographic stochasticity and inbreeding depression. These populations are not large enough to withstand threats to long-term viability from the process of genetic drift unless immigration is maintained. Secondary core populations should be expanded to maximum population goals based on available habitat to protect genetic resources as much as possible and to provide maximum resilience to environmental effects. Habitat limitations for secondary core populations prevent their designation as primary core populations. Secondary core populations may not necessarily harbor 250 potential breeding groups at the time of downlisting.

There are 11 secondary core populations, located on federal lands including national forests, national wildlife refuges, and Department of Energy lands (see map insert). State lands, such as the Sand Hills State Forest in South Carolina, support important segments of secondary core populations.

Benefits of the Primary and Secondary Core Population Strategy

The 12 primary and 11 secondary core populations of red-cockaded woodpeckers are well distributed throughout the species' range. This widespread distribution serves several critical ecological objectives. First, such a distribution conserves red-cockaded woodpeckers in varied habitats and geographic regions in which they currently exist (above). Second, the wide distribution and relatively high number of populations reduces threat of species extinction from catastrophic events such as hurricanes (see 2C). Finally, secondary and primary core populations together create a network which, when population goals are reached, may facilitate the natural dispersal among populations that is critical to long-term genetic viability (2C).

Red-cockaded woodpeckers are capable of long-distance movements between populations (Walters *et al.* 1988b, Conner *et al.* 1997c, Ferral *et al.* 1997; see 2B), although under present conditions these dispersal events are rare. With increasing population size, natural movements between populations are expected to increase. Primary and secondary core populations at and after delisting will be large and healthy; thus, natural dispersal among recovered core populations may be sufficient to maintain species-wide genetic variability. If not, translocation may have to be conducted to achieve this objective. In the meantime, support populations (below) play a vital role in facilitating gene flow through natural dispersal and translocation.

Primary core, secondary core, and essential support (below) populations are delineated by estimated biological population boundaries. Most of these designated populations are currently functioning, or will function at recovery, as one demographic and genetic unit. If this were not the case, expected resistance to stochastic threats would be compromised. There are four cases, however, in which a defined recovery population may continue to be a composite of relatively isolated subpopulations: (1) Angelina/Sabine Primary Core, (2) Coastal North Carolina Primary Core, (3) Osceola/Okefenokee Primary Core, and (4) Northeast North Carolina/Southeast Virginia Essential Support. For these cases, it remains to be seen whether, as isolated subpopulations grow in size, these designated populations can begin to function as single biological units.

Support Populations

All populations not designated a primary or secondary core are designated support populations. There are three classifications for support populations:

1. Essential support populations are those populations, identified in recovery criteria, that represent unique or important habitat types that cannot support a larger, core population. They are located on federal, state, and, in two cases, private lands in agreement with the U.S. Fish and Wildlife Service (Table 3).

2. Significant support populations are populations, not identified in recovery criteria, that contain and/or have a population goal of 10 or more active clusters. (A population size of 10 active clusters, if highly aggregated in space, has a good probability of persistence over a 20-year time period; Crowder *et al.* 1998, Walters et al. 2002b.) They are located on federal and state lands and on private lands enrolled in agreements with the U.S. Fish and Wildlife Service (see Tables 5 and 9).

3. Important support populations are populations, not identified in recovery criteria, that contain and have a population goal of less than 10 active clusters. They are located on federal and state lands (Table 9) and on private lands enrolled in agreements with the U.S. Fish and Wildlife Service.

All populations of red-cockaded woodpeckers have intrinsic ecological, cultural, and historical value. In addition to these intrinsic values, support populations aid in the conservation and recovery of the species. Support populations are important reservoirs of genetic resources. They help represent natural variation in habitats occupied by red-cockaded woodpeckers. Support populations are an important source of immigrants for core populations to increase retention of genetic variation and could potentially provide a buffer against stochastic loss of core populations. These functions are especially critical now, because many core populations are currently well below the population sizes necessary to withstand threats of environmental, demographic, and genetic uncertainty. Because of small population size of most support populations, extirpation of some due to stochastic events is expected.

Significant and important support populations identified within this plan are defined by ownership, rather than biological population boundaries. Some of the populations listed below may be functioning as part of larger populations. Recovery populations—primary core, secondary core, and essential supports—are defined by estimated biological boundaries rather than ownership.

Management prescriptions for all support populations on public lands will be the same as those applied in core populations. Managers should increase their populations to the maximum the habitat base will support, using the level of monitoring recommended based on population size (see 8C) and the recovery standard for foraging habitat (8I). Management plans for federal and state lands are approved by the U.S. Fish and Wildlife Service (contact the Recovery Coordinator for further information). Support populations on private lands will be managed under Memoranda of Agreement, Habitat Conservation Plans, Safe Harbor Agreements or other management instruments approved by the U.S. Fish and Wildlife Service (contact the Recovery Coordinator for further information). Management prescriptions for these populations depend on agreements.

Individual Recovery Units

For each recovery unit, we list populations identified in delisting criteria below. See Tables 5, 6, and 7, and the map insert, for other populations including those on private, state, and federal properties.

Cumberlands/Ridge and Valley Recovery Unit

The Cumberlands/Ridge and Valley Recovery Unit (Table 8, map insert) contains one essential support population: Talladega/Shoal Creek, which consists of the Talladega and Shoal Creek Ranger Districts of the Talladega National Forest.

East Gulf Coastal Plain Recovery Unit

The East Gulf Coastal Plain Recovery Unit (Table 8, map insert) contains three primary core populations: (1) Central Florida Panhandle, consisting of Apalachicola and Wakulla Ranger Districts of the Apalachicola National Forest, Ochlockonee River State Park, St. Mark's National Wildlife Refuge, and Tate's Hell State Forest; (2) Chickasawhay Ranger District of the DeSoto National Forest, and (3) Eglin Air Force Base. The Central Florida Panhandle Primary Core will harbor 1000 potential breeding groups at delisting. This recovery unit also contains three secondary core populations: (1) Conecuh/Blackwater, consisting of Conecuh National Forest and Blackwater River State Forest, (2) DeSoto Ranger District of the DeSoto National Forest, and (3) Homochitto National Forest.

Mid-Atlantic Coastal Plain Recovery Unit

The Mid-Atlantic Coastal Plain Recovery Unit (Table 8, map insert) contains two primary core populations: (1) Coastal North Carolina, consisting of Croatan National Forest, Holly Shelter Game Lands, and Marine Corps Base Camp Lejeune; and (2) Francis Marion National Forest. It also contains one essential support population: Northeast North Carolina/Southeast Virginia, consisting of Alligator River National Wildlife Refuge, Dare County Bombing Range, Palmetto-Peartree Preserve (owned by the Conservation Fund), Pocosin Lakes National Wildlife Refuge, and Piney Grove Preserve (owned by The Nature Conservancy).

Ouachita Mountains Recovery Unit

The Ouachita Mountains Recovery Unit (Table 8, map insert) contains one secondary core population, Ouachita National Forest.

Piedmont Recovery Unit

The Piedmont Recovery Unit (Table 8, map insert) contains one secondary core population: Oconee/Piedmont, consisting of Oconee National Forest and Piedmont National Wildlife Refuge.

Sandhills Recovery Unit

The Sandhills Recovery Unit (Table 8, map insert) contains two primary core populations: (1) North Carolina Sandhills East[1], consisting of Calloway Tract (owned by The Nature Conservancy), Carver's Creek Tract (owned by The Nature Conservancy), Fort Bragg, McCain Tract, and Weymouth Woods State Nature Preserve; and (2) Fort Benning. This unit contains one secondary core population: the South Carolina Sandhills, consisting of Carolina Sandhills National Wildlife Refuge and Sand Hills State Forest. This unit also contains one essential support population: North Carolina Sandhills West[11], consisting of Camp Mackall and the Sandhills Game Lands.

South Atlantic Coastal Plain Recovery Unit

The South Atlantic Coastal Plain Recovery Unit (Table 8, map insert) contains two primary core populations: (1) Fort Stewart, and (2) Osceola/Okefenokee, consisting of Osceola National Forest and Okefenokee National Wildlife Refuge. This recovery unit contains a single secondary core population, the Savannah River Site.

South/Central Florida Recovery Unit

The South/Central Florida Recovery Unit (Table 8, map insert) is one of two recovery units that do not contain a primary or secondary core population, because no

[1] Additional private properties acquired and/or managed under the provisions of the cooperative agreement between the Department of the Army and The Nature Conservancy, or protected in perpetuity through other mechanisms, will be considered as contributing to the total number of potential breeding groups in the North Carolina Sandhills East and North Carolina Sandhills West populations, as appropriate given property location.

federal properties in this unit have sufficient land base to support populations of this size. For this reason, the 1985 Recovery Plan (USFWS 1985) did not include south and central Florida in species recovery. However, maintaining populations of red-cockaded woodpeckers in south and central Florida is essential to the recovery of the species. These populations are associated with unique habitat types such as native hydric slash pine (Beever and Dryden 1992) and critically endangered sand ridge communities. South/central Florida populations contain a high degree of among-population genetic variation and at least one unique allele (Haig *et al.* 1996). In addition, south and central Florida served as the source of the longleaf pine/scrub oak community roughly 5000 to 8000 years ago (Watts 1971, Watts *et al.* 1992). The region was a refuge for red-cockaded woodpeckers during the Wisconsin Glaciation just prior to the longleaf advance, and it is likely that red-cockaded woodpeckers evolved here during a previous glacial event (Jackson 1971, Conner *et al.* 2001). Therefore, red-cockaded woodpeckers in south and central Florida are considered an essential component of the species.

All populations on state and federal lands in this unit that have the capacity to harbor 10 or more active clusters are designated essential support populations. Support populations within the South/Central Florida Recovery Unit are included in criteria for delisting (see 6). It is recognized that this recovery unit will not in itself sustain viable populations and that one or more of these populations may be lost to stochastic events. Translocation among populations within this unit is likely to be necessary for long-term maintenance of genetic variation.

Essential support populations within the South/Central Florida Recovery Unit are (1) Avon Park, consisting of Avon Park Air Force Range and Kicco Wildlife Management Area, (2) Babcock/Webb Wildlife Management Area, (3) Big Cypress National Preserve, (4) Camp Blanding Training Site, (5) Goethe State Forest, (6) Hal Scott Preserve, (7) Corbett/Dupuis, consisting of J. W. Corbett Wildlife Management Area and Dupuis Wildlife Management Area, (8) Ocala National Forest, (9) Picayune Strand State Forest, (10) St. Sebastian River State Buffer Preserve, (11) Three Lakes Wildlife Management Area, (12) Withlacoochee State Forest – Citrus Tract, and (13) Withlacoochee State Forest – Croom Tract. Currently, there are no private lands enrolled in agreements with the U.S. Fish and Wildlife Service in this recovery unit.

Upper East Gulf Coastal Plain Recovery Unit

The Upper East Gulf Coastal Plain (Table 8, map insert) contains one primary core population, Bienville National Forest, and one secondary core population, Oakmulgee Ranger District of the Talladega National Forest.

Upper West Gulf Coastal Plain Recovery Unit

The Upper West Gulf Coastal Plain (Table 8, map insert) contains one primary core population, the Sam Houston National Forest. This unit contains no secondary core populations.

West Gulf Coastal Plain Recovery Unit

The West Gulf Coastal Plain Recovery Unit (Table 8, map insert) contains two primary core populations: (1) the Angelina/Sabine National Forests and (2) Vernon/Fort Polk, consisting of the Vernon Unit of the Calcasieu Ranger District of Kisatchie National Forest, and Fort Polk. This recovery unit contains two secondary core populations: (1) Davy Crockett National Forest and (2) Catahoula Ranger District/Winn Ranger District (portion) of Kisatchie National Forest. These secondary core populations were chosen from among several federal properties that can hold populations of 250 potential breeding groups, and were selected to create a stepping-stone pattern in the hopes of enhancing natural dispersal.

Gulf Coast Prairies and Marshes Ecoregion

The Gulf Coast Prairies and Marshes ecoregion (Table 8, map insert) is not considered a recovery unit because there is only a single, small population within it and habitat for red-cockaded woodpeckers is limited. Big Branch National Wildlife Refuge is a significant support population. Because of its unusual habitat type, Big Branch National Wildlife Refuge should be conserved to the fullest extent possible.

Mississippi Alluvial Plain

The Mississippi Alluvial Plain ecoregion (Table 8, map insert) is likewise not considered a recovery unit because there is only a single, small population within it and habitat is limited. Pine City Natural Area is an important support population which, because of its unusual habitat type (pure, site-appropriate loblolly), should be conserved to the fullest extent possible.

TABLE 8. Primary core, secondary core, and essential support populations, and the properties that comprise these populations, by recovery unit. Each of these populations has a designated role in recovery. Also listed is minimum size at delisting (potential breeding groups; PBG), current size (active clusters in 2000; ACT), state, ownership type, and responsible agency. Number of active clusters is generally equal to 1.1 to 1.4 times the number of potential breeding groups. See 10 (Table 16) for key to agency abbreviations.

Recovery Unit **Population** **Property**	**Size at Delisting (PBG)**	**Current Size (ACT)**	**State**	**Type**	**Agency**
Cumberlands/Ridge and Valley					
Talladega/Shoal Creek Essential Support	100				
Shoal Creek Ranger District, Talladega NF		6	AL	Federal	USFS
Talladega Ranger District, Talladega NF		0	AL	Federal	USFS
East Gulf Coastal Plain					
Central Florida Panhandle Primary Core	1000				
Apalachicola Ranger District, Apalachicola NF		486	FL	Federal	USFS
Ochlockonee River State Park		3	FL	State	FPS
St. Mark’s National Wildlife Refuge		9	FL	Federal	USFWS
Tate's Hell State Forest		29	FL	State	FDF
Wakulla Ranger District, Apalachicola NF		138	FL	Federal	USFS
Chickasawhay Primary Core	350				
Chickasawhay Ranger District, Desoto NF		15	MS	Federal	USFS
Conecuh/Blackwater Secondary Core	250				
Blackwater River State Forest		26	FL	State	FDF
Conecuh National Forest		18	AL	Federal	USFS
DeSoto Secondary Core	250				
DeSoto Ranger District, DeSoto NF		7	MS	Federal	USFS
Eglin Primary Core	350				
Eglin Air Force Base		301	FL	Federal	USAF
Homochitto Secondary Core	250				
Homochitto National Forest		51	MS	Federal	USFS
Mid-Atlantic Coastal Plain					
Coastal North Carolina Primary Core	350				
Croatan National Forest		62	NC	Federal	USFS
Holly Shelter Game Lands		38	NC	State	NCWRC
Marine Corps Base Camp Lejeune		59	NC	Federal	USMC
Francis Marion Primary Core	350				
Francis Marion National Forest		344	SC	Federal	USFS
Northeast North Carolina/Southeast Virginia Essential Support	100				
Alligator River National Wildlife Refuge		3	NC	Federal	USFWS
Dare County Bombing Range		3	NC	Federal	USAF
Palmetto-Peartree Preserve		25	NC	Private	
Piney Grove Preserve		3	NC	Private	
Pocosin Lakes National Wildlife Refuge		1	NC	Federal	USFWS

Table continued next page.

TABLE 8 (cont.). Primary core, secondary core, and essential support populations.

Recovery Unit / Population / Property	Size at Delisting (PBG)	Current Size (ACT)	State	Type	Agency
Ouachita Mountains					
Ouachita Secondary Core	250				
Ouachita National Forest		21	AR	Federal	USFS
Piedmont					
Oconee/Piedmont Secondary Core	250				
Oconee National Forest		20	GA	Federal	USFS
Piedmont National Wildlife Refuge		39	GA	Federal	USFWS
Sandhills					
Fort Benning Primary Core	350				
Fort Benning		219	GA	Federal	USARMY
North Carolina Sandhills East Primary Core	350				
Calloway Tract		5	NC	Private	TNC
Carver's Creek Tract		4	NC	Private	TNC
Fort Bragg		350	NC	Federal	USARMY
McCain Tract		5	NC	Federal	NCDA
Weymouth Woods State Nature Preserve		7	NC	State	NCDENR
North Carolina Sandhills West Essential Support	100				
Camp Mackall		11	NC	Federal	USARMY
Sandhills Game Lands		134	NC	State	NCWRC
South Carolina Sandhills Secondary Core	250				
Carolina Sandhills National Wildlife Refuge		116	SC	Federal	USFWS
Sand Hills State Forest		51	SC	State	SCFC
South Atlantic Coastal Plain					
Fort Stewart Primary Core	350				
Fort Stewart		212	GA	Federal	USARMY
Osceola/Okefenokee Primary Core	350				
Okefenokee National Wildlife Refuge		37	GA	Federal	USFWS
Osceola National Forest		63	FL	Federal	USFS
Savannah River Secondary Core	250				
Savannah River Site		34	SC	Federal	DOE
South/Central Florida					
Avon Park Essential Support	40				
Avon Park Air Force Range		21	FL	Federal	USAF
Kicco Wildlife Management Area		1	FL	State	FFWCC
Babcock/Webb Essential Support	40				
Babcock/Webb Wildlife Management Area		27	FL	State	FFWCC
Big Cypress Essential Support	40				
Big Cypress National Preserve		42	FL	Federal	NPS

Table continued next page.

TABLE 8 (cont.). Primary core, secondary core, and essential support populations.

Recovery Unit / Population / Property	Size at Delisting (PBG)	Current Size (ACT)	State	Type	Agency
South/Central Florida (cont.)					
Camp Blanding Essential Support	25[1]				
Camp Blanding Training Site		14	FL	Federal	FDMA
Corbett/Dupuis Essential Support	40				
J. W. Corbett/Dupuis Wildlife Management Area		13	FL	State	FFWCC/ SFWMD
Goethe Essential Support	40				
Goethe State Forest		30	FL	State	FDF
Hal Scott Essential Support	15[1]				
Hal Scott Preserve		7	FL	State	SJRWMD
Ocala Essential Support	40				
Ocala National Forest		22	FL	Federal	USFS
Picayune Strand Essential Support	25[1]				
Picayune Strand State Forest		3	FL	State	FDF
St. Sebastian River Essential Support	25[1]				
St. Sebastian River State Buffer Preserve		8	FL	State	SJRWMD
Three Lakes Essential Support	40				
Three Lakes Wildlife Management Area		51	FL	State	FFWCC
Withlacoochee Citrus Tract Essential Support	40				
Withlacoochee State Forest - Citrus Tract		46	FL	State	FDF
Withlacoochee Croom Tract Essential Support	30[1]				
Withlacoochee State Forest - Croom Tract		5	FL	State	FDF
Upper East Gulf Coastal Plain					
Bienville Primary Core	350				
Bienville National Forest		104	MS	Federal	USFS
Oakmulgee Secondary Core	250				
Oakmulgee Ranger District, Talladega NF		110	AL	Federal	USFS
Upper West Gulf Coastal Plain					
Sam Houston Primary Core	350				
Sam Houston National Forest		168	TX	Federal	USFS
West Gulf Coastal Plain					
Angelina/Sabine Primary Core	350				
Angelina National Forest		29	TX	Federal	USFS
Sabine National Forest		28	TX	Federal	USFS

Table continued next page.

TABLE 8 (cont.). Primary core, secondary core, and essential support populations.

Recovery Unit Population Property	Size at Delisting (PBG)	Current Size (ACT)	State	Type	Agency
Catahoula Secondary Core	250				
Catahoula Ranger District, Kisatchie NF		32	LA	Federal	USFS
Winn Ranger District (portion), Kisatchie NF		5	LA	Federal	USFS
Davy Crockett Secondary Core	250				
Davy Crockett National Forest		53	TX	Federal	USFS
Vernon/Fort Polk Primary Core	350				
Fort Polk		46	LA	Federal	USARMY
Vernon Unit, Calcasieu Ranger District, Kisatchie NF		152	LA	Federal	USFS

[1]These populations each have an estimated potential size of less than 40 potential breeding groups but can contribute significantly to the delisting criterion of 250 potential breeding groups (275-350 active clusters) in the South/Central Florida Recovery Unit overall.

TABLE 9. Significant and important support populations on state and federal properties, by recovery unit. Also listed are location (state), current size (number of active clusters in 2000) and potential size (number of active clusters). Except where noted, potential size is based on an agency estimate or property goal identified in a draft or approved red-cockaded woodpecker management plan, or submitted in an Annual Report (2000). See Table 5 for significant support populations on private properties.

Recovery Unit / Property	State	Designation	Current Size	Potential Size[2]
Mid-Atlantic Coastal Plain				
Bladen Lakes State Forest	NC	Important Support	3	3[1]
Hampton Plantation State Park	SC	Important Support	1	1[1]
Jones Lake State Park	NC	Important Support	1	4
Lewis Ocean Bay Heritage Preserve	SC	Significant Support	2	10[1]
Longleaf Pine Heritage Preserve	SC	Important Support	2	4[1]
Military Ocean Terminal Sunny Point	NC	Significant Support	9	17
Sandy Island	SC	Significant Support	32	35[1]
Santee Coastal Reserve	SC	Significant Support	8	16
Singletary Lake State Park	NC	Important Support	4	6
Wedge Plantation	SC	Important Support	2	2[1]
Yawkey Wildlife Center	SC	Significant Support	8	15[1]
subtotal			72	113
Ouachita Mountains				
McCurtain County Wilderness Area	OK	Significant Support	12	44
subtotal			12	44
Piedmont				
Pee Dee National Wildlife Refuge	NC	Significant Support	1	10
Johnston Community College	NC	Important Support	1	1
subtotal			2	11
Sandhills				
Cheraw State Fish Hatchery	SC	Important Support	1	1
Cheraw State Park	SC	Significant Support	7	25
Fort Gordon	GA	Significant Support	5	25
Fort Jackson	SC	Significant Support	24	126
Manchester State Forest	SC	Important Support	3	3[1]
Poinsett Weapons Range	SC	Significant Support	6	30
subtotal			46	210
South Atlantic Coastal Plain				
Charleston Naval Weapons Station	SC	Significant Support	1	12
Persanti Island	SC	Important Support	3	3[1]
Santee State Park	SC	Important Support	1	7[1]
Webb Wildlife Center	SC	Significant Support	12	30[1]
subtotal			17	52

Table continued next page.

TABLE 9 (cont.). Significant and important populations on state and federal properties.

Recovery Unit / Property	State	Designation	Current Size	Potential Size[2]
South/Central Florida				
Central Florida Reception Center - South Unit	FL	Important Support	1	1[1]
Platt Branch Mitigation Park	FL	Important Support	4	7[1]
subtotal			5	8
Upper East Gulf Coastal Plain				
Noxubee National Wildlife Refuge	MS	Significant Support	44	88
subtotal			44	88
Upper West Gulf Coastal Plain				
D'Arbonne National Wildlife Refuge	LA	Important Support	2	5
Felsenthal National Wildlife Refuge	AR	Significant Support	15	34
Huntsville State Fish Hatchery	TX	Important Support	1	1[1]
I. D. Fairchild State Forest	TX	Important Support	4	7
Upper Ouachita National Wildlife Refuge	LA	Important Support	1	1
W. G. Jones State Forest	TX	Significant Support	14	14
subtotal			37	62
West Gulf Coastal Plain				
Alabama-Coushatta Tribe of Texas	TX	Important Support	2	2[1]
Alexander State Forest	LA	Important Support	5	5
Black Bayou National Wildlife Refuge	LA	Important Support	1	1
Evangeline Unit, Calcasieu Ranger District, Kisatchie National Forest	LA	Significant Support	72	231
Kisatchie Ranger District, Kisatchie National Forest	LA	Significant Support	29	292
Peason Ridge	LA	Significant Support	23	120
Winn Ranger District, Kisatchie National Forest	LA	Significant Support	18	263
subtotal			150	914
Outside Recovery Units:				
Pine City Natural Area	AR	Important Support	1	2[1]
Big Branch Marsh National Wildlife Refuge	LA	Significant Support	15	20
subtotal			16	22
TOTAL			**401**	**1524**

[1]Property goal based on U.S. Fish and Wildlife Service or responsible agency's estimate derived by dividing the area of currently or potentially suitable upland pine on the property by 81 ha (200 ac) per cluster.

[2] Except for those potential sizes identified as property goals in approved agency management plans, all other potential sizes are non-binding and subject to change pending approval of site-specific management plans.

8. MANAGEMENT GUIDELINES

The following management guidelines are fundamental to conservation and recovery of red-cockaded woodpeckers. We strongly encourage and recommend the application of these guidelines to the management of all woodpecker populations, including those on private lands. Managers of private lands may choose to substitute guidelines given in Appendix 5 (Private Lands Guidelines) for comparable sections below, but again are encouraged to follow the management guidelines given in this section as these have been designed specifically for population and species recovery.

A. ASSESSING PROGRESS TOWARD RECOVERY

Trends of all populations, but particularly for those identified in recovery criteria, will be monitored closely by the Red-cockaded Woodpecker Recovery Coordinator to ensure that significant progress toward recovery is being made. This assessment is a critical aspect of species conservation, management, and recovery. In this section, we define recommended rate of increase and critical rates of population decline. We identify the schedule by which assessments will be made. We also describe actions to be taken if populations are not increasing at the recommended rate or if populations are declining at a rate equal to or greater than the identified critical values. Monitoring for population size and trend is described in 3A, and population monitoring guidelines are given in 8C.

Guidelines

1. Recommended Rate and Assessment of Population Increase.

Populations are to be increasing at a rate of 5 percent per year. Population trend will be assessed by the Red-cockaded Woodpecker Recovery Coordinator annually using the U.S. Fish and Wildlife Service Annual Report. Depending on the results of annual assessments, and specifically for those populations not increasing at the recommended rate, more thorough 5-year population trend assessments and analyses will be conducted as necessary (see below).

2. Management Review for Populations Not Increasing

For those populations not increasing at the recommended rate, an investigation of which factors are restricting potential increases will be undertaken. Factors to be investigated include:

1.1.1. Condition of nesting habitat within active clusters, including number of suitable cavities and presence of hardwood midstory in clusters.

1.1.2. Condition of foraging habitat corresponding to active clusters, including age, size, and density of pines, height and density of pine and hardwood midstory, percent of canopy hardwoods, and presence of herbaceous groundcover.

1.1.3. Number of recruitment clusters available, and their placement within the landscape.

1.1.4. Condition of recruitment clusters, including condition of nesting and foraging habitat as indicated by variables listed in 1.1.1. and 1.1.2.

Once factors potentially limiting population growth have been identified, implementation of management plans will be changed accordingly. If management plans require adjustment, re-initiation of consultation with the U.S. Fish and Wildlife Service will be strongly recommended.

3. Critical Rate and Assessment of Population Decline

It is essential to conservation and recovery of red-cockaded woodpeckers that population declines be detected quickly and accurately. Population declines can occur in various forms, such as a sudden large drop or a small, slow, steady decrease in size. We therefore define critical population decline in two different ways. A population is considered declining if either of the following criteria is met:

(1) number of active clusters decreases by 10% from one year to the next.
(2) number of active clusters decreases by 10% within five years.

Captured clusters must not be included in this calculation. Each year, the Red-cockaded Woodpecker Recovery Coordinator will assess population trend for evidence of critical decline.

4. Re-initiation of Consultation for Critically Declining Populations

If populations are found to be declining at or above these critical rates, re-initiation of consultation with the US Fish and Wildlife Service will be strongly recommended. Review and adjustment of management plans and their implementation is the only appropriate response to such evidence. Declining populations are not eligible to act as a donor population for translocation (8H). Ineligibility will remain in place until populations once again meet the criteria for donor populations (8H).

Early indicators of population decline include a decreasing proportion of groups that contain potential breeding groups, increasing proportions of solitary males and/or captured clusters, and decreases in mean group size. Currently, a population exhibiting an increasing proportion of solitary males, captured clusters, or a decline in mean group size will not be formally considered critically declining populations, if number of active clusters is not declining as described above. However, this is important evidence of a population in poor health and managers are strongly encouraged to review and adjust management actions accordingly. In the future, the U.S. Fish and Wildlife Service may develop an additional definition of a critically declining population based on number of potential breeding groups, which would give an earlier indication of decline than current definitions.

5. Annual Reporting

Assessing progress toward recovery is highly dependent on conscientious reporting. Managers and researchers are required to submit an Annual Report to the Red-cockaded Woodpecker Recovery Coordinator. The Annual Report contains results of annual population monitoring and a description of management actions, including management of cavities and clusters, management and restoration of foraging habitat, and translocation if used.

TABLE 10. Worksheet to assess population trend for all primary core, secondary core, and essential support populations, sorted by recovery unit. This table presents expected population size (number of active clusters; ACT) at 5-year intervals under 5 percent annual increase through estimated time of delisting. Populations are to be increasing at this rate until the species is delisted or until the property goal is reached. Property goals are derived directly from agency or site-specific management plans, except where noted. Also listed is minimum population size required for delisting (potential breeding groups). Number of active clusters is equivalent to 1.1 – 1.4 times the number of potential breeding groups. Updates of this table will be provided on the Red-cockaded Woodpecker Recovery web page (http://rcwrecovery.fws.gov).

Recovery Unit / Population / Property	**Delisting Size (PBG)**	**Expected Size Based on Recommended Rate of Increase (ACT)**																
		2000	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**2055**	**2060**	**2065**	**2070**	**2075**	**2080**
Cumberlands/Ridge and Valley																		
Talladega/Shoal Creek	100																	
Shoal Creek RD		6	8	10	12	16	20	26	33	42	54	69	88	112	125	125	125	125
Talladega RD		0	5	6	8	10	13	17	22	28	35	45	57	73	93	110	110	110
East Gulf Coastal Plain																		
Central Florida Panhandle	1000																	
Apalachicola RD		486	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Ochlockonee River SP[1]		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
St. Mark's NWR		9	11	15	19	24	30	39	50	63	71	71	71	71	71	71	71	71
Tate's Hell SF[1]		29	37	47	60	77	98	125	160	204	261	333	400	400	400	400	400	400
Wakulla RD		138	176	225	287	366	467	506	506	506	506	506	506	506	506	506	506	506
Chickasawhay	350																	
Chickasawhay RD		15	19	24	31	40	51	65	83	106	135	172	220	280	358	456	502	502
Conecuh/Blackwater	250																	
Blackwater River SF		26	33	42	45	45	45	45	45	45	45	45	45	45	45	45	45	45
Conecuh NF		18	23	29	37	48	61	78	99	127	162	206	263	309	309	309	309	309
DeSoto	250																	
DeSoto RD		7	9	11	15	19	24	30	39	49	63	80	102	131	167	213	272	347[2]
Eglin	350																	
Eglin Air Force Base		301	384	490	500	500	500	500	500	500	500	500	500	500	500	500	500	500

Table continued next page.

TABLE 10 (cont.). Worksheet to assess population trend for all primary core, secondary core, and essential support populations.

Recovery Unit Population Property	Delisting Size (PBG)	Expected Size Based on Recommended Rate of Increase (ACT)																
		2000	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**2055**	**2060**	**2065**	**2070**	**2075**	**2080**
East Gulf Coastal Plain (cont.)																		
Homochitto	250																	
Homochitto NF		51	65	83	106	135	173	220	254	254	254	254	254	254	254	254	254	254
Mid-Atlantic Coastal Plain																		
Coastal North Carolina	350																	
Croatan NF		62	79	101	129	165	169	169	169	169	169	169	169	169	169	169	169	169
Holly Shelter Game Lands		38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38
MCB Camp Lejeune		59	75	96	123	157	173	173	173	173	173	173	173	173	173	173	173	173
Francis Marion	350																	
Francis Marion NF		344	439	453	453	453	453	453	453	453	453	453	453	453	453	453	453	453
Northeast North Carolina/ Southeast Virginia	100																	
Alligator River NWR		3	4	5	6	8	10	13	17	20	20	20	20	20	20	20	20	20
Dare Co. Bombing Range		3	4	5	6	8	10	13	17	21	17	34	44	46	46	46	46	46
Palmetto-Peartree Preserve		25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Piney Grove Preserve		3	4	5	6	8	10	10	10	10	10	10	10	10	10	10	10	10
Pocosin Lakes NWR		1	1	2	2	3	3	4	6	7	9	11	15	19	24	30	39	50
Ouachita Mountains																		
Ouachita	250																	
Ouachita NF		21	27	34	44	56	71	91	116	148	189	241	307	392	400	400	400	400

Table continued next page.

TABLE 10 (cont.). Worksheet to assess population trend for all primary core, secondary core, and essential support populations.

Recovery Unit / Population / Property	Delisting Size (PBG)	Expected Size Based on Recommended Rate of Increase (ACT)																
		2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080
Piedmont																		
Oconee/Piedmont	250																	
Oconee NF		20	26	33	42	53	68	86	110	141	176	176	176	176	176	176	176	176
Piedmont NWR		39	50	64	81	96	96	96	96	96	96	96	96	96	96	96	96	96
Sandhills																		
Fort Benning	350																	
Fort Benning		219	280	357	450	450	450	450	450	450	450	450	450	450	450	450	450	450
North Carolina Sandhills East	350																	
Calloway Tract		5	6	8	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Carver's Creek Tract		4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Fort Bragg		350	436	436	436	436	436	436	436	436	436	436	436	436	436	436	436	436
McCain Tract		5	6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Weymouth Woods SNP		7	9	11	13	13	13	13	13	13	13	13	13	13	13	13	13	13
North Carolina Sandhills West	100																	
Camp Mackall		11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Sandhills Game Lands		134	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160
South Carolina Sandhills	250																	
Carolina Sandhills NWR		116	148	189	193	193	193	193	193	193	193	193	193	193	193	193	193	193
Sand Hills SF[1]		51	65	83	106	135	143	143	143	143	143	143	143	143	143	143	143	143
South Atlantic Coastal Plain																		
Fort Stewart	350																	
Fort Stewart		212	271	345	441	500	500	500	500	500	500	500	500	500	500	500	500	500
Osceola/Okefenokee	350																	
Okefenokee NWR		37	47	60	77	86	86	86	86	86	86	86	86	86	86	86	86	86
Osceola NF		63	80	103	131	167	213	272	348	444	462	462	462	462	462	462	462	462

Table continued next page.

TABLE 10 (cont.). Worksheet to assess population trend for all primary core, secondary core, and essential support populations.

Recovery Unit Population Property	Delisting Size (PBG)	Expected Size Based on Recommended Rate of Increase (ACT)																
		2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080
South Atlantic Coastal Plain (cont.)																		
Savannah River	250																	
Savannah River Site		34	43	55	71	90	115	147	188	239	305	390	418	418	418	418	418	418
South/Central Florida																		
Avon Park	40																	
Avon Park Air Force Range		21	27	34	44	56	68	68	68	68	68	68	68	68	68	68	68	68
Kicco WMA[1]		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Babcock/Webb	40																	
Babcock/Webb WMA[1]		27	34	44	56	72	91	117	149	190	240	240	240	240	240	240	240	240
Big Cypress	40																	
Big Cypress NP		42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42
Camp Blanding	25																	
Camp Blanding Training Site		14	18	23	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Corbett/Dupuis	40																	
J. W. Corbett/Dupuis WMA[1]		13	17	21	27	34	44	56	72	90	90	90	90	90	90	90	90	90
Goethe	40																	
Goethe SF		30	38	49	62	80	102	130	150	150	150	150	150	150	150	150	150	150
Hal Scott	15																	
Hal Scott Preserve[1]		7	9	11	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Ocala	40																	
Ocala NF		22	28	36	46	58	74	95	121	155	179	179	179	179	179	179	179	179
Picayune Strand	25																	
Picayune Strand SF[1]		3	4	5	6	8	10	13	17	21	25	25	25	25	25	25	25	25

Table continued next page.

TABLE 10 (cont.). Worksheet to assess population trend for all primary core, secondary core, and essential support populations.

Recovery Unit / Population / Property	Delisting Size (PBG)	Expected Size Based on Recommended Rate of Increase (ACT)																
		2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080
South/Central Florida (cont.)																		
St. Sebastian River	25																	
St. Sebastian River SBP		8	10	13	17	21	25	25	25	25	25	25	25	25	25	25	25	25
Three Lakes	40																	
Three Lakes WMA[1]		51	65	83	106	125	125	125	125	125	125	125	125	125	125	125	125	125
Withlacoochee – Citrus Tract	40																	
Withlacoochee – Citrus		46	59	75	96	100	100	100	100	100	100	100	100	100	100	100	100	100
Withlacoochee –Croom Tract	30																	
Withlacoochee – Croom		5	6	8	10	13	17	22	28	30	30	30	30	30	30	30	30	30
Upper East Gulf Coastal Plain																		
Bienville	350																	
Bienville NF		104	133	169	216	276	352	449	500	500	500	500	500	500	500	500	500	500
Oakmulgee	250																	
Oakmulgee RD		110	140	179	229	292	372	394	394	394	394	394	394	394	394	394	394	394
Upper West Gulf Coastal Plain																		
Sam Houston	350																	
Sam Houston NF		168	214	274	349	446	541	541	541	541	541	541	541	541	541	541	541	541
West Gulf Coastal Plain																		
Angelina/Sabine	350																	
Angelina NF		29	37	47	60	77	98	125	160	204	252	252	252	252	252	252	252	252
Sabine NF		28	36	46	58	74	95	121	154	197	252	262	262	262	262	262	262	262

Table continued next page.

TABLE 10 (cont.). Worksheet to assess population trend for all primary core, secondary core, and essential support populations.

Recovery Unit Population Property	Delisting Size (PBG)	Expected Size Based on Recommended Rate of Increase (ACT) 2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080
West Gulf Coastal Plain (cont.)																		
Catahoula	250																	
Catahoula RD		32	41	52	67	85	108	138	177	225	288	317	317	317	317	317	317	317
Winn RD (portion)		5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Davy Crockett	250																	
Davy Crockett NF		53	68	86	110	141	179	229	292	330	330	330	330	330	330	330	330	330
Vernon/Fort Polk	350																	
Fort Polk		46	59	75	96	122	156	179	179	179	179	179	179	179	179	179	179	179
Vernon Unit		152	194	248	302	302	302	302	302	302	302	302	302	302	302	302	302	302

[1]For these properties for which no management plan is available, property goals are non-binding estimates only and are subject to change when management plans are drafted and approved.

[2]Population goal is 386. However, 347 active clusters will provide at least the 250 potential breeding groups needed for delisting.

B. USE OF RECRUITMENT CLUSTERS

Substantial increases in population sizes are required to achieve recovery of red-cockaded woodpeckers (see 8A). Proper management of the nesting and foraging habitat of existing groups (see 8E, 8F, 8I) is a prerequisite for population increase, but recent research and experience strongly indicate that management of existing groups by itself is not sufficient to bring about the rates of increase necessary for recovery. Because population dynamics of red-cockaded woodpeckers are regulated by the number of potential breeding groups (see 2B), substantial increases in population size are best obtained through continued addition of recruitment clusters. Therefore, we have developed the following guidelines for the use of recruitment clusters in all populations being managed for increasing population size. Recruitment clusters are clusters of artificial cavities in habitat containing mature and old pines (greater than 60 years in age), with little or no hardwood midstory and a healthy grass and forb groundcover (see 2D for discussion of cluster ecology and 8F for cluster management guidelines).

Guidelines

1. Recommended Number of Recruitment Clusters: To achieve recommended rates of increase (8A), provide a constant supply of unoccupied recruitment clusters equal to 10 percent of total active clusters in the population. As recruitment clusters become occupied, establish additional recruitment clusters on an annual basis to sustain the required pool of unoccupied recruitment clusters. Do not establish more recruitment clusters than can reasonably be occupied within 1 to 3 years.

An exception to this guideline is made for recruitment clusters used in reintroductions or the development of new population segments (a set of clusters in suitable habitat somewhat removed from other groups). For these purposes, a number of recruitment clusters greater than 10 percent of active clusters may be used. These management actions will always be conducted using translocations of multiple potential pairs. Typically, for translocations of multiple potential pairs, two recruitment clusters will be established for each pair of birds being translocated.

2. Placement of Recruitment Clusters: Placement of recruitment clusters is critical to successful use. Place recruitment clusters no closer than 0.4 km (0.25 mi) to existing active clusters, to reduce the likelihood of capture by an existing group. Place recruitment clusters no farther than 3.2 km (2 mi), and preferably no farther than 1.6 km (1 mi), from existing active clusters to facilitate occupation and to develop beneficial spatial arrangements and densities within the population (see 2C).

Recruitment clusters for use in reintroduction or for developing a new segment of a population are exempt from this recommendation. Recruitment clusters for these purposes must be highly aggregated.

Recent research performed with a spatially explicit, individual based model of population dynamics (see 2C) has indicated that edges of populations are particularly vulnerable to decay from disrupted dispersal. Maintain group densities as high as possible throughout the population, and pay particular attention to population edges.

3. Recruitment Cluster Requirements:

a. Nesting and Roosting Habitat. Provision recruitment clusters with three suitable cavities and two starts, or four suitable cavities, when first installed. Once the cluster is occupied, ensure that a minimum of four suitable cavities is maintained. See 3B and 8E for further details concerning the definition of suitable cavities and recommended methods for constructing artificial cavities and starts.

b. Foraging Habitat. We anticipate that much of the foraging habitat assigned to recruitment clusters may not meet all elements of good quality foraging habitat as described under the recovery standard (8I). If the recovery standard is not met, then assign each recruitment cluster at least 49 ha (120 ac) of foraging habitat that meets elements (b, c, d, f, g, h, and i), and additionally, stands should contain no more than 70 ft^2/ac basal area in total. Within this habitat, restore habitat structure and encourage the development of old pines so that all elements of the recovery standard can be met in the future.

C. Population Monitoring

Population monitoring is an essential aspect of red-cockaded woodpecker management and recovery. Only through accurate monitoring can we determine the success and failure of our management actions, and adapt these actions accordingly. Appropriate intensity of monitoring varies with population size, role in recovery, and management objectives. In section 3A and Appendix 2 we describe basic monitoring techniques. In this section, we present guidelines for determining recommended monitoring levels for individual populations.

Guidelines

1. In primary core, secondary core, and essential support populations, monitor number of active clusters and number of potential breeding groups so that population trend and size can be determined. Follow directions for monitoring number of active clusters and potential breeding groups given in 3A. Use random sampling without replacement to select a sample of the size recommended in Table 11. For populations in which no banding is being conducted, select random samples annually. For populations in which some groups are banded, select random samples at 5-year intervals; within this five-year

period, samples remain fixed. Use stratified random sampling whenever appropriate (see 3A).

2. In critically small populations (less than 30 potential breeding groups) on federal and state lands, monitor number of active clusters, number of potential breeding groups, group size, and reproductive success. Follow directions for monitoring number of active clusters and potential breeding groups in 3A, and for group size and reproductive success given in Appendix 2. Sample the population completely. These populations are to be completely color-banded, to enable the monitoring of group size and reproductive success. In addition, this level of monitoring is required to receive translocated birds from donor populations.

3. In populations containing mitigation sites, monitor number of active clusters and number of potential breeding groups as recommended for recovery populations (see above). In addition, monitor group size and reproductive success in the neighborhood of the mitigation site both before and after the installation of mitigation sites, until successful mitigation is completed. Follow directions for monitoring number of active clusters and potential breeding groups in 3A, and for group size and reproductive success given in Appendix 2.

4. In populations serving as mitigation banks or planned as future mitigation banks, monitor number of active clusters and number of potential breeding groups as recommended for recovery populations (see above). In addition, monitor group size and reproductive success by maintaining a completely color-banded population. Follow directions for monitoring number of active clusters and potential breeding groups in 3A, and for group size and reproductive success given in Appendix 2.

5. For other populations, publicly or privately owned, we strongly recommend that the above monitoring guidelines be followed.

TABLE 11. Recommended sample sizes for monitoring number of active clusters (ACT) and potential breeding groups (PBG) in red-cockaded woodpecker populations, by population size.

	Population Size (PBG)				
Parameter	**<30**	**30 - 99**	**100 – 249**	**250 - 349**	**≥ 350 or at approved property goal**
ACT	100% of potentially active clusters per year	100% per year	100% per year	100% every 2 yrs.	consult with FWS
PBG	100% of potentially active clusters per year	100% per year	50% per year	33% per year	consult with FWS

6. For those populations and or forests that have suffered catastrophic losses of habitat and or red-cockaded woodpeckers, individualized habitat and population monitoring programs will be developed in consultation with the U.S. Fish and Wildlife Service.

D. HABITAT MONITORING

The primary cause of species decline was sharp decreases in the quantity and quality of habitat (1A), and habitat limitations remain a major threat to species recovery (1B). It is therefore critical to species recovery that quantity and quality of habitat be closely monitored. We give specific guidelines for habitat monitoring in several different sections of this plan. Here we briefly summarize them and refer the reader to relevant sections.

1. Monitoring Nesting/Roosting Habitat

a. Number of Suitable Cavities per Cluster. Assess number of suitable cavities in each cluster at recommended frequencies based on population size. See 8E for sampling frequency and definition of a suitable cavity. These assessments are best conducted during cluster activity checks (March – July). If populations with a designated recovery role are not increasing at recommended rates (8A), or if they are found to be declining at or above the identified critical values of decline (8A), number of suitable cavities per cluster will be reviewed by the Red-cockaded Woodpecker Recovery Coordinator.

b. Habitat Structure within Clusters. Maintain clusters that are free of pine and hardwood midstory, as described in 8F. If populations with a designated recovery role are not increasing at recommended rates (8A), or if they are found to be declining at or above the identified critical values of decline (8A), habitat structure within clusters will be reviewed by the Red-cockaded Woodpecker Recovery Coordinator.

2. Monitoring Foraging Habitat

Assess quality and quantity of foraging habitat at a minimum frequency of once every 10 years, with the exception of midstory which is to be assessed at a minimum frequency of once every 5 years. More frequent assessments are encouraged. Evaluate foraging habitat for all habitat elements described within the recovery standard (8I), including ages of pines, pine size class distribution, presence of hardwood midstory, and percent native, site-appropriate, herbaceous groundcover. More information on monitoring these elements is given in 8I. Ensure that substantial progress toward meeting all elements put forth in the recovery standard is made. If populations with a designated recovery role are not increasing at recommended rates (8A), or if they are found to be declining at or above the identified critical values of decline (8A), quality and quantity of foraging habitat will be reviewed by the Red-cockaded Woodpecker Recovery Coordinator.

3. Documenting Prescribed Fire

Keep accurate and detailed records of all prescribed burns.

4. Reporting

Report results of all habitat monitoring and history of prescribed burns to the Red-cockaded Woodpecker Recovery Coordinator using the Annual Report.

E. Cavity Management, Artificial Cavities, and Restrictor Plates

Maintaining an adequate number of suitable cavities in each woodpecker cluster is fundamental to the recovery of the species. Loss of cavity trees was a major factor in the species' decline (see 1A), and availability of cavity trees currently limits many populations. This limitation will remain in effect until large old pines are restored throughout the lands managed for red-cockaded woodpeckers. Until large old pines become widely available, artificial cavities and restrictor plates are essential management tools that can bring about population increases, if used carefully and in suitable habitat.

Here we present guidelines for the use of artificial cavities and restrictor plates. The role of cavities in population dynamics and the cooperative breeding system of red-cockaded woodpeckers is discussed in 2B. Further information concerning nesting ecology is provided in 2D. Descriptions of artificial cavity construction techniques and their usefulness are given in 3B. Restrictor plates are also discussed in 3B, and cavity enlargement in general is described in sections 2F and 3B.

Guidelines

1. Monitor the cavity resource. Assess the number of suitable cavities in each potentially active cluster at a frequency determined by the size of the population (Table 12). Conduct these assessments in March – July. A suitable cavity has a single entrance, an entrance tunnel that is not enlarged, a cavity chamber that is not enlarged, a solid base, and is dry and free of debris. In addition, the cavity plate must not contain large amounts of dead wood. Relict, enlarged, or any suspect cavities must not be considered suitable for use by red-cockaded woodpeckers. Suitable cavities may be either naturally excavated or artificially constructed. If a restrictor is present, it must be inspected for safety during cavity suitability assessments.

To conduct this assessment, examine all unenlarged cavities internally by climbing the tree or using a video 'peeper'. An enlarged cavity is unsuitable unless a restrictor is installed and the cavity is otherwise found to be suitable by internal inspection.

TABLE 12. Frequency of cavity suitability assessment by population size and trend (see 8A for definitions of trend).

Population Size (potential breeding groups)		
< 100	**100 to 349**	**≥ 350 or at approved property goal**
100% of all cavities per year	50% of all cavities if not increasing at recommended rate	50% of all cavities if decreasing by the critical rate or more

2. Maintain the recommended number of suitable cavities in each cluster.

    a. Maintain at least four suitable cavities in each active cluster, in all populations not meeting population size goals identified in delisting criteria (6) or in approved management plans. However, ensure there are sufficient cavities for all group members post-breeding season.

    b. Maintain at least four suitable cavities (or three suitable cavities and two starts) in each unoccupied recruitment cluster, in all populations not meeting population goals identified in delisting criteria (6) or in approved management plans.

    c. Do not provision excessive numbers of artificial cavities within active or recruitment clusters. Count natural suitable cavities first, then install artificial cavities as necessary to make four to six suitable cavities.

3. Use the appropriate method of cavity construction. See 3B for more information.

    a. Use the Copeyon-drilled method when heartwood is sufficient to house the cavity.

    b. Use drilled starts when heartwood is insufficient to house the cavity and cavities are not needed for a year or more. Provide more than one start for each new cavity desired.

    c. Use cavity inserts when heartwood is insufficient to house a drilled cavity and cavities are needed as soon as possible. Inserts must always be used with full restrictor plates, and all inserts must be coated with a thick layer of non-toxic sealant such as non-toxic polyurethane glue (e.g. EXCEL ONE) or wood putty. Annual maintenance of cavity inserts prolongs their suitability and minimizes potential injury or mortality to red-cockaded woodpeckers.

    d. Avoid using the modified-drilled method (see 3B).

4. Install artificial cavities as close to existing cavity trees as possible, preferably within 71 m (200 ft.).

5. If installing a cavity insert, select a tree that is greater than 45 years old but not a relict, flat-top, or very old pine.

6. Select the appropriate location on the tree. Place artificial drilled cavities as high as heartwood diameter of the recipient tree will allow. Do not place cavities above or below the range of natural cavity heights in the surrounding area. Orient entrances so that they are facing west, if possible.

7. Protect the birds from sap leakage. Ensure that no artificial cavity has resin leaking into the chamber or entrance tunnel.

a. Prior to installation, coat all inserts with a thick layer of non-toxic sealant such as non-toxic polyurethane glue or wood putty. Do not use toxic coatings or inserts without coatings.

b. Screen all drilled starts and drilled cavities with heavy wire mesh (0.64 by 0.64 cm [0.25 by 0.25 in]) for at least four weeks following installation.

c. Inspect cavity interiors when the screens are removed. If resin leaks are detected, keep the screens on and conduct additional checks. Persistent resin leaks into entrance tunnels can be treated with repeated scraping, application of wood putty, replacement of veneer, or redrilling. If severe leaks continue, block the cavity with a wooden plug at least 7.6 cm (3 in) long, and construct a replacement cavity.

d. Construct artificial cavities and starts between August and March to reduce likelihood of leaks.

e. Check all new artificial cavities and starts for resin leaks during or just prior to the first breeding season following installation, and screen or plug those found to be leaking.

f. During cavity suitability assessment (1, above), replace, screen, or plug any insert found to be dangerously faulty (i.e., containing or likely to contain resin in the interior).

8. Use cavity restrictors judiciously to control cavity enlargement.

a. Use only when necessary on active cavities. Do not restrict all cavities. Slightly enlarged cavities may be restricted but do not use to repair excessively enlarged cavities.

b. Use restrictors on a cluster-by-cluster basis to minimize potential damage to any cavity, natural or artificial, by pileated woodpeckers. Only use restrictors if there is a known problem with enlargement by pileated woodpeckers or there is a good possibility, based on past experience, that cavities may be damaged.

c. Use full restrictors on all cavity inserts and previously installed modified-drilled cavities.

d. Inspect all restrictors at least once each year and repair if loose or out of place. Do not use restrictors if annual inspections cannot be performed.

e. Do not use on unenlarged cavities for the purpose of excluding cavity kleptoparasites.

F. CLUSTERS AND CAVITY TREES

Conservation and recovery of red-cockaded woodpeckers in today's second- and third-growth forests requires skillful management of their cavity trees and clusters. Successful cluster management consists of three main programs: (1) protection of existing cavity trees, (2) development and protection of sufficient large, old pines for future cavity trees, and (3) restoration and maintenance of appropriate habitat structure, including no hardwood midstory, low densities of small pines, low to moderate densities of large pines, and abundant native grass and forb groundcovers. We recommend the removal of excessive overstory hardwoods in regions where fire suppression has resulted in the establishment of large hardwood trees. We also recommend that human disturbance within the cluster be minimized.

In this section, we provide guidelines for management of cavity trees and clusters. Information concerning nesting ecology is given in 2D. Any discussion of nesting ecology is not complete without considering fire. The role of fire in the southeastern pine ecosystem, prescribed burning as a management tool, and guidelines for the use of prescribed fire are discussed in sections 2G, 3F, and 8K, respectively.

To facilitate management and conservation, we use a management-based definition of a cluster for these guidelines. Here, the cluster is the minimum convex polygon containing all cavity trees in use by a group of red-cockaded woodpeckers *and* a 61 m (200 ft) wide buffer of continuous forest surrounding the minimum convex polygon. The cluster must contain a minimum of 4.0 ha (10 ac). Recommendations for cluster management apply to the entire cluster; that is, these guidelines apply to the buffer as well as the minimum convex polygon containing all cavity trees.

Guidelines

1. Protect existing cavity trees.

    a. Reduce risk of accidental damage or removal. Mark cavity trees for easy identification.

    b. Protect against fire damage. The application of regular, frequent fire in the clusters is the best method of protecting cavity trees against damage from fires (prescribed or wild) that are too intense. Until cavity trees are no longer a limiting resource, use one or more additional methods of protecting individual cavity trees presented in 8K.

    c. Protect cavity tree roots. Prohibit, with rare exceptions, the use of heavy machinery and vehicles within 15.25 m (50 ft) of cavity trees, and do not use at all within 15.25 m (50 ft) of cavity trees in wet areas. Do not establish plow lines within 61 m (200 ft) of cavity trees.

    d. Protect against southern pine beetle infestations. Thin dense loblolly and shortleaf pine forests regularly to maintain basal areas of less than 18.4 m^2/ha (80 ft^2/ac) or to maintain a minimum average spacing of 7.6 m (25 ft) between trees. Minimize physical disturbance to soil and roots during management operations such as thinning, midstory reduction, and prescribed burning.

    e. Reduce risk of damage from high winds. Retain a 61 m (200 ft) wide buffer of continuous forest around the minimum convex polygon containing each group's set of cavity trees, as part of the cluster. Consider retaining an additional buffer and minimize the establishment of openings adjacent to the cluster. Over time, risk of wind damage can be reduced by the development of an open habitat structure that encourages the growth of wind-resistant trees. Conversion to longleaf pine, where appropriate, also can reduce risk from winds.

2. Develop sufficient large and old pines to serve as cavity trees.

    a. Retain all potential cavity trees (pines greater than 60 years in age) within clusters, unless pine basal area is above 11.5 m^2/ha (50 ft^2/ac) and all trees are above 60 years in age.

    b. Supply trees for future cavity trees and clusters in abundance. Grow large, old pines throughout the landscape managed for red-cockaded woodpeckers (see 3E, 8J).

c. If potential cavity trees are rare, consider protecting them from fire, root damage, and other potential risks as described above for existing cavity trees.

3. Restore and maintain appropriate habitat structure.

a. Control hardwood and pine midstory. Apply prescribed fire to the entire cluster every one to five years, preferably during the growing season. This will maintain a cluster that is relatively free of midstory. If necessary, remove excessive hardwoods by hand (with chainsaws and brushhooks), mechanical means such as brush-hogging or mulching, one-time application of herbicides to live trees or stumps, or a combination of these methods. Mechanized equipment for the purpose of hardwood control will not be used within the cluster when woodpeckers are nesting. Broadcasting herbicides by hand within the cluster is permitted during nesting season. Recently abandoned clusters should be managed with the same intensity as active clusters.

b. Foster native grasses and forbs. Native grasses and forbs facilitate prescribed burning and are maintained by prescribed burning. Apply frequent growing season fire and avoid soil disturbance that negatively impacts fragile ground covers. Restrict vehicle use to existing roads and prohibit use of off-road vehicles in clusters.

c. Reduce excessive overstory hardwoods within the cluster. Overstory hardwoods within the cluster should not total more than 2.3 m^2/ha (10 ft^2/ac) in basal area. Remove all hardwoods within 50 ft. of cavity trees.

Retain natural oak inclusions of upland species, such as post, blackjack, turkey, and bluejack oak, within the cluster if they are considered a historic component of the site prior to fire suppression. The area occupied by these oaks is not counted toward the required minimum 4.0 ha (10 ac). These historic oak inclusions should be managed with prescribed fire and artificial cavities should not be installed near them. Overstory trees of mesic hardwood species such as sweetgum (*Liquidambar styraciflua*) and maples (*Acer* spp.) are generally considered undesirable components of fire suppression and are to be removed from red-cockaded woodpecker clusters.

d. Locate recruitment clusters away from stream drainages whenever possible. Although some clusters naturally occur in wetland habitats, use of upland sites as recruitment clusters whenever possible can reduce midstory encroachment associated with mesic hardwoods.

e. Retain dead and dying cavity trees and all other snags, unless they present a safety hazard.

4. Reduce human disturbance within clusters as much as possible, especially during nesting season. As a minimum, follow these guidelines:

a. Restrict vehicle use to existing roads. Avoid construction of new roads and trails (for motorized and unmotorized use) within clusters.

b. Limit pine and hardwood silvicultural and cultural operations to daylight hours; avoid these activities within at least one or two hours of dawn and dusk.

c. Military training activities are restricted to those specified in installation-specific management plans approved through consultation with the U.S. Fish and Wildlife Service.

d. Use of mechanized equipment in a cluster is permitted during the non-breeding season for red-cockaded woodpecker management activities only (e.g., mechanical midstory reduction).

e. Habitat management activities other than prescribed burning, for example timber thinning and hardwood midstory control, are prohibited during the breeding season (April – July).

G. PREDATORS AND CAVITY KLEPTOPARASITES

Red-cockaded woodpecker populations that are healthy and of medium to large size require no predator control and few measures to combat cavity kleptoparasites. Predators and cavity kleptoparasites were not among the original causes of decline (see 1A), and their removal will not result in population increases. Occasional loss of nests to predators does not affect population size or trend in larger populations. Maintaining good quality nesting and foraging habitat, and retaining snags throughout the landscape, are the recommended management tools to control kleptoparasitism in all but the smallest populations.

Managers of critically small populations of red-cockaded woodpeckers (less than 30 potential breeding groups), especially those in shortleaf and loblolly pine habitats, may choose to use exclusion devices and other methods for predator/kleptoparasite control. A less invasive technique, bark-shaving, may be employed in any population to protect newly installed artificial cavities. However, further research into direct and indirect species interactions is necessary before the full consequences of such control are understood.

We present guidelines for the use of predator and kleptoparasite control below. Research supporting these guidelines is described in detail in 2F. The techniques themselves are described in 3C. Control of cavity enlargement through the use of restrictor plates is required in many populations regardless of population size, and is discussed in 3B and 8E.

Guidelines

1. Use methods of predator control only in small populations (less than 30 potential breeding groups).

2. If snake control measures are considered necessary, use the bark-scraping procedure or metal snake excluders and restrict this use to trees containing newly installed artificial cavities or to active trees with minimal resin that are likely to be used as nest sites. Do not use snake nets—their use is prohibited because of risk to red-cockaded woodpeckers.

3. If flying squirrel control measures are considered necessary, avoid lethal methods if possible; use flying squirrel excluder devices or removal.

4. Retain snags in clusters and throughout the landscape, and consider the protection of snags in active clusters during prescribed burns.

5. Consider using nest boxes for species other than red-cockaded woodpeckers.

H. TRANSLOCATION

Translocation is an important management tool for small or disjunct populations to be used only in conjunction with aggressive management of nesting and foraging habitat. All translocations should serve to enhance the spatial structure of the population. Potential breeding groups should be developed in locations carefully chosen to link isolated groups or population segments and increase territory density. We refer to this critical management concern as strategic recruitment. Strategic recruitment is accomplished by translocating birds from within or outside the population to (1) unoccupied recruitment clusters or (2) clusters containing solitary birds.

Translocation of birds within populations is conducted solely for the purpose of strategic recruitment. Translocation of birds from donor to recipient populations may be used for population augmentation (increasing the size of the recipient population), mitigation (see 4A), and reintroduction (establishment of a population). Again, translocation for population augmentation, mitigation, or reintroduction must also serve to create beneficial spatial arrangements of groups. See 8B for guidelines governing the use of recruitment clusters. See 3D for background information concerning translocation. Use of translocation for any purpose requires permits from the U.S. Fish and Wildlife Service as discussed in Appendix 1. Use of reintroduction requires consultation with the U.S. Fish and Wildlife Service.

Guidelines

1. Populations Eligible for Within-population Translocation.— Birds can be translocated within a population if the population meets each of the following requirements:

a. Full administrative support, including valid state and federal permits and staff well trained in the handling, banding, and transport of birds;

b. A management plan approved by the U.S. Fish and Wildlife Service that includes each of the following.

i. Population monitoring at recommended levels (3A, 8C).

ii. A prescribed burning program for both nesting and foraging habitat in place.

iii. Specific identification of objectives and locations of the proposed translocations. Objective of proposed translocations should include definitions of target areas (the area in which birds must be found for the translocation to be judged successful; see 3D).

c. Recipient clusters that are in excellent condition, with a minimum of four suitable cavities per cluster, no or very low midstory within the cluster, and suitable foraging habitat (see 8B, 8E, 8I). Generally, provide no more than two recruitment sites for each potential pair moved (but see 3B).

2. Populations Eligible for Augmentation. A population can receive birds from a donor population (augmentation) if the receiving population or a demographically isolated population segment of the receiving population contains fewer than 30 potential breeding groups, has a population goal of and current habitat capacity to support at least 10 active clusters, and meets criteria a, b, and c listed above.

Not all populations eligible for augmentation will receive birds, because available birds are limited. Whether or not a population receives birds is decided annually based on population need and importance to species recovery.

3. Populations Eligible to Donate Birds. Eligibility criteria for donor populations differ by role in recovery.

a. Populations designated as recovery populations may donate birds for translocation if one of the following conditions is met:

i. The population has reached the size required for delisting, and population trend is stable or increasing,

ii. The population is within 75 percent of its population goal (based on designated habitat), at least 50 active clusters in size, and population trend is increasing at 3 percent annually or more, or

iii. The population is at least 100 active clusters in size and population trend is stable or increasing, or

iv. The population contains multiple properties and the donor property has attained its property goal.

b. Populations not designated as recovery populations may donate birds for translocation if one of the following conditions is met:

i. The population goal (based on designated habitat) has been met, and population trend is stable or increasing,

ii. The population is within 75 percent of its goal (based on designated habitat), at least 50 active clusters in size, and population trend is increasing at 3 percent annually or more, or

iii. The population is at least 100 active clusters in size and population trend is stable or increasing.

Populations that do not meet one or more of the criteria identified above (3a, 3b) may serve as donor populations on a case-by-case basis to be evaluated through consultation with the U.S. Fish and Wildlife Service. Factors considered during the consultation process will include, but not be limited to: (1) benefit to recovery, (2) value to the recipient population, and (3) agency or landowner objectives, and (4) population size and trend.

4. Matching Recipient Populations with Appropriate Donors. Translocations will be conducted within recovery units whenever possible. This is to maintain genetic integrity and enhance translocation success by accommodating local adaptations of translocated birds, to the maximum extent possible. Translocations between non-adjacent recovery units are prohibited, except in extenuating circumstances to be determined by consultation with the U.S. Fish and Wildlife Service.

5. Recipient Clusters. Translocate birds only to clusters that are:

a. Within 3.2 km (2 mi) of an occupied cluster. This guideline applies to all translocations, whether the translocation is within a population, between populations, to an unoccupied cluster, or to a cluster containing a solitary individual. The only exception to this guideline is translocation of multiple potential pairs into the same target area, which may be unoccupied or sparsely occupied. The purpose of this guideline, and its exception, is to ensure that all translocations serve to develop a beneficial, highly aggregated spatial arrangement of groups.

b. In excellent condition prior to receiving birds, as stated above. Recipient clusters must have a minimum of four suitable cavities per cluster, no or very low midstory within the cluster, and suitable foraging habitat. Generally, provide no more than two recruitment sites for each potential pair moved (but see 3B).

6. Impacts to Donor Populations. Impacts of translocation on donor populations require further research before specific guidelines can be developed. Currently, we recommend that managers refrain from removing excessive numbers of birds. Number of individuals removed should be no more than 25 percent of potential breeding groups within the donor population or population segment. Exceptions to this may be made on a case-by-case basis through consultation with the U.S. Fish and Wildlife Service. To be considered for this exception a population must be undergoing intensive monitoring and be increasing in size. Stable populations that have met their population goals will also be considered as possible exceptions to the 25 percent guideline, pending approval by consultation. Individuals moved within a population are not counted as part of this 25 percent.

7. Birds Eligible for Translocation. Determine which birds may be removed for translocation by following these guidelines:

a. Remove only subadult males or subadult females. A subadult is less than 12 months in age.

b. Remove birds only from their natal territory.

c. Do not remove any males unless there will be at least one male helper or male fledgling remaining in the group after the individual is removed. Do not remove more than two subadult males from any group within any one year.

d. Do not remove more than two subadult females from any group.

e. Translocation of any birds not meeting these criteria (above) must be approved on a case-by-case basis through consultation with the Red-cockaded Woodpecker Recovery Coordinator.

8. When to Translocate Birds. Translocations can be performed from September 15 through January 1. Translocations in the fall may have lower success, because translocated birds will also experience winter mortality. Translocations after January 1 may have higher impacts on the donor neighborhood and donor populations,

because females that have survived the early winter have a high likelihood of becoming breeders in their native population. More research on the effects of season on translocation is required before more specific recommendations can be made. Exceptions to this time period may be made on a case-by-case basis through consultation with the Red-cockaded Woodpecker Recovery Coordinator.

9. Procedures for Capture, Transport, and Release. Procedures for the capture, transport, and release of translocated birds are provided in Appendix 3. Translocation is not to be conducted when air temperature is below 32 degrees Fahrenheit (0 degrees Celsius) or during wet weather.

10. Monitoring, Evaluation of Success, and Reporting. Adequate population monitoring, evaluation of success, and reporting are required for regulatory compliance with permits authorizing translocations. Follow these guidelines:

a. Monitor all populations in which translocation is used at recommended levels (above, 3A, 8C, Appendix 2).

b. Determine success of all translocations by presence or absence of translocated birds within target areas in the following breeding season. Management objectives (identified in management plans) dictate target areas. For example:

i. The objective of mate provisioning is successful only if the translocated bird is found in the target cluster in the following breeding season.

ii. The objective of population augmentation is successful if the translocated bird is found anywhere within the target area in the following breeding season.

c. Report all translocations and translocation attempts, both within and between populations, to the Red-cockaded Woodpecker Recovery Coordinator using the Annual Report. Include a description of the management objective, the target area, and the success of the translocation.

I. FORAGING HABITAT

Recent research has expanded our understanding of the foraging ecology of red-cockaded woodpeckers considerably (2E). We know that the structure of foraging habitat is important to fitness of red-cockaded woodpeckers as well as influencing habitat selection. Fitness increases if foraging habitat is burned regularly, has an open character and herbaceous groundcovers, and contains large old trees. Selection of habitat increases with these same characteristics. This structure constitutes good quality foraging habitat for the species. Quality of foraging habitat also affects home range size: as quality increases, the amount of foraging habitat used decreases. We base the following guidelines for the management of foraging habitat on what we now know about both habitat quality and quantity.

We provide two sets of guidelines for the management of foraging habitat: the recovery standard (below) and the standard for managed stability (Appendix 5). Under section 7(a)(1) of the Endangered Species Act, federal agencies have a responsibility to (i.e., "federal agencies shall") use their authorities to carry out programs for the conservation (i.e., recovery) of listed species. Use of the recovery standard by federal agencies will facilitate recovery. Additionally, we strongly recommend that all state properties, particularly those involved in recovery, manage under the recovery standard. We also recommend this standard for those populations on private lands that landowners wish to manage for increasing population size.

The second set of guidelines, referred to as the standard for managed stability, should be used for instances in which a landowner cannot manage to the recovery standard. If a private landowner follows the standard for managed stability, the U.S. Fish and Wildlife Service will not recommend that the landowner needs, or applies for, an incidental take permit, based on the amount of foraging habitat remaining post-project. However, other project-related impacts, for instance, disturbance in the cluster during the nesting season, may require an incidental take permit. The standard for managed stability is presented in Appendix 5, the Private Lands Guidelines. The standard for managed stability is not designed to increase population size. Additionally, its wide-scale implementation, or application, will: (1) not provide future nesting habitat or good quality foraging habitat, (2) result in population fragmentation with subsequent problems related to demographic stochasticity, and (3) based on (1) and (2) above, not maintain that population's long-term viability.

A general discussion of foraging ecology is presented in 2E, and a detailed rationale for each component of the recovery standard is given in Table 13 (below). The recovery standard includes a discussion of habitat variation. Following the recovery standard, we present guidelines on foraging habitat assessment, including general habitat monitoring. We then provide a brief description of foraging habitat partitioning. Guidelines for silvicultural methods to implement the recovery standard are given in 8J.

Guidelines

Part A. Recovery Standard

We recommend this standard for all populations on federal lands, state lands, and those populations on private lands being managed for increasing population size.

1. Area Provided by Site Productivity

a. In systems of medium to high site productivity (site index 60 or more, for the dominant pine species), provide each group of woodpeckers 49 ha (120 ac) of good quality habitat as defined below. A specific exception to this area requirement is made for longleaf and shortleaf habitat types under group selection silviculture; see below for details.

b. In systems of low site productivity (site index below 60, for the dominant pine species), provide each group of woodpeckers 80 to 120 ha (200 to 300 ac) of good quality habitat as defined below. (We recognize that some aspects of the following definition of good quality habitat may not be achievable on extremely dry or wet sites. See discussions below on geographic variation in habitat for more information.)

2. Definition of Good Quality Foraging Habitat. Good quality foraging habitat has some large old pines, low densities of small and medium pines, sparse or no hardwood midstory, and a bunchgrass and forb groundcover. Based on results of studies described in 2E and Table 13, good quality habitat has all of the following characteristics:

a. There are 45 or more stems/ha (18 or more stems/ac) of pines that are $\geq$ 60 years in age *and* $\geq$ 35 cm (14 in) dbh. Minimum basal area for these pines is 4.6 m^2/ha (20 ft^2/ac). Recommended minimum rotation ages apply to all land managed as foraging habitat.

b. Basal area of pines 25.4 – 35 cm (10 – 14 in) dbh is between 0 and 9.2 m^2/ha (0 and 40 ft^2/ac).

c. Basal area of pines < 25.4 cm (< 10 in) dbh is below 2.3 m^2/ha (10 ft^2/ac) *and* below 50 stems/ha (20 stems/ac).

d. Basal area of all pines $\geq$ 25.4 cm (10 in) dbh is at least 9.2 m^2/ha (40 ft^2/ac). That is, the minimum basal area for pines in categories (a) and (b) above is 9.2 m^2/ha (40 ft^2/ac).

e. Groundcovers of native bunchgrass and/or other native, fire-tolerant, fire-dependent herbs total 40 percent or more of ground and midstory plants and are dense enough to carry growing season fire at least once every 5 years.

f. No hardwood midstory exists, or if a hardwood midstory is present it is sparse and less than 2.1 m (7 ft) in height.

g. Canopy hardwoods are absent or less than 10 percent of the number of canopy trees in longleaf forests and less than 30 percent of the number of canopy trees in loblolly and shortleaf forests. Xeric and sub-xeric oak inclusions that are naturally existing and likely to have been present prior to fire suppression may be retained but are not counted in the total area dedicated to foraging habitat.

h. All of this habitat is within 0.8 km (0.5 mi) of the center of the cluster, and preferably, 50 percent or more is within 0.4 km (0.25 mi) of the cluster center.

i. Foraging habitat is not separated by more than 61 m (200 ft) of non-foraging areas. Non-foraging areas include (1) any predominantly hardwood forest, (2) pine stands less than 30 years in age, (3) cleared land such as agricultural lands or recently clearcut areas, (4) paved roadways, (5) utility rights of way, and (6) bodies of water.

3. Discussion of Foraging Habitat Types.

a. Longleaf Pine. Longleaf pine communities vary from highly xeric to mesic and seasonally wet (see 2E), and each of these can support red-cockaded woodpeckers if the habitat structure is suitable. Red-cockaded woodpeckers in some highly xeric sites, such as Eglin Air Force Base in Florida, have very large home ranges, sparse groundcovers, and low density of large old trees that may result from low productivity and past management practices. Thus, we recommend that between 80 to 120 ha (200 and 300 ac) of good quality foraging habitat be provided each group in such sites. Note that this number of hectares (acres) does not refer to home range size in this habitat type, but the recommended amount of good quality foraging habitat within the home range. The latter may be much larger, due to unsuitable areas and home range overlap.

Extremely dry and extremely wet longleaf habitats may be unable to support some of the characteristics identified for good quality habitat. Pine sizes, pine density, and groundcover density may be below those specified above. Failure to meet these three criteria in extremely dry and extremely wet sites is understandable, as long as habitats are burned frequently and conscientious restoration is underway. Further research will help determine the extent of the natural ability of these habitats to support longleaf pines, native groundcovers, and red-cockaded woodpeckers at higher densities.

b. Shortleaf Pine. Historically, shortleaf pine communities included those without hardwoods, those with a small hardwood component, and those dominated by hardwoods. For red-cockaded woodpeckers, some shortleaf habitats, especially those on upland areas, should be free or almost free of hardwoods. Other habitats, such as those grading into mesic sites and north facing slopes, may support more hardwood overstory (up to 20 percent) and still be important red-cockaded woodpecker foraging habitat. Overstory hardwoods should not be removed entirely from communities in which they were historically present; however, neither should they be allowed to dominate a historic pine site. Stands with an overstory hardwood component greater than 30 percent are not considered suitable foraging habitat for red-cockaded woodpeckers.

c. Loblolly Pine. Because of fire sensitivity, loblolly pine was historically much less widespread than today. Prior to fire suppression, loblolly pine was a minor component of riparian and other mesic forests in the coastal plain and a secondary component of mixed pine and pine hardwood forests in the interior uplands. Forests dominated by loblolly were rare and restricted to a part of southern Arkansas and perhaps eastern Virginia and northeastern North Carolina. Currently, because of the fire suppression of the past century, loblolly pine is the dominant pine throughout the southeast, in areas that were historically covered by longleaf pine, shortleaf pine, and shortleaf/loblolly pine forests. These off-site loblolly pine forests provide important resources for red-cockaded woodpeckers. Loblolly pine does not provide as high quality habitat as do longleaf and shortleaf pines, because it produces less resin and is more sensitive to fire, southern pine beetles, and windthrow. These characteristics also render the management of loblolly for use by red-cockaded woodpeckers somewhat more difficult. However, with care, loblolly pine can be successfully managed to provide important habitat for red-cockaded woodpeckers. Additionally, there may be opportunities to carefully restore loblolly stands to site-appropriate pines. Foraging habitat for red-cockaded woodpeckers in loblolly forests should be managed according to the recovery standard, with the additional recommendation that total stand basal area in off-site loblolly forests be kept below 18.4 m^2/ha (80 ft^2/ac).

d. South Florida Slash Pine. Foraging ecology of red-cockaded woodpeckers in native slash pine (*Pinus elliottii* var. *densa*) communities in south Florida has received little research attention. It is clear, though, that home ranges of red-cockaded woodpeckers in native slash pines are unusually large. It is also clear that hydric slash pine flatwoods do not support the size of pines, and may not support the pine density, recommended in the Recovery Standard (above). Until further information is available, we can make only intermediate provisions for these populations. Each group in south Florida slash pine habitat is to be provided at least 80 to 120 ha or more (200 to 300 ac) of good quality foraging habitat containing mature and old pines and healthy native groundcovers that are frequently burned. Again, this is not the home range size but the amount of good quality habitat to be provided. Further research will help determine the density to which south Florida slash pines can be restored, as well as the specific requirements of red-cockaded woodpeckers in this unique habitat type.

e. Slash Pine. Historically, slash pine (*Pinus elliottii* var. *elliottii*) was typically found in transitional mesic sites within longleaf pine forests, such as in narrow drainages and along pond margins. Slash pine is now much more widespread than historically, as a result of fire suppression and aggressive planting. Foraging habitat for red-cockaded woodpeckers in slash pine (var. *elliottii*) forests should be managed according to the recovery standard.

f. Pond Pine. Ecology of red-cockaded woodpeckers in pond pine communities is virtually unknown. Catastrophic natural fire regimes of these communities confound red-cockaded woodpecker management. Certainly, reintroduction of fire and restoration of an open habitat structure are important. We recognize that the above definition of good quality habitat may not apply to this habitat type but can offer no alternative at this time. Further research is necessary before more specific recommendations can be made for this habitat type.

4. Population-specific Guidelines.

Managers may formulate population-specific foraging guidelines in consultation with the U.S. Fish and Wildlife Service. Population-specific guidelines must be based on site-specific research consisting of multi-year (typically 3-5 years) data on red-cockaded woodpecker group and population health and their relationships to quantity and quality of foraging habitat. Such guidelines must still meet or exceed recommendations put forth in the recovery standard concerning these habitat elements: (1) herbaceous groundcover, (2) hardwood midstory, (3) canopy hardwoods, and (4) distance from cluster center. Site-specific guidelines may deviate from the recovery standard in these habitat elements: (1) pine basal area, (2) pine age, and (3) the size class distribution and stem density of pines. Again, deviations must be based on sound science and meet approval through consultation with the U.S. Fish and Wildlife Service.

5. Multiple Ownership.

For those situations in which more than one property is included within the foraging partition of an active cluster, each property owner shall be responsible for providing foraging habitat in proportion to the area of their property currently containing foraging habitat within the partition.

TABLE 13. Rationale for foraging guidelines based on habitat structure[1] (recovery standard).

	Recommendation	Rationale	Source
1a	49 ha (120 ac) good quality habitat	Home range/foraging habitat required decreased with habitat quality.	Walters *et al.* 2000, 2002a
		51 ha (126 ac) good quality habitat recommended.	James *et al.* 2001
		Average home range of groups with access to old growth foraging (Wade Tract, GA) was 47 ha (116 ac), including overlap.	Engstrom and Sanders 1997
1b	More foraging required for sites of low productivity	Large home ranges in Eglin Air Force Base and South/Central Florida.	DeLotelle *et al.* 1987 Beever and Dryden 1992 Hardesty *et al.* 1977
2a	$\geq$ 45 pines/ha (18/ac) that are at least 35 cm dbh (14 in) and 60 yrs in age. Minimum basal area for these pines is 4.6 m^2/ha (20 ft^2/ac).	Group size and reproduction increased with density of large pines; recommended 40 35 cm pines per ha (16 14 in pines/ac).	James *et al.* 2001
		RCWs selected stands with 50 or more pines at least 35 cm in dbh per ha (20 or more pines at least 14 in dbh/ac).	Walters *et al.* 2000, 2002a
		Group size increased with number of flat-tops per acre.	Walters *et al.* 2000, 2002a
		Pines and patches of pines selected if over 60 yrs. in age.	Zwicker and Walters 1999 Walters *et al.* 2000, 2002a

Table continued next page.

TABLE 13 (cont.). Rationale for foraging guidelines based on habitat structure[1] (recovery standard).

	Recommendation	Rationale	Source
2a (cont.)		RCWs selected large old pines in greater proportion than their availability.	Hooper and Lennartz 1981 DeLotelle *et al.* 1983, 1987 Hooper and Harlow 1986 Porter and Labisky 1986 Jones 1994 Epting *et al.* 1995 Engstrom and Sanders 1997 Hardesty *et al.* 1997 Bowman *et al.* 1998 Doster and James 1998 Zenitsky 1999 Zwicker and Walters 1999 Walters *et al.* 2000, 2002a
2b	Basal area of pines 25.4 – 35 cm (10 – 14 in) dbh is between 0 and 9.2 m^2/ha (0 and 40 ft^2/ac).	High pine density negatively affected group size and productivity.	James *et al.* 1997 Hardesty *et al.* 1997 Walters *et al.* 2000, 2002a James *et al.* 2001
2c	Basal area of pines $\geq$ 25 cm (10 in) dbh < 2.3 m^2/ha (10 ft^2/ac) *and* below 50 stems/ha (20 stems/ac).	High densities of small pines negatively affected group size and productivity.	James *et al.* 1997 James *et al.* 2001
		High densities of small pines negatively affected selection of stands for foraging.	Porter and Labisky 1986 Bradshaw 1995 Walters *et al.* 2000, 2002a
2d	Basal area of all pines $\geq$ 25.4 cm (10 in) dbh is at least 2.3 m^2/ha (40 ft^2/ac).	RCWs avoided patches with basal areas below these ranges.	Walters *et al.* 2000, 2002a
2e	Herbaceous groundcovers $\geq$ 40% of groundcovers.	Group size and reproduction increased with herbaceous groundcovers; this level recommended.	Hardesty *et al.* 1997 James *et al.* 1997 James *et al.* 2001

Table continued next page.

TABLE 13 (cont.). Rationale for foraging guidelines based on habitat structure[1] (recovery standard).

	Recommendation	Rationale	Source
2f	Hardwood midstory below 2.1 m (7 ft).	Patches with midstory below 2.1 m (7 ft) were preferred. Stand use decreased with midstory above 2.1 m (7 ft).	Walters *et al.* 2000, 2002a
		Patch and stand use decreased with midstory in general.	Hooper and Harlow 1986 Jones 1994 Epting *et al.* 1995 Bradshaw 1995 Doster and James 1998
2g	Canopy hardwoods < 10% of canopy trees in longleaf stands and < 30 % of canopy trees in loblolly and shortleaf stands.	Large hardwoods negatively affected habitat selection; Jones (1994) found a negative effect above 10%.	Jones 1994 Bradshaw 1995
2h, 2i	Within 0.8 km (0.5 mi), not separated by more than 61 m (200 ft) non-forested land.	Fragmentation of foraging habitat negatively affected RCWs.	Conner and Rudolph 1991b Rudolph and Conner 1994 Conner and Dickson 1997 Ferral 1998

[1]Foraging guidelines are based on structural components rather than total number of pines $\geq$ 10 dbh because of the evidence presented in this table and because no relationship has been found between this variable and group size or reproduction (Hooper and Lennartz 1995, Beyer *et al.* 1996, Wigley *et al.* 1999).

Part B. Assessment of Foraging Habitat

Assessment of foraging habitat is an important component of red-cockaded woodpecker conservation and recovery. Improvements in quality of foraging habitat are necessary for the recovery of the species, and progress in improving foraging habitat is to be assessed through general habitat monitoring. Also, foraging habitat assessment is required prior to executing any projects that may impact foraging habitat. Here we first discuss partitioning, which is the allocation of foraging habitat to specific woodpecker clusters. We then describe general habitat monitoring and interim guidelines for assessment of project impacts in foraging partitions (below) not meeting recommendations for foraging habitat set forth in the recovery standard.

1. Allocating Foraging Habitat

Foraging habitat is best allocated to a specific cluster by performing follows on individual groups, to ascertain which portions of forest stands a particular group is using. Acquiring such data-intensive knowledge is generally far beyond the resources of managers and researchers, but may be required for some projects.

An alternative approach has been developed using geographic information systems (GIS), based on the recommendation within previous foraging guidelines (USFWS 1985) that all foraging habitat be within 0.8 km (0.5 mi) of the center of the cluster. The technique consists of first creating 0.8 km (0.5 mi) foraging circles around the center of each cluster, then applying tabular data of stand characteristics to determine availability of foraging habitat within the newly created circular polygon. Where foraging circles overlap, the area of overlap is partitioned into equal sections and allocated accordingly. Technical resources are available to assist managers and researchers in partitioning the complex overlaps that are common in areas with high cluster densities (Lipscomb and Williams 1996, 1998). Complete and partitioned foraging circles are referred to as foraging partitions.

Revised foraging guidelines (this document) recommend that all foraging habitat be within 0.8 km (0.5 mi) of the center of the cluster, and that, preferably, 50 percent or more be within 0.4 km (0.25 mi) of the cluster center. Foraging partitions should therefore include a second, smaller circle denoting the 0.4 km (0.25 mi) radius. Because cavity tree clusters are spatially dynamic, foraging partitions should be reevaluated periodically as described below.

2. General Monitoring of Foraging Habitat

a. Monitor quality and quantity of all foraging habitat dedicated to red-cockaded woodpecker groups and recruitment clusters at a minimum frequency of 10 years, with the exception of midstory which is to be monitored at a minimum frequency of 5 years. Begin monitoring foraging habitat as soon as possible. Substantial change in habitat quality should be made during each ten-year interval until all habitat elements put forth in the recovery standard are met. Once the recovery standard is met, continued habitat monitoring will ensure that habitat quality and quantity are maintained.

b. Record, for each territory or foraging partition associated with active and recruitment clusters, the following information:

i. the number of ha (ac) of foraging habitat that meets all elements of good quality habitat identified in the recovery standard (above).

ii. the number of ha (ac) of foraging habitat that meets all elements but one, and for each forest stand, identify the missing element.

iii. the number of ha (ac) of foraging habitat that meets all elements but two, and for each forest stand, identify the missing elements.

c. Use appropriate management techniques to increase the number of ha (ac) in categories (i) and (ii) above, and to move toward meeting the standard of 49 ha (120 ac) in category (i).

d. To monitor groundcover, estimate percent native, site-appropriate herbaceous cover using as simple standard technique such as that presented by James and Shugart (1970) and proportional sampling based on the size of the stand. If necessary, more specific recommendations for groundcover monitoring will be formulated by the U.S. Fish and Wildlife Service.

e. To monitor pine size and density, use standard forestry techniques. Age of pines can be determined by coring a sample and determining the relationship between age and size for each habitat type.

3. Interim Guidelines. Here we discuss interim guidelines for assessment of project impacts in territories or foraging partitions not meeting foraging habitat recommendations. The major theme of these recommendations is that if reasonable progress toward meeting the recovery standard can be demonstrated, most projects can be implemented.

a. Demonstration of Reasonable Progress. Reasonable progress toward meeting the recovery standard is best demonstrated by increases in the area of foraging habitat that meets all of the elements of good quality habitat as set forth in the recovery standard (above). Reasonable progress can also be demonstrated by increasing habitat area that meets all elements but one, with no corresponding decrease in the habitat area meeting all elements. Finally, reasonable progress can also be demonstrated if one or more of the individual components are being moved toward the desired condition. For example, if managers can document that an area once supporting no herbaceous groundcover now supports 20 percent native herbaceous cover, reasonable progress is being made. Any of these improvements in foraging habitat have to be current (within the past 3 years) to be considered reasonable progress.

b. Guidance on Specific Projects - Cluster-level Analysis

i. If the project itself (e.g. pine thinning) will move the habitat dedicated to specific clusters toward the desired structure identified in the recovery standard, project concurrence is provided.

ii. If the project **will not** impact the best 49 ha (120 ac) dedicated to foraging habitat (or the best 80 – 120 ha (200-300 ac) in sites of low productivity), and that dedicated foraging habitat is being actively moved toward the desired structure by demonstration of reasonable progress, then project (e.g., a land use change) concurrence is provided. Here we use the term 'best' to refer to those hectares (acres) that best reflect the desired habitat structure and important habitat elements put forth in the recovery standard.

iii. If the project **will** impact some of the best 49 ha (120 ac) dedicated to foraging habitat (or the best 80 – 120 ha (200-300 ac) in sites of low productivity), and will not move the habitat directly toward the desired structure, then the project will typically require reconsideration and modification prior to concurrence. However, in some cases such as restoration of site-appropriate pine species, the project may continue at a reduced level (e.g., group selection or very small patches) so that impacts to foraging are minimized and weighed against future benefits. Such concurrence requires a case-by-case review.

c. Guidance on Specific Projects - Neighborhood-level Analysis

Foraging habitat loss or alteration can have direct effects on group size and reproduction (cluster-level analysis, above). Additionally, by affecting landscape configuration, projects may affect the health and distribution of red-cockaded groups at a neighborhood scale. Habitat fragmentation affects dispersal of individuals in adjacent or nearby groups, and the likelihood that breeding vacancies become filled. Demographic viability of groups, neighborhoods, and populations is primarily dependent on the ability of group members to disperse. If dispersal opportunities are limited or inhibited by a project, even if adequate foraging habitat remains post-project, group status, group size, and reproduction may be affected. It is important that these neighborhood effects be assessed during analysis of project impacts.

J. SILVICULTURE

Silviculture is an important tool for conservation, management, and recovery of red-cockaded woodpeckers. We describe silvicultural methods and techniques in 3E. We present general guidelines for silviculture below (Part A). These general guidelines are based on research documenting the importance of old pines and impacts of habitat fragmentation on red-cockaded woodpeckers (see 2D, 2E). We also present some approaches to satisfying foraging guidelines (8I) under various silvicultural systems currently in use. These approaches reflect our new understanding of foraging ecology (2E) and current silviculture in general; they are not based on research of the effects of these silvicultural treatments on red-cockaded woodpeckers. Experimental research into effects of specific silvicultural treatments on fitness of red-cockaded woodpeckers is a critical research need.

Guidelines

Part A. General Guidelines for Silviculture

1. Use two-aged management, uneven-aged management, or low intensity management to manage habitat for red-cockaded woodpecker populations on public lands. These guidelines are to be applied throughout the habitat managed for red-cockaded woodpeckers, unless otherwise noted.

a. If two-aged management is used, then

i. Use rotation intervals not less than 120 years for longleaf and shortleaf pines and 100 years for loblolly, slash, and pond pines. An exception to this for loblolly and shortleaf stands under high risk of mortality due to insects, disease, or other site-related problems may be given on a case-by-case basis through consultation with the U.S. Fish and Wildlife Service. These rotation intervals are considered the minimum intervals compatible with red-cockaded woodpecker conservation.

ii. Limit regeneration areas to less than 10 ha (25 ac) in populations of less than 100 potential breeding groups, and to less than 16 ha (40 ac) in populations of 100 potential breeding groups or more.

iii. Leave a minimum of 15 – 25 pines on each ha (6 – 10 pines on each ac).

iv. Retain all flat-tops, turpentine pines, and other relict pines.

b. If uneven-aged management is used, then

i. Retain 12 or more pines on each hectare (5 or more on each acre) of the oldest pines present, to establish very old pines throughout the landscape at this minimum density.

ii. Retain all flat-tops, turpentine pines, and other relict pines.

c. If low-intensity management is used, ensure that the appropriate habitat structure, as described in foraging (8I) and cluster management guidelines (8F), is maintained.

2. Use even-aged, two-aged, and/or uneven-aged management systems to restore off-site pines to native pine species. Generally, limit size of regeneration areas for restoration to 16 ha (40 ac) or less. However, regeneration areas up to 32 ha (80 ac) are acceptable for native pine restoration if such stands are at least 1.6 km (1 mi) from active or recruitment clusters.

3. Use the least invasive form of site preparation possible given habitat conditions. In most instances, prescribed burning is the preferred method.

4. Protect against infestation of southern pine beetles by practicing Integrated Pest Management, including thinning pines to maintain adequate spacing (7.6 m or 25 ft among canopy pines) and minimizing disturbance. For more specific information consult the U.S. Forest Service's Final Environmental Impact Statement for the Suppression of the Southern Pine Beetle (USFS 1987).

Part B. Silvicultural Systems and Implementation of Foraging Guidelines

Here we present a brief description of how foraging guidelines can be satisfied in forests managed under modified two-aged or uneven-aged silviculture. See 3E for more information concerning silviculture.

1. Modified Two-aged Management

a. Loblolly, Slash, and Pond Pines. Forests of these pine types are to be managed on a minimum rotation of 100 years. An exception to the minimum may be permitted in forests under high risk of infestation by southern pine beetles through consultation with the U.S. Fish and Wildlife Service. To implement foraging guidelines under a minimum rotation of 100 years, follow these recommendations:

i. Retain a minimum basal area of 4.6 m^2/ha (20 ft^2/ac) in leave trees.

ii. Do not count stands with dense, young regeneration as foraging habitat. Stands that do not meet criterion (c) in the Recovery Standard (above) cannot be counted as foraging habitat.

iii. Once regeneration reaches 25.4 cm (10 in) dbh, thin the regeneration to a maximum basal area of 9.2 m^2/ha (40 ft^2/ac) and protect or restore herbaceous groundcover. The stand should then meet the criteria of good quality habitat (above) and can be counted as foraging habitat.

b. Longleaf and Shortleaf Pines. Longleaf and shortleaf pine woodlands under modified two-aged silviculture are to be managed with a minimum rotation of 120 years. An exception to the minimum may be obtained in shortleaf forests under high risk of disease (e.g. little-leaf disease). There are at least three options for implementing the recovery standard in these woodlands. The first is to extend the rotation interval to 150 years for woodpecker groups maintained at a current or projected density of 81 ha (200 ac) per group. This would provide 49 ha (120 ac) of good quality habitat in each foraging partition. The second option is to follow the approach described above for loblolly/slash/pond pine forests under modified two-aged silviculture. However, some managers may consider leaving a minimum of 4.6 m^2/ha (20 ft^2/ac) of basal area in leave pines unrealistic in longleaf woodlands because of the shade intolerance of the species. These managers may consider a third option, which is to extend the projected density of red-cockaded woodpecker groups to 97 ha (240 ac) per group. Under this third option, regeneration areas (still requiring 15 – 25 leave pines/ha, or 6 to 10 pines/ac) are not counted as foraging habitat until the regeneration reaches at least 60 years in age and 35 cm (14 in) dbh.

2. Uneven-aged Management

Uneven-aged silviculture includes both single tree and group selection. Both silvicultural methods are compatible with management for red-cockaded woodpeckers. If single tree selection is applied appropriately, the entire forest can meet all elements of good quality foraging habitat as put forth in the recovery standard. However, when group selection is applied, small patches of regeneration (< 0.8 ha, or 2 ac) are interspersed throughout the managed forest. These individual patches of regeneration may be included within the area identified as good quality foraging habitat once the regenerating pines are at least 25.4 cm (10 in) dbh, the density of these pines is 9.2 m^2/ha (40 ft^2/ac), and the appropriate percentage of native groundcovers is present. Once the regenerating pines are 35 cm (14 in) in dbh or greater, regeneration areas should meet all elements of the recovery standard.

If red-cockaded woodpecker groups are being managed at a density of 81 ha (200 ac) per group, this approach to satisfying the recovery standard in forests under group selection will result in 40 ha (100 ac) of good quality habitat and an additional 20 ha (50 ac) of small patches that meet all elements of good quality habitat except the requirement for pines 35 cm (14 in) and larger. This is the only acceptable exception to the minimum area requirement of 49 ha (120 ac) of good quality habitat put forth in the recovery standard. This exception is considered acceptable because of the spatial distribution and size of regenerating patches (that is, regenerating patches that lack pines 35 cm (14 in) dbh and larger are small and interspersed throughout the forest).

K. PRESCRIBED BURNING

Prescribed burning is basic to the management, conservation, and recovery of red-cockaded woodpeckers. In addition, prescribed burning provides benefits for a long list of species associated with southern pine/bunchgrass ecosystems, many of which are rare, threatened, or endangered. Discussions of the integral role of fire in southern pine ecosystems and the use of prescribed fire are given in 2G and 3F. Prescribed burning should mimic natural fire regimes as closely as possible, but must be carefully planned and conducted to reduce the likelihood of damage to nesting and foraging habitat. In general, managers are to work toward a prescribed burning program of early to mid-growing season burns on a 1 to 5 year return interval. Habitat with excessive hardwood midstory is to be restored to one with an herbaceous groundcover, preferably by burning at a frequency of 1 to 3 years. Longer intervals are appropriate only for habitat that can be maintained with recommended herbaceous groundcover at those longer burn frequencies.

Guidelines

1. Planning a Prescribed Burning Program. In planning a prescribed burning program to benefit red-cockaded woodpeckers, consider the following guidelines:

    a. Prioritize areas of the forest in need of burning.

        i. Review the status of red-cockaded woodpeckers throughout the forest.

        ii. Give first priority to maintaining active clusters that support healthy herbaceous groundcovers.

        iii. Give second priority to restoring herbaceous groundcovers in active clusters with excessive hardwood midstory.

        iv. Give third priority to recently inactive clusters with excessive midstory.

b. As special needs are being addressed, move to implement an effective broad-scale burning program to maintain and enhance quality of nesting and foraging habitat.

2. Burn Prescriptions. Prepare burn prescriptions for each burn unit prior to conducting prescribed burning based on habitat evaluations for individual woodpecker groups. Each prescription should include:

a. The management objective of the burn, such as habitat restoration, habitat maintenance, or fuel reduction.
b. The parameter values necessary to achieve the objective, including season of burn, fuel moisture, wind speed and direction, and relative humidity.

c. Maps indicating the location of all cavity trees within the burn unit as well as specific directions for protecting each of these cavity trees.

In light of stringent laws regulating smoke management, it is imperative that all prescribed burns comply with state and federal regulations.

3. Season of Prescribed Burning. Determine the appropriate season for prescribed burns based on management objectives. Consider the following guidelines when determining appropriate season:

a. Strive for a program of frequent early to mid-growing season burns to maintain and enhance quality of nesting and foraging habitat.

b. Apply dormant season fire prior to growing season burns when reintroducing fire to fire-suppressed habitats, but be aware that fires conducted during the late growing season and into the fall can result in increased pine mortality. Growing season burns can be used as a method of habitat restoration in some sites (see 3G and below).

c. Do not rely on dormant season fire. Once hazardous fuel accumulations have been reduced by dormant season burns, place the area on a growing season fire rotation.

d. Bear in mind geographic variation in the timing of the seasons.

e. Remember that regardless of the season, heavy fuels are very dangerous to cavity trees. During dormant season as well as growing season burns, thick duff layers surrounding pines can result in deadly smolder fires.

4. Size of Burn Units. Size of prescribed burns can vary from single clusters to over a thousand hectares (several thousand acres). In general, larger burns have a lower cost per hectare (acre) and provide the greatest benefit to the ecosystem. However, cost efficiency should not be the sole factor in determining the size of burn units. The prescribed burn should be large enough to accomplish the primary objective of the burn without reducing the burn boss's ability to maintain control of the fire's intensity.

5. Cavity Tree Protection. Protect cavity trees within and in close proximity to the burn unit, following these guidelines:

a. Ensure that all members of the burn crew have maps detailing the location and status of all cavity trees within and in close proximity to the burn unit. Information distributed to each crew member should include activity status, cavity height, and relative amount of resin present, as determined by surveys performed within one year of the burn date.

b. Determine the appropriate level of protection for cavity trees, according to the following:

i. Protect active cavity trees, inactive cavity trees, and relict pines (flat-tops, very old pines, and turpentine pines) within the burn unit if one or more of the following conditions exist: (1) the population consists of less than 30 potential breeding groups; (2) fire intensity of the prescribed burn would likely result in ignition of an unprotected tree; or (3) potential cavity trees (i.e., pines over 60 years in age, including relict pines) are limited.

ii. Protect only active cavity trees within the burn unit if all of the following conditions exist: (1) the population consists of 30 or more potential breeding groups; (2) the area proposed for burning has been burned in recent years (3 – 5 years or less) and the fuel loads have been reduced to acceptable limits; and (3) potential cavity trees are not limited.

c. Protect individual cavity trees by reducing fuels at the base of cavity trees for a minimum distance of 3 m (10 ft) from the trunk. The necessary distance varies depending on fuel types, fuel loads, amount of resin present, cavity heights, and firing technique as well as on the objective of the burn. Restoration burns require a greater distance of fuel reduction than less intense maintenance burns. Use maximum distances during the nesting season and when protecting cavity trees with turpentine scars and resin low on the bole.

d. Use one or more of the following methods of cavity tree protection:

i. Small preparation burns. Conduct preparation burns of the cluster or areas surrounding individual cavity trees before conducting the larger burn. Preparation burns can be performed immediately before or several weeks ahead of the larger burn. Carefully monitor and extinguish preparation burns to avoid damage to cavity trees or unintentional ignition of the larger burn unit. A strong advantage of this method is that it benefits groundcover plants that are harmed by other methods such as raking and mowing (below).

ii. Raking. Rake fuels far enough from the trunk to prevent cavity tree ignition. Avoid the formation of mounds or rings of concentrated fuels (such as pine straw); such piles of fuels can cause greater mortality than if no action had been taken. Remove small trees and shrubs by hand prior to raking fuels.

iii. Mowing. Mowing is effective, but heavy machinery can compact soils and damage tree roots. To reduce these negative impacts, avoid repeated mowing and use of heavy equipment, and minimize use of machinery in wet sites. Weed-whipping is a low impact alternative.

iv. Light bark scraping. Lightly scraping off the loose bark from ground to breast height can improve the effectiveness of other methods such as raking and mowing.

v. Wetting the cavity trees. A solution of water and foaming agent applied to the base of cavity trees is currently being tested as a method for cavity tree protection. This may become available for widespread use in the future. Foam may be especially effective in combination with mowing or raking.

vi. Plow lines as cavity tree protection are prohibited. Never install circular plow lines around individual cavity trees because such plow lines can cause the death of the tree.

6. Method of Ignition. Apply fire to the landscape using aerial or ground ignition. Ground ignition may require less financial resources and training. Aerial ignition increases the area burned per unit time, and improves dispersal of smoke. Either technique is suitable, and both are discussed in 3F.

If using aerial ignition, provide a greater degree of cavity tree protection than normally provided for burns ignited on the ground. Rake, mow, or burn for a distance of at least 6.1 m (20 ft) or more from the cavity trees. Even greater protection is necessary if the area has not been burned frequently and the habitat requires restoration. If restoration is required, we recommend a prescribed burn of the cluster ignited on the ground prior to igniting the larger burning unit from the air.

7. Restoration Burning. Restoration burning and the reintroduction of fire can be used to reduce or remove dense hardwood midstories. When applying restoration burns, have fire suppression equipment on site in case the fire crosses control lines. Clusters on deep, sandy soils, with a dense hardwood midstory and a sparse accumulation of ground fuels, can be effectively treated with a restoration burn during the growing season.

Key to success of this management action is a thorough understanding of fire behavior in those fuel types under a variety of weather conditions. The use of fire for restoration purposes often requires burning under very specific weather conditions, which may include moderate winds, low relative humidity, and low fuel moistures. Use of prescribed burns under these conditions requires extensive experience in the application of growing season fire and must be conducted only by qualified burners. Again, it is imperative that all prescribed burns comply with state and federal regulations.

8. Consider the use of wildland fire to accomplish management objectives in appropriate areas. Protect public safety and property if implementing this policy. Protect cavity trees from ignition, and ensure that emergency fire suppression personnel are familiar with cavity protection methods and the need to protect cavity tree roots from plow lines and other firebreaks.

9. RECOVERY TASKS

The following recovery tasks are presented as a stepdown outline, a format required by the U.S. Fish and Wildlife Service's recovery planning guidelines. Ecology and management techniques relevant to these tasks are described in the Introduction. Management guidelines are given in detail in previous sections of Recovery. Specific guidelines relevant to tasks are referred to in parentheses.

1. Increase existing populations on all federal lands, and on those state lands identified in recovery criteria, until population objectives are reached.

1.1. Protect existing active clusters.

1.1.1. Apply prescribed burns every 1 to 5 years, preferably during the growing season (included in task 1.7., see 8K).

1.1.2. Provide and maintain four suitable cavities per cluster, if necessary using artificial cavities and/or restrictor plates (8E).

1.1.3. Control midstory and overstory hardwoods using means other than prescribed fire as necessary, but minimize disturbance to soil and native herbaceous groundcovers (8F, 8K).

1.1.4. Retain and protect active and inactive cavity trees and potential cavity trees (8F, 8K).

1.1.5. Practice integrated pest management to limit risk of damage by southern pine beetles.

1.2. Provide and maintain a sufficient number of recruitment clusters to achieve an annual average rate of population increase between 5 and 10 percent (8A).

1.2.1. Choose strategic locations for recruitment clusters, to facilitate occupation and develop beneficial spatial arrangements of groups (8B).

1.2.2. Restore suitable habitat structure prior to the installation of artificial cavities in recruitment clusters, using prescribed fire and other means as necessary to remove midstory and overstory hardwoods. Conduct pine thinning if densities are too high. Minimize disturbance to soils and native herbaceous groundcovers (8B, 8E, 8F, 8K).

1.2.3. Provision a number of recruitment clusters equal to 10 percent of potential breeding groups (or number of active clusters, if potential breeding groups is unknown). For each recruitment cluster, provide 3 artificial cavities and two drilled starts, or four artificial cavities (8A, 8B).

1.2.4. Apply prescribed burns to unoccupied recruitment clusters every 1 to 5 years, preferably during the growing season (8K).

1.2.5. When occupied, manage recruitment clusters as in 1.1 above.

1.3. Provide suitable quality and quantity of foraging habitat for each active and recruitment cluster, following the recovery standard (8I).

1.3.1. Apply prescribed fire to foraging habitat every 1 to 5 years, preferably during the growing season, to protect and restore native herbaceous groundcovers and control densities of midstory hardwoods and pines (8I, 8K).

1.3.2. Use means other than prescribed fire, if necessary, to control densities of midstory and overstory hardwoods and small and medium-sized pines (8I, 8K).

1.3.3. Protect and/or develop an old growth or mature pine component within the foraging habitat, at recommended densities (8I, 8J).

1.3.4. Provide suitable quantity of good quality foraging habitat (8I).

1.3.5. Practice integrated pest management to limit risk of damage by southern pine beetles.

1.4. Combat effects of fragmentation on demography and genetic resources.

1.4.1. Locate newly developed recruitment clusters of artificial cavities in strategic locations to enhance natural dispersal (same as task 1.2.1).

1.4.2. Use within-population translocation when appropriate to stabilize and increase isolated sub-populations (8H).

1.4.3. Consider population augmentation if your population is less than 30 potential breeding groups, through enrolling in a regional translocation program (8H). Provide high quality nesting and foraging habitat prior to translocation (8B, 8E, 8F, 8I).

1.4.4. Avoid further fragmentation of forests managed for red-cockaded woodpeckers (8J).

1.5. Provide additional habitat for population growth to achieve population objectives.

1.5.1. Use appropriate silvicultural techniques to produce suitable foraging and nesting habitat for future population expansion (8J).

1.5.2. Restore historic vegetation type (e.g., longleaf and shortleaf pine communities) where appropriate (8J).

1.6. Monitor woodpecker populations using recommended monitoring intensity (8C).

1.7. Apply prescribed fire to all habitat managed for red-cockaded woodpeckers at least every 1 to 5 years (tasks 1.1.1, 1.2.4, and 1.3.1).

2. Maintain and/or increase populations on state lands not identified in recovery criteria.

2.1. Provide regulatory and economic incentives for state managers to participate in recovery efforts.

2.2. Enlist managers in statewide and regional recovery programs and partnerships.

2.3. Protect existing active clusters and encourage population increase (see tasks 1.1-1.7).

3. Maintain and/or increase populations on private lands, and establish new populations.

3.1. Provide regulatory and economic incentives for private landowners to participate in recovery efforts.

3.2. Enroll private landowners in management, conservation, and recovery programs, including Safe Harbor, Habitat Conservation Plans, and Memoranda of Agreement.

3.3. Provide awards to private landowners, both citizens and corporations, for exemplary conservation efforts.

3.4. Protect existing active clusters and encourage population increase (see tasks 1.1-1.7.).

4. Increase awareness of stakeholders and the general public.

4.1. Increase awareness of red-cockaded woodpecker ecology, status, and recovery.

4.2. Increase awareness of the role of fire in southeastern ecosystems and the need for prescribed burning.

4.3. Increase awareness of the need to restore an old growth pine component to federal, state, and private lands of the south.

5. Conduct research to further our understanding of woodpecker ecology, management, and recovery.

5.1. Explore and evaluate best management practices to increase populations at a rate appropriate for the recovery potential and habitat availability of individual populations.

5.2. Expand current understanding of relationships between condition of foraging habitat (structure, age, and species composition) and measures of group fitness and population health, for various habitat types such as mesic and xeric longleaf pine, south Florida slash pine, pond pine, off-site and site-appropriate loblolly, and shortleaf pine systems.

5.3. Expand current understanding of the relationships between condition of nesting habitat (density of pines, age of cavity trees, and groundcover composition) and measures of group fitness and population health.

5.4. Research conditions and factors that promote territorial budding and pioneering.

5.5. Further evaluate genetic threats.

5.6. Gain a better understanding of effects of cavity kleptoparasitism and predation on population dynamics, for various population sizes and habitat conditions.

5.7. Further research juvenile dispersal, especially factors promoting movements between populations.

5.8. Identify the thresholds at which quantity and quality of foraging habitat affect population trends, to better evaluate management of woodpeckers on private lands.

5.9. Further evaluate the relative benefits and drawbacks of artificial cavity installation methods.

5.10. Further assess the value of translocation as a management tool, including research on impacts to donor populations, benefits to receiving populations, and best techniques to increase success. Determine if translocation among recovery populations is warranted for genetic conservation (informed by results of tasks 5.5 and 5.7) or if drawbacks outweigh potential benefits of this action.

5.11. Further research the relationships among bark beetles, red-cockaded woodpeckers, and habitat management, including the extent and cause of elevated mortality of cavity trees infested with bark beetles, effects of habitat management on risk of infestation, and reasons why cavity trees attract bark beetles. Develop measures to prevent or reduce beetle-induced mortality of cavity trees.

5.12. Research the impacts of exotic species such as melaleuca and fire ants on red-cockaded woodpeckers.

6. Explore costs, benefits, and feasibility of moving from management based on single clusters to landscape level management.

6.1. On federal lands.

6.2. On state lands.

6.3. On private lands.

6.4. On tribal lands.

10. IMPLEMENTATION SCHEDULE AND ESTIMATED COSTS

We present several tables in this section. First are tables of estimated time to delisting (Table 14) and downlisting (Table 15), as calculated by projecting a 5 percent annual increase. Next is the implementation schedule and estimated costs for each recovery task (Table 16). These costs are given per unit (e.g., per active cluster, or per unit area). Finally, there are tables that illustrate estimated costs, by recovery population and responsible agency, for three recovery tasks: cavity maintenance (Table 17), cavity installation in recruitment clusters (Table 18), and frequent prescribed burning of all woodpecker habitat (Table 19).

TABLE 14. Estimated time (years, to the nearest 5 years) for each recovery population to meet size specified in delisting criteria, by recovery unit. Also listed is current size (number of active clusters in 2000, ACT) and minimum size required at delisting (potential breeding groups, PBG). Each estimated time is calculated based on a recommended 5% annual growth rate and a ratio of 1.4 active clusters per potential breeding group. Estimated time to delisting is 75 years, the maximum time in this table.

Recovery Unit	**Population**	**Current Size (ACT)**	**Size at Delisting (PBG)**	**Time to Required Size (yrs)**
Cumberlands/Ridge and Valley	Talladega/Shoal Creek	6	100	55
East Gulf Coastal Plain	Central Florida Panhandle	665	1000	50
	Chickasawhay	15	350	75
	Conecuh/Blackwater	44	250	60
	DeSoto	7	250	75
	Eglin	301	350	10
	Homochitto	51	250	35
Mid-Atlantic Coastal Plain	Coastal North Carolina	159	350	25
	Francis Marion	344	350	10
	Northeast North Carolina/Southeast Virginia	35	100	50
Ouachita Mountains	Ouachita	21	250	60
Piedmont	Oconee/Piedmont	59	250	45
Sandhills	Fort Benning	219	350	15
	North Carolina Sandhills East	371	350	15
	North Carolina Sandhills West	145	100	0
	South Carolina Sandhills	167	250	25
South Atlantic Coastal Plain	Fort Stewart	212	350	20
	Osceola/Okefenokee	100	350	40
	Savannah River	34	250	50
South/Central Florida	Avon Park	21	40	20
	Babcock/Webb	27	40	15
	Big Cypress	42	40	5
	Camp Blanding	14	25[1]	15
	Corbett/Dupuis	13	40	30
	Goethe	30	40	15
	Hal Scott	7	15[1]	15
	Ocala	22	40	20
	Picayune Strand	3	25[1]	45
	St. Sebastian River	8	25[1]	30
	Three Lakes	51	40	5
	Withlacoochee - Citrus Tract	46	40	5
	Withlacoochee - Croom Tract	5	30[1]	40
Upper East Gulf Coastal Plain	Bienville	104	350	35
	Oakmulgee	110	250	25
Upper West Gulf Coastal Plain	Sam Houston	168	350	25

Table continued next page.

TABLE 14 (cont.). Estimated time for each recovery population to meet size specified in delisting criteria.

Recovery Unit	**Population**	**Current Size (ACT)**	**Size at Delisting (PBG)**	**Time to Required Size (yrs)**
West Gulf Coastal Plain	Angelina/Sabine	57	350	45
	Catahoula	37	250	55
	Davy Crockett	53	250	40
	Vernon/Fort Polk	198	350	15

[1]These populations each have an estimated potential size of less than 40 potential breeding groups but can contribute significantly to the delisting criterion of 250 potential breeding groups (275-350 active clusters) in the South/Central Florida Recovery Unit overall.

TABLE 15. Estimated minimum time (years, to the nearest 5 years) for each recovery unit to meet downlisting criteria, assuming the currently largest populations within each recovery unit fulfill downlisting criteria first. Estimated time is calculated based on a recommended 5% annual growth rate and a ratio of 1.4 active clusters per potential breeding group. Estimated time to downlisting is 50 years.

Recovery Unit	**Time to Meet Downlisting Criteria (yrs)**
Cumberlands/Ridge and Valley	50
East Gulf Coastal Plain	0
Mid-Atlantic Coastal Plain	25
Ouachita Mountains	30
Piedmont	15
Sandhills	0
South Atlantic Coastal Plain	15
South/Central Florida	15
Upper East Gulf Coastal Plain	25
Upper West Gulf Coastal Plain	20
West Gulf Coastal Plain	15

TABLE 16. Implementation schedule and estimated costs by recovery task. See key below for explanation of abbreviations and cost estimates. For more information on costs and implementation schedule for select recovery tasks, see Tables 17, 18, and 19. See key (below) for explanation of column headings and abbreviations.

Task	Task No.	P	D	Responsible Parties	Cost Estimates ($1) FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
Increase All Federal and Specific State Populations														
Nesting Habitat, Active Clusters														
Prescribed burning	1.1.1	1	C	AGENCY	50/ha[1]	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha
Cavity installation and restriction (see Table 17)	1.1.2	1	D	AGENCY	200/ACT[2]	200/ACT	100/ACT	100/ACT	100/ACT	100/ACT	100/ACT	100/ACT	100/ACT	100/ACT
Other hardwood control	1.1.3	1	C	AGENCY	0-250/ha[3]	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha
Protect cavity trees	1.1.4	1	C	AGENCY	*Included in prescribed burning costs above*									
Practice IPM	1.1.5	1	C	AGENCY	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Nesting Habitat, Recruitment Clusters														
Strategic locations	1.2.1	1	D	AGENCY	0	0	0	0	0	0	0	0	0	0
Initial habitat restoration	1.2.2	1	D	AGENCY	0-250/ha[3]	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha
Cavity installation (see Table 18)	1.2.3	1	D	AGENCY	800/RC[4]	800/RC	800/RC	800/RC	800/RC	800/RC	800/RC	800/RC	800/RC	800/RC
Maintenance burning	1.2.4	1	D	AGENCY	50/ha[1]	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha
Appropriate management when occupied (task 1.1)	1.2.5	1	C	AGENCY	*Included in task 1.1*									
Foraging Habitat														
Prescribed burning	1.3.1	1	C	AGENCY	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha
Other hardwood or pine control	1.3.2	1	C	AGENCY	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha
Develop mature pines	1.3.3	1	C	AGENCY	0	0	0	0	0	0	0	0	0	0
Provide suitable quantity	1.3.4	1	C	AGENCY	0	0	0	0	0	0	0	0	0	0
Practice IPM	1.3.5	1	C	AGENCY	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

Table continued next page.

TABLE 16 (cont.). Implementation schedule and estimated costs by recovery task.

Task	Task No.	P	D	Responsible Parties	Cost Estimates ($1) FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
Increase All Federal and Specific State Populations (cont.)														
Combat Fragmentation				AGENCY										
Strategically locate recruitment clusters (1.2.1)	1.4.1	1	D	AGENCY	0	0	0	0	0	0	0	0	0	0
Within-pop. translocation	1.4.2	2	D	AGENCY	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Population augmentation, pops. < 30 PBG only	1.4.3	1	D	AGENCY	3000-9000 /new PBG[5]	3000-9000 /new PBG	3000-9000 /new PBG	3000-9000 /new PBG	3000-9000 /new PBG	3000-9000 /new PBG	3000-9000 /new PBG	3000-9000 /new PBG	3000-9000 /new PBG	3000-9000 /new PBG
Avoid fragmentation	1.4.4	1	C	AGENCY	0	0	0	0	0	0	0	0	0	0
Develop Additional Habitat														
Silviculture	1.5.1	1	D	AGENCY	0	0	0	0	0	0	0	0	0	0
Habitat restoration	1.5.2	1	D	AGENCY	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Monitor Populations	1.6	1	C	AGENCY	750/ACT[6]	750/ACT	750/ACT	750/ACT	750/ACT	750/ACT	750/ACT	750/ACT	750/ACT	750/ACT
Burn All Habitat in HMA at least every 1-5 yrs. (1.1.1, 1.2.4, 1.3.1; see Table 19)	1.7	1	C	AGENCY	50/ha[1]	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha
Maintain and/or increase all other state populations														
Provide incentives	2.1	2	C	STATES &USFWS	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Enlist in programs	2.2	2	D	STATES & USFWS	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Protect existing clusters, encourage increases	2.3	2	C	STATES & USFWS	*See tasks 1.1 – 1.7*									
Maintain and/or increase populations on private lands														
Provide incentives	3.1	2	C	STATES & USFWS	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Enlist in programs	3.2	2	D	STATES & USFWS	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Provide awards	3.3	2	D	USFWS	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Protect existing clusters, encourage increases	3.4	2	C	STATES & USFWS	*See tasks 1.1 – 1.7*									
Increase public awareness														
Ecology, status, recovery	4.1	2	C	ALL	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Importance of fire	4.2	2	C	ALL	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Importance of old pines	4.3	2	C	ALL	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

Table continued next page.

TABLE 16 (cont.). Implementation schedule and estimated cost by recovery task.

Task	Task No.	P	D	Resp. Parties	Cost Estimates ($1*1000) FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
Research needs														
Best management to increase populations	5.1	1	TBD	PI	200	200	200	200	200	200	200	200	200	200
Foraging habitat & fitness, in various habitat types	5.2	1	TBD	PI	200	200	200	200	200	200	100	100	100	100
Nesting habitat & fitness	5.3	1	TBD	PI	100	100	100	100	100	100	0	0	0	0
Budding & pioneering	5.4	2	TBD	PI	100	100	100	100	0	0	0	0	0	0
Genetic threats	5.5	2	TBD	PI	50	50	50	50	50	50	0	0	0	0
Cavity kleptoparasitism & predation	5.6	3	TBD	PI	30	30	30	30	0	0	0	0	0	0
Dispersal	5.7	2	TBD	PI	100	100	100	100	100	100	0	0	0	0
Foraging & private lands	5.8	2	TBD	PI	200	200	200	200	0	0	0	0	0	0
Cavity installation methods	5.9	3	TBD	PI	30	30	30	30	30	30	30	30	0	0
Translocation	5.10	2	TBD	PI	50	50	50	50	50	50	0	0	0	0
Bark Beetles	5.11	1	TBD	PI	100	100	100	100	100	100	0	0	0	0
Threats from exotic species	5.12	3	TBD	PI	30	30	30	30	0	0	0	0	0	0

Key to Column Headings and Abbreviations:

Task: Recovery task from stepdown outline, section 9. See section 8 for guidelines.
Task No.: Task number identified in stepdown outline (see 9).
P: Priority assigned to recovery task, including (1) tasks that must be completed to meet delisting criteria; (2) tasks that should be done to help meet recovery objective; and (3) tasks that should be done to enhance management of the species.
D: Duration of recovery task. Two levels are identified here: (C) continuous, up to and after delisting; and (D) until delisting.
Resp. Parties: Agencies and other parties responsible for the completion of recovery task. Abbreviations are as follows:

AGENCY **-** all agencies responsible for properties identified in delisting criteria, i.e. the following:
Florida Department of Military Affairs (FDMA)
Florida Division of Forestry (FDF)
Florida Fish and Wildlife Conservation Commission (FFWCC)
Florida Park Service (FPS)
National Park Service (NPS)
North Carolina Department of Agriculture (NCDA)
North Carolina Department of Environment and Natural Resources (NCDENR)
North Carolina Wildlife Resources Commission (NCWRC)

Key to Column Headings and Abbreviations (cont.):

South Carolina Forestry Commission (SCFC)
South Florida Water Management District (SFWMD)
Saint John's River Water Management District (Florida; SJRWMD)
U.S. Air Force (USAF)
U.S. Army (USARMY)
U.S. Department of Energy (USDOE)
U.S. Forest Service (USFS)
U.S. Fish and Wildlife Service (USFWS)
U.S. Marine Corps (USMC)
U.S. Navy (USNAVY)

PI	Principal investigators
STATES	All state agencies with occupied properties
ALL	All federal and state agencies with occupied properties and principal investigators

Cost Estimates: The figures in this column represent the estimated annual cost of each task. Further information is given in the following notes and in Tables 17, 18, and 19.
[1]Estimate for prescribed burning is a well-known figure in the field.
[2]Estimate for artificial cavity installation includes salary, equipment, overhead, and associated costs.
[3]Estimate for chemical and mechanical control varies within this range, well-known in the field.
[4]Estimate for cavity installation in recruitment clusters is four times the cost per cavity (4 x $200).
[5]Estimate for translocation for population augmentation is based on price per bird ($1500), success rate (varies between 25 and 50%), and movement of one or two birds; it does not include costs of constructing recruitment clusters.
[6]Estimate for monitoring is based on survey of federal properties' annual expenditures.

Abbreviations under Cost Estimates:

ACT	active cluster
FY	fiscal year
PBG	potential breeding group
RC	recruitment cluster
TBD	to be determined

TABLE 17. Estimated annual cost and schedule for implementation of recovery task 1.1.2 (*maintain four suitable cavities in each active cluster*) by responsible agency, for all federal properties and those state properties identified in recovery criteria. See key to Table 16 for agency abbreviations. Annual estimated cost = $200 x number of active clusters for the first 2 years, then $100 x number of active clusters for the remaining time period[1]. Estimated cost per artificial cavity = $200. Number of active clusters (ACT, 2000) is projected over 10 years with an annual population increase of 5 percent[1] until property goal is met. Properties that reach their goal are considered to require the same level of cavity maintenance over these ten years, with the exception of the Apalachicola Ranger District. Properties will require cavity maintenance until the average age of potential cavity trees is at least 80 and 100 years for loblolly and longleaf pine, respectively.

Responsible Agency	**Property**	**ACT 2000**	**Property Goal[2]**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
				Estimated Annual Cost ($1) for Cavity Maintenance									
FDF	Blackwater River SF	26	45	5600	5800	3100	3200	3400	3500	3700	3900	4100	4300
	Goethe SF	30	150	6400	6800	3500	3700	3900	4100	4300	4500	4700	4900
	Picayune Strand SF	3	25	800	800	400	400	400	500	500	500	500	500
	Tate's Hell SF	29	400	6200	6400	3400	3600	3800	3900	4100	4300	4500	4800
	Withlacoochee - Citrus Tract	46	100	9800	10200	5400	5600	5900	6200	6500	6800	7200	7500
	Withlacoochee - Croom Tract	5	30	1200	1200	600	700	700	700	800	800	800	900
	subtotal	139	750	30000	31200	16400	17200	18100	18900	19900	20800	21800	22900
FDMA	Camp Blanding Training Site	14	25	3000	3200	1700	1800	1800	1900	2000	2100	2200	2300
	subtotal	14	25	3000	3200	1700	1800	1800	1900	2000	2100	2200	2300
FFWCC	Babcock/Webb WMA	27	240	5800	6000	3200	3300	3500	3700	3800	4000	4200	4400
	J.W. Corbett/Dupuis WMA[3]	13	90	2800	3000	1600	1600	1700	1800	1900	2000	2100	2200
	Three Lakes WMA	51	125	10800	11400	6000	6200	6600	6900	7200	7600	8000	8400
	subtotal	91	455	19400	20400	10800	11100	11800	12400	12900	13600	14300	15000
FPS	Ochlockonee River SP	3	3	600	600	300	300	300	300	300	300	300	300
	subtotal	3	3	600	600	300	300	300	300	300	300	300	300
NCDA	McCain Tract	5	7	1200	1200	600	700	700	700	700	700	700	700
	subtotal	5	7	1200	1200	600	700	700	700	700	700	700	700

Table continued next page.

TABLE 17 (cont.). Estimated annual cost and schedule for implementation of recovery task 1.1.2 (*maintain four suitable cavities in each active cluster*).

Responsible Agency	**Property**	**ACT 2000**	**Property Goal[2]**	**Estimated Annual Cost ($1) for Cavity Maintenance 2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
NCDENR	Weymouth Woods State NP	7	13	1600	1600	900	900	900	1000	1000	1100	1100	1200
	subtotal	7	13	1600	1600	900	900	900	1000	1000	1100	1100	1200
NCWRC	Holly Shelter Game Lands	38	38	7600	7600	3800	3800	3800	3800	3800	3800	3800	3800
	Sandhills Game Lands	134	160	28200	29600	15600	16300	17200	18000	18900	19800	20800	21900
	subtotal	172	198	35800	37200	19400	20100	21000	21800	22700	23600	24600	25700
NPS	Big Cypress NP	42	42	8400	8400	4200	4200	4200	4200	4200	4200	4200	4200
	subtotal	42	42	8400	8400	4200	4200	4200	4200	4200	4200	4200	4200
SCFC	Sand Hills SF	51	143	10800	11400	6000	6200	6600	6900	7200	7600	8000	8400
	subtotal	51	143	10800	11400	6000	6200	6600	6900	7200	7600	8000	8400
SFWMD	Kicco WMA	1	1	200	200	100	100	100	100	100	100	100	100
	St. Sebastian River SBP	8	25	1800	1800	1000	1000	1100	1100	1200	1200	1300	1400
	subtotal	9	26	2000	2000	1100	1100	1200	1200	1300	1300	1400	1500
SJRWMD	Hal Scott Preserve	7	15	1600	1600	900	900	900	1000	1000	1100	1100	1200
	subtotal	7	15	1600	1600	900	900	900	1000	1000	1100	1100	1200
USAF	Avon Park AFR	21	68	4600	4800	2500	2600	2700	2900	3000	3200	3300	3500
	Dare County Bombing Range	3	46	800	800	400	400	400	500	500	500	500	500
	Eglin AFB	301	500	63400	66400	34900	36600	38500	40400	42400	44500	46700	49100
	Poinsett Weapons Range	6	30	1400	1400	700	800	800	900	900	900	1000	1000
	subtotal	331	644	70200	73400	38500	40400	42400	44700	46800	49100	51500	54100

Table continued next page.

TABLE 17 (cont.). Estimated annual cost and schedule for implementation of recovery task 1.1.2 (*maintain four suitable cavities in each active cluster*).

Responsible Agency	Property	ACT 2000	Property Goal[2]	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
				Estimated Annual Cost ($1) for Cavity Maintenance									
USARMY	Camp Mackall	11	11	2200	2200	1100	1100	1100	1100	1100	1100	1100	1100
	Fort Benning	219	450	46000	48400	25400	26700	28000	29400	30900	32400	34000	35700
	Fort Bragg	350	436	73600	77200	40600	42600	43600	43600	43600	43600	43600	43600
	Fort Gordon	5	25	1200	1200	600	700	700	700	800	800	800	900
	Fort Jackson	24	126	5200	5400	2800	3000	3100	3300	3400	3600	3800	4000
	Fort Polk	46	179	9800	10200	5400	5600	5900	6200	6500	6800	7200	7500
	Fort Stewart	212	500	44600	46800	24600	25800	27100	28500	29900	31400	32900	34600
	MOT Sunny Point	9	17	2000	2000	1100	1100	1200	1300	1300	1400	1400	1500
	Peason Ridge	23	120	5000	5200	2700	2800	3000	3100	3300	3400	3600	3800
	subtotal	899	1864	189600	198600	104300	109400	113700	117200	120800	124500	128400	132700
USDOE	Savannah River Site	34	418	7200	7600	4000	4200	4400	4600	4800	5100	5300	5600
	subtotal	34	418	7200	7600	4000	4200	4400	4600	4800	5100	5300	5600
USFS	Angelina NF	29	252	6200	6400	3400	3600	3800	3900	4100	4300	4500	4800
	Apalachicola RD	486	500	0	0	0	0	0	0	0	0	0	0
	Bienville NF	104	500	22000	23000	12100	12700	13300	14000	14700	15400	16200	17000
	Catahoula RD	32	317	6800	7200	3800	3900	4100	4300	4600	4800	5000	5300
	Chickasawhay RD	15	502	3200	3400	1800	1900	2000	2100	2200	2300	2400	2500
	Conecuh NF	18	309	3800	4000	2100	2200	2300	2500	2600	2700	2800	3000
	Croatan NF	62	169	13200	13800	7200	7600	8000	8400	8800	9200	9700	10100
	Davy Crockett NF	53	330	11200	11800	6200	6500	6800	7200	7500	7900	8300	8700
	DeSoto NF	7	368	1600	1600	900	900	900	1000	1000	1100	1100	1200
	Evangeline RD	72	231	15200	16000	8400	8800	9200	9700	10200	10700	11200	11800
	Francis Marion NF	344	453	72400	76000	39900	41900	44000	45300	45300	45300	45300	45300

Table continued next page.

TABLE 17 (cont.). Estimated annual cost and schedule for implementation of recovery task 1.1.2 (*maintain four suitable cavities in each active cluster*).

Responsible Agency	**Property**	**ACT 2000**	**Property Goal[2]**	**Estimated Annual Cost ($1) for Cavity Maintenance 2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
USFS (cont.)	Homochitto NF	51	254	10800	11400	6000	6200	6600	6900	7200	7600	8000	8400
	Kisatchie RD	29	292	6200	6400	3400	3600	3800	3900	4100	4300	4500	4800
	Oakmulgee RD	110	394	23200	24400	12800	13400	14100	14800	15500	16300	17100	18000
	Ocala NF	22	179	4800	5000	2600	2700	2900	3000	3100	3300	3500	3600
	Oconee NF	20	176	4200	4600	2400	2500	2600	2700	2900	3000	3200	3300
	Osceola NF	63	462	13400	14000	7300	7700	8100	8500	8900	9400	9800	10300
	Ouachita NF	21	400	4600	4800	2500	2600	2700	2900	3000	3200	3300	3500
	Sabine NF	28	262	6000	6200	3300	3500	3600	3800	4000	4200	4400	4600
	Sam Houston NF	168	541	35400	37200	19500	20500	21500	22600	23700	24900	26100	27400
	Shoal Creek RD	6	125	1400	1400	700	800	800	900	900	900	1000	1000
	Talladega RD	0	110	200	400	300	400	500	600	600	600	700	700
	Vernon Unit	152	302	32000	33600	17600	18500	19400	20400	21400	22500	23600	24800
	Wakulla RD	138	506	29000	30600	16000	16800	17700	18500	19500	20400	21500	22500
	Winn RD	18	263	3800	4000	2100	2200	2300	2500	2600	2700	2800	3000
	subtotal	2048	8197	330600	347200	182300	191400	201000	210400	218400	227000	236000	245600
USFWS	Alligator River NWR	3	20	800	800	400	400	400	500	500	500	500	500
	Big Branch Marsh NWR	15	20	3200	3400	1800	1900	2000	2000	2000	2000	2000	2000
	Black Bayou NWR	1	1	200	200	100	100	100	100	100	100	100	100
	Carolina Sandhills NWR	116	193	24400	25600	13500	14100	14900	15600	16400	17200	18000	18900
	D'Arbonne NWR	2	5	600	600	300	300	300	300	300	300	400	400
	Felsenthal NWR	15	34	3200	3400	1800	1900	2000	2100	2200	2300	2400	2500
	Noxubee NWR	44	88	9400	9800	5100	5400	5700	5900	6200	6600	6900	7200
	Okefenokee NWR	37	86	7800	8200	4300	4500	4800	5000	5300	5500	5800	6100
	Pee Dee NWR	1	10	400	400	200	200	200	200	200	200	200	200

Table continued next page.

TABLE 17 (cont.). Estimated annual cost and schedule for implementation of recovery task 1.1.2 (*maintain four suitable cavities in each active cluster*).

Responsible Agency	Property	ACT Property 2000	Goal[2]	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
				Estimated Annual Cost ($1) for Cavity Maintenance									
USFWS	Piedmont NWR	39	96	8200	8600	4600	4800	5000	5300	5500	5800	6100	6400
(cont.)	Pocosin Lakes NWR	1	50	400	400	200	200	200	200	200	200	200	200
	St. Marks NWR	9	71	2000	2000	1100	1100	1200	1300	1300	1400	1400	1500
	Upper Ouachita NWR	1	1	200	200	100	100	100	100	100	100	100	100
	subtotal	284	675	60800	63600	33500	35000	36900	38600	40300	42200	44100	46100
USMC	MCB Camp Lejeune	59	173	12400	13200	6900	7200	7600	8000	8400	8800	9200	9700
	subtotal	59	173	12400	13200	6900	7200	7600	8000	8400	8800	9200	9700
USNAVY	Charleston Naval Weapons Station	1	12	400	400	200	200	200	200	200	200	200	200
	subtotal	1	12	400	400	200	200	200	200	200	200	200	200
	TOTAL	**4196**	**13660**	**785600**	**822800**	**432000**	**452300**	**473700**	**494000**	**512900**	**533300**	**554400**	**577400**

[1]Methods of rounding can substantially affect estimates of future population sizes and costs. Here, number of active clusters was not rounded in projections of future population size but future population size was then rounded up for cost estimates. For example, estimated population size in 2001 for Charleston Naval Weapons Station was 1.05 in 2001, rounded up to 2, and the cost estimate was thus $400 for that year. Cost estimate for Upper Ouachita NWR, as a second example, remained at $100/year throughout 2003-2010 because the property has reached its goal of 1 active cluster.

[2]Some property goals are non-binding estimates; see notes for Tables 6 and 9 for further information.

[3]Dupuis WMA is managed by SFWMD.

TABLE 18. Estimated annual cost for implementation of recovery task 1.2.3 (*provision recruitment clusters equal to 10 percent of population, 4 artificial cavities each*), for all federal properties and those state properties identified in recovery criteria. See key (Table 16) for agency abbreviations. Annual estimated cost = $800 x (0.1 x number of active clusters). Number of recruitment clusters to be provisioned annually is adjusted at 5-year intervals, based on a population size increasing at 5 percent annually[1]. Populations at or above property goal[2] require no more recruitment clusters. This estimate does not include habitat restoration (see Tables 16 and 19).

Responsible Agency	**Property**	**ACT 2000**	**Property Goal[2]**	**Recruitment Clusters/Yr 2001-2006**	**Cost/Yr ($1) 2001-2006**	**Recruitment Clusters/Yr 2006-2010**	**Cost/Yr ($1) 2006-2010**
FDF	Blackwater River SF	26	45	3	2400	4	3200
	Goethe SF	30	150	3	2400	5	4000
	Picayune Strand SF	3	25	1	800	1	800
	Tate's Hell SF	29	400	3	2400	4	3200
	Withlacoochee - Citrus Tract	46	100	5	4000	7	5600
	Withlacoochee - Croom Tract	5	30	1	800	1	800
	subtotal	139	750	16	12800	22	17600
FDMA	Camp Blanding Training Site	14	25	2	1600	2	1600
	subtotal	14	25	2	1600	2	1600
FFWCC	Babcock/Webb WMA	27	240	3	2400	4	3200
	J. W. Corbett/Dupuis WMA[3]	13	90	2	1600	2	1600
	Three Lakes WMA	51	125	6	4800	7	5600
	subtotal	91	455	11	8800	13	10400
FPS	Ochlockonee River SP	1	3	0	0	0	0
	subtotal	1	3	0	0	0	0
NCDA	McCain Tract	5	7	1	800	1	800
	subtotal	5	7	1	800	1	800
NCDENR	Weymouth Woods State NP	7	13	1	800	1	800
	subtotal	7	13	1	800	1	800
NCWRC	Holly Shelter Game Lands	38	38	0	0	0	0
	Sandhills Game Lands	134	160	14	11200	0	0
	subtotal	172	198	14	11200	0	0
NPS	Big Cypress NP	42	42	0	0	0	0
	subtotal	42	42	0	0	0	0
SCFC	Sand Hills SF	51	143	6	4800	7	5600
	subtotal	51	143	6	4800	7	5600

Table continued next page.

TABLE 18 (cont.). Estimated annual cost for implementation of recovery task 1.2.3 (*provision recruitment clusters equal to 10 percent of population, 4 artificial cavities each*).

Responsible Agency	Property	ACT 2000	Property Goal[2]	Recruitment Clusters/Yr 2001-2006	Cost/Yr ($1) 2001-2006	Recruitment Clusters/Yr 2006-2010	Cost/Yr ($1) 2006-2010
SFWMD	Kicco WMA	1	1	0	0	0	0
	St. Sebastian River SBP	8	25	1	800	2	1600
	subtotal	9	26	1	800	2	1600
SJRWMD	Hal Scott Preserve	7	15	1	800	1	800
	subtotal	7	15	1	800	1	800
USAF	Avon Park AFR	21	68	3	2400	3	2400
	Dare County Bombing Range	3	46	1	800	1	800
	Eglin AFB	301	500	31	24800	41	32800
	Poinsett Weapons Range	6	30	1	800	1	800
	subtotal	331	644	36	28800	46	36800
USARMY	Camp Mackall	11	11	0	0	0	0
	Fort Benning	219	450	22	17600	30	24000
	Fort Bragg	350	436	35	28000	0	0
	Fort Gordon	5	25	1	800	1	800
	Fort Jackson	24	126	3	2400	4	3200
	Fort Polk	46	179	5	4000	7	5600
	Fort Stewart	212	500	22	17600	29	23200
	MOT Sunny Point	9	17	1	800	2	1600
	Peason Ridge	23	120	3	2400	4	3200
	subtotal	899	1864	92	73600	77	61600
USDOE	Savannah River Site	34	418	4	3200	5	4000
	subtotal	34	418	4	3200	5	4000
USFS	Angelina NF	29	252	3	2400	4	3200
	Apalachicola RD	486	500	49	39200	0	0
	Bienville NF	104	500	11	8800	14	11200
	Catahoula RD	32	317	4	3200	5	4000
	Chickasawhay RD	15	502	2	1600	3	2400
	Conecuh NF	18	309	2	1600	3	2400
	Croatan NF	62	169	7	5600	9	7200
	Davy Crockett NF	53	330	6	4800	8	6400
	DeSoto NF	7	368	1	800	1	800
	Evangeline RD	72	231	8	6400	10	8000
	Francis Marion NF	344	453	35	28000	0	0
	Homochitto NF	51	254	6	4800	7	5600

Table continued next page.

TABLE 18 (cont.). Estimated annual cost for implementation of recovery task 1.2.3 (*provision recruitment clusters equal to 10 percent of population, 4 artificial cavities each*).

Responsible Agency	Property	ACT 2000	Property Goal[2]	Recruitment Clusters/Yr 2001-2006	Cost/Yr ($1) 2001-2006	Recruitment Clusters/Yr 2006-2010	Cost/Yr ($1) 2006-2010
USFS (cont.)	Kisatchie RD	29	292	3	2400	4	3200
	Oakmulgee RD	110	394	11	8800	15	12000
	Ocala NF	22	179	3	2400	3	2400
	Oconee NF	20	176	2	1600	3	2400
	Osceola NF	63	462	7	5600	9	7200
	Ouachita NF	21	400	3	2400	3	2400
	Sabine NF	28	262	3	2400	4	3200
	Sam Houston NF	168	541	17	13600	23	18400
	Shoal Creek RD	6	125	1	800	1	800
	Talladega RD	0	110	8	6400	8	6400
	Vernon Unit	152	302	16	12800	21	16800
	Wakulla RD	138	506	14	11200	19	15200
	Winn RD	18	263	2	1600	3	2400
	subtotal	2048	8197	224	179200	180	144000
USFWS	Alligator River NWR	3	20	1	800	1	800
	Big Branch Marsh NWR	15	20	2	1600	0	0
	Black Bayou NWR	1	1	0	0	0	0
	Carolina Sandhills NWR	116	193	12	9600	16	12800
	D'Arbonne NWR	2	5	1	800	1	800
	Felsenthal NWR	15	34	2	1600	3	2400
	Noxubee NWR	44	88	5	4000	6	4800
	Okefenokee NWR	37	86	4	3200	5	4000
	Pee Dee NWR	1	10	1	800	1	800
	Piedmont NWR	39	96	4	3200	6	4800
	Pocosin Lakes NWR	1	50	1	800	1	800
	St. Marks NWR	9	71	1	800	2	1600
	Upper Ouachita NWR	1	1	0	0	0	0
	subtotal	284	675	34	27200	42	33600
USMC	MCB Camp Lejeune	59	173	6	4800	8	6400
	subtotal	59	173	6	4800	8	6400
USNAVY	Charleston Naval Weapons Station	1	12	1	800	1	800
	subtotal	1	12	1	800	1	800
	TOTAL	**4194**	**13660**	**448**	**358400**	**405**	**324000**

[1]Population size was not rounded for size projections but was rounded up to calculate recruitment clusters.

[2]Some property goals are non-binding estimates; see notes for Table 6 for further information.

[3]Dupuis WMA is managed by SFWMD.

TABLE 19. Estimated annual cost for implementation of recovery task 1.7 (*burn entire area managed for red-cockaded woodpeckers at least once every 1 to 5 years*), for all federal properties and those state properties identified in recovery criteria. See key (Table 16) for agency abbreviations. Annual estimated cost = $49.4 x (1/3 total ha), or $20 x (1/3 total ac), assuming all habitat is burned once every 3 years. Estimated available habitat is based on property goal; see notes in Table 6 for further information on property goals.

Responsible Agency	**Property**		**Estimated Available Habitat [ha (ac)]**		**Estimated Annual Cost ($1)**
FDF	Blackwater River SF		3640	(9000)	60000
	Goethe SF		12140	(30000)	200000
	Picayune Strand SF		2020	(5000)	3330
	Tate's Hell SF		32380	(80000)	533330
	Withlacoochee - Citrus Tract		8090	(20000)	133330
	Withlacoochee - Croom Tract		2430	(6000)	40000
		subtotal	60700	(150000)	999990
FDMA	Camp Blanding Training Site		2020	(5000)	33330
		subtotal	2020	(5000)	33330
FFWCC	Babcock/Webb WMA		19420	(48000)	320000
	J. W. Corbett/Dupuis WMA[1]		7280	(18000)	120000
	Three Lakes WMA		10120	(25000)	166670
		subtotal	36820	(91000)	606670
FPS	Ochlockonee River SP		240	(600)	4000
		subtotal	240	(600)	4000
NCDA	McCain Tract		570	(1400)	9330
		subtotal	570	(1400)	9330
NCDENR	Weymouth Woods State NP		1050	(2600)	17330
		subtotal	1050	(2600)	17330
NCWRC	Holly Shelter Game Lands		3080	(7600)	50670
	Sandhills Game Lands		12950	(32000)	213330
		subtotal	16030	(39600)	264000
NPS	Big Cypress NP		3400	(8400)	56000
		subtotal	3400	(8400)	56000
SCFC	Sand Hills SF		11570	(28600)	190670
		subtotal	11570	(28600)	190670

Table continued next page.

TABLE 19 (cont.). Estimated annual cost for implementation of recovery task 1.7 (burn entire area managed for red-cockaded woodpeckers at least once every 1 to 5 years).

Responsible Agency	**Property**		**Estimated Available Habitat [ha**	**(ac)]**	**Estimated Annual Cost ($1)**
SFWMD	Kicco WMA		80	(200)	13330
	St. Sebastian River SBP		2020	(5000)	33330
		subtotal	2100	(5200)	46660
SJRWMD	Hal Scott Preserve		1210	(3000)	20000
		subtotal	1210	(3000)	20000
USAF	Avon Park AFR		5500	(13600)	90670
	Dare County Bombing Range		3720	(9200)	61330
	Eglin AFB		40470	(100000)	666670
	Poinsett Weapons Range		2430	(6000)	40000
		subtotal	52120	(128800)	858670
USARMY	Camp Mackall		890	(2200)	14670
	Fort Gordon		2020	(5000)	33330
	Fort Bragg		35290	(87200)	581330
	Fort Jackson		10200	(25200)	168000
	Fort Stewart		40470	(100000)	666670
	Fort Benning		36420	(90000)	600000
	Fort Polk		14490	(35800)	238670
	MOT Sunny Point		1380	(3400)	22670
	Peason Ridge		9710	(24000)	160000
		subtotal	150870	(372800)	2485330
USDOE	Savannah River Site		33830	(83600)	557330
		subtotal	33830	(83600)	557330
USFS	Angelina NF		20400	(50400)	336000
	Apalachicola RD		40470	(100000)	666670
	Bienville NF		40470	(100000)	666670
	Catahoula RD		25660	(63400)	422670
	Chickasawhay RD		40630	(100400)	669330
	Conecuh NF		25010	(61800)	412000
	Croatan NF		13680	(33800)	225330
	Davy Crockett NF		26710	(66000)	440000
	DeSoto NF		29790	(73600)	490670
	Evangeline RD		18700	(46200)	308000
	Francis Marion NF		36670	(90600)	604000
	Homochitto NF		20560	(50800)	338670
	Kisatchie RD		23630	(58400)	389330

Table continued next page.

TABLE 19 (cont.). Estimated annual cost for implementation of recovery task 1.7 (*burn entire area managed for red-cockaded woodpeckers at least once every 1 to 5 years*).

Responsible Agency	**Property**		**Estimated Available Habitat [ha (ac)]**		**Estimated Annual Cost ($1)**
USFS (cont.)	Oakmulgee RD		31890	(78800)	525330
	Ocala NF		14490	(35800)	238670
	Oconee NF		14250	(35200)	234670
	Osceola NF		37390	(92400)	616000
	Ouachita NF		32380	(80000)	533330
	Sabine NF		21210	(52400)	349330
	Sam Houston NF		43790	(108200)	721330
	Shoal Creek RD		10120	(25000)	166670
	Talladega RD		8900	(22000)	146670
	Vernon Unit		24440	(60400)	402670
	Wakulla RD		40960	(101200)	674670
	Winn RD		21290	(52600)	350670
		subtotal	645200	(1594200)	10628010
USFWS	Alligator River NWR		1620	(4000)	26670
	Big Branch Marsh NWR		1620	(4000)	26670
	Black Bayou NWR		80	(200)	1330
	Carolina Sandhills NWR		15620	(38600)	257330
	D'Arbonne NWR		400	(1000)	6670
	Felsenthal NWR		2750	(6800)	45330
	Noxubee NWR		7120	(17600)	117330
	Okefenokee NWR		6960	(17200)	114670
	Pee Dee NWR		810	(2000)	13330
	Piedmont NWR		7770	(19200)	128000
	Pocosin Lakes NWR		4050	(10000)	66670
	St. Marks NWR		5750	(14200)	94670
	Upper Ouachita NWR		80	(200)	1330
		subtotal	54630	(135000)	900000
USMC	MCB Camp Lejeune		14000	(34600)	230670
		subtotal	14000	(34600)	230670
USNAVY	Charleston Naval Weapons Station		970	(2400)	16000
		subtotal	970	(2400)	16000
		TOTAL	**1005860**	**(2500000)**	**16569330**

[1] Dupuis WMA is managed by SFWMD.

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GLOSSARY OF TERMS

Active cavity	A completed cavity or start exhibiting fresh pine resin associated with cavity maintenance, cavity construction, or resin well excavation by red-cockaded woodpeckers.
Active cavity tree	Any tree containing one or more active cavities.
Active cluster	A cluster containing one or more active cavity trees.
Adaptive management	The process of implementing flexible management and policy that is responsive to results of continuous biological monitoring and scientific experimentation.
Allozyme	An enzyme that has different forms, resulting from different alleles at the locus encoding the enzyme.
Augmentation	Increasing the size of a population by translocating individuals between populations.
Basal area	The area of a horizontal cross section of a tree's stem, generally measured at breast height.
Breeding dispersal	Movement of individuals between consecutive breeding locations.
Budding	One of two processes of new group formation in red-cockaded woodpeckers (see also pioneering), referring to the splitting of one territory into two.
Canopy	The uppermost layer of foliage in a forest or forest stand.
Captured cluster	A cluster that does not support its own group of red-cockaded woodpeckers, but contains active cavity trees in use or kept active by birds from a neighboring cluster.
Catastrophe	A random environmental event of great consequence.
Clayhills	Pine communities on clay soils, especially in northwestern Florida, eastern Alabama, and southwestern Georgia.
Clearcut	An area in which all trees have been removed in one cutting.
Cluster	The aggregation of cavity trees previously and currently used and defended by a group of woodpeckers, or this same aggregation of cavity trees *and* a 61 m (200 ft) wide buffer of continuous forest. Here, the second definition is used. For management purposes, the minimum area encompassing the cluster is 4 ha (10 ac). Use of the term cluster is preferred over colony because colony implies more than one nest (as in colonial breeder).
Cluster, active	See active cluster.
Cluster, captured	See captured cluster.

Coadapted gene complexes	Genes, having evolved together, that as a unit confer higher fitness than the sum of the individual genes' contributions. A coadapted gene's fitness effect depends on the genetic environment (the presence of other genes).
Coastal plain	In the United States, an ecoregion or physiographic province located near the Atlantic Ocean or Gulf of Mexico.
Cooperative breeding	A breeding system in which one or more adults assist a breeding pair in rearing of young. These extra adults, called helpers, delay their own dispersal and reproduction and are generally related to the offspring of the breeding pair.
Critical rate of decline	Critical rate of population decline identified in this recovery plan is 10% decrease in number of active cluster clusters from one year to the next, or within 5 years.
Decreasing population trend	See critical rate of decline.
Demographic stochasticity	Randomly occurring events affecting individuals.
Demography	Vital rates, including birth, death, and dispersal rates, and the analysis of population size and trend.
Dispersal	Movement of individuals from natal to first breeding location (natal dispersal), or between consecutive breeding locations (breeding dispersal).
Ecoregion	A system of classification based on physiography.
Effective population size	The size of the ideal, hypothetical population in which all individuals mate randomly and all contribute equally to reproduction. Variation in reproductive success and other processes in a real population affect how many genes are conserved in subsequent generations. The concept of effective population size is used to control for the effects of such processes when discussing genetic conservation.
Environmental stochasticity	Random changes in environmental conditions and their effects on populations.
Even-aged management	A silvicultural method designed primarily for timber production, in which all trees in a stand are of one age/size class. The forest is regulated by developing equal areas in each age/size class.
Extirpation	Loss of a population or all populations within a specified region.
Flatwoods	Mesic pine communities on the Gulf and Atlantic coastal plains with a well-developed woody shrub or midstory layer.
Floater	An adult bird not associated with a breeding group.
Forb	A herbaceous plant that has broad leaves, not a grass.
Fragmentation	Habitat loss that results in isolated patches of remaining habitat.
Gene flow	The movement of genetic material among populations or within a population.

Genetic drift	Random sampling of genetic resources within a population from one generation to the next. In populations of finite size, this sampling will always result in loss of variation. In populations of large size, such loss may be offset by new variation arising through mutation.
Genetic stochasticity	Random changes in gene frequencies.
Group	The social unit in red-cockaded woodpeckers, consisting of a breeding pair with one or more helpers, a breeding pair without helpers, or a solitary male.
Habitat selection	Use of a resource above what is expected based on the availability of that resource.
Heartwood	The inner, inactive core of a tree.
Helper	An adult that delays its own reproduction to assist in the rearing of another breeding pair's young. Typically, helpers are related to the breeding pairs that they assist.
Herbs	Grasses and forbs.
Herbaceous	Non-woody.
Heterozygosity	Genetic diversity within an individual or population, as measured by the proportion of loci containing two different alleles.
Home range	The area supporting the daily activities of an animal, generally throughout the year.
Homozygosity	Genetic similarity within an individual or population, as measured by the proportion of loci containing two identical alleles.
Immigration	Movement of one or more individuals into a population.
Inbreeding	Mating between relatives.
Inbreeding depression	Loss of fitness due to the increase in homozygosity that results from inbreeding.
Increasing population trend, recommended rate of	Five percent increase in active clusters from one year to the next.
Kleptoparasitism	Theft by one species of resources procured by another species, resulting in positive effects for the parasite and negative effects for the species being parasitized. Generally this term is applied to theft of food, but has recently been expanded to include theft of spatial resources.
Local adaptation	Traits conferring higher fitness in a local environment.
Metapopulation	A set of interacting populations.
Midstory	A layer of foliage intermediate in height between canopy and groundcover, litter layer, or soil surface.

Mitigation	Reduction of negative impacts.
Mutation	A heritable change in a DNA molecule.
Natal dispersal	Movement of individuals from their place of birth to their first breeding location.
Pioneering	One of two processes of new group formation in red-cockaded woodpeckers (see also budding), by which a group colonizes previously unoccupied areas. Because of the difficulty of cavity excavation, this process occurs at very low frequencies.
Plate	On a cavity tree, the area surrounding the cavity entrance with bark removed by red-cockaded woodpeckers. Newly formed cavities may not exhibit a well-developed plate.
Pocosin	A wetland dominated by a dense cover of evergreen and deciduous shrubs.
Population	A group of individuals of the same species occupying a given area. Methods of specifying such an area may differ according to purpose. A common specification is the area within which gene flow is sufficient to avoid genetic differentiation.
Population augmentation	Translocation between populations to increase population size.
Population dynamics	Properties of a population such as trend and regulation of population size.
Population trend	See increasing population trend, decreasing population trend, and stable population trend.
Potential breeding group	An adult female and adult male that occupy the same cluster, whether or not they are accompanied by a helper, attempt to nest, or successfully fledge young.
Predation	The acquisition of food by killing and eating another organism.
Prescribed burning	Fire applied to the landscape to meet specific management objectives.
Primary cavity nester	Species that nest in cavities they created.
Primary core population	A population identified in recovery criteria that will hold at least 350 potential breeding groups at the time of and after delisting. Defined by biological boundaries.
RAPD	Randomly amplified polymorphic DNA; used as a genetic marker.
Recovery	Species viability.
Recovery population	One of a set of populations designated necessary to the recovery of the species.
Recovery unit	One of a set of geographical areas, delineated according to ecoregions, that likely represent broad-scale geographic and genetic

	variation in red-cockaded woodpeckers. Viable populations in each recovery unit, to the fullest extent that available habitat allows, are considered essential to the recovery of the species.
Recruitment	The addition of individuals into a breeding population through reproduction and/or immigration and attainment of a breeding position.
Recruitment cluster	A cluster of artificial cavities in suitable nesting habitat, located close to existing groups.
Regeneration	A silvicultural method of simultaneously harvesting, and establishing reproduction in, a stand of trees.
Regulation	A process of implementing silvicultural techniques to establish equal areas of tree size classes, to sustain a given level of timber production over time.
Reintroduction	Translocation of individuals from a captive or wild population to previously occupied but currently unoccupied habitat.
Resinosis	A process through which injured sapwood in a pine tree becomes saturated with hardened resin, reducing and eventually preventing loss of resin.
Resin well	A wound in a pine tree's cambium, created and maintained by red-cockaded woodpeckers, for the purpose of resin production.
Restrictors	Metal plates used to prevent or repair enlargement of cavity entrances.
Rotation	In even-aged management of forests, the number of years between regeneration events.
Sandhills	Xeric and sub-xeric longleaf pine communities on deep sandy soils. Also, the ecoregion encompassing the fall-line sandhills communities, between the mid- and south-Atlantic coastal plains and Piedmont.
Sapwood	The outer, active layer of tissue in a tree, lying just inside the cambium.
Savannah	A mesic and seasonally wet pine community, often transitional between xeric pine systems and wetlands, characterized by diverse grass and forb groundcovers.
Secondary cavity nester	Species that inhabit cavities they did not create.
Secondary core population	A population identified in recovery criteria that will hold at least 250 potential breeding groups at the time of and after delisting. Defined by biological boundaries.
Seed-tree	A method of timber regeneration in which most trees in a site are cut, and tree seedlings become established under remnant large trees. Remnant large trees are retained at lower densities than under the shelterwood method.

Selection cutting	A method of timber regeneration in which single trees or patches of trees (0.8 ha or less, 2 ac or less) are cut.
Shelterwood	A method of timber regeneration in which many but not all trees in a site are cut, and tree seedlings become established under remnant large trees. Remnant large trees are retained at higher densities than under the seed-tree method.
Silviculture	The theory and practice of controlling the establishment, composition, structure, and growth of forests to achieve management objectives. Silviculture was developed primarily for the purpose of timber production, but can be used for other purposes including biological conservation.
Snag	A standing, dead tree.
SNEDs	Snake excluder devices.
Solitary male	An unpaired male that is the sole resident of a cluster.
SQEDs	Squirrel excluder devices.
Stable population	A population that exhibits neither an increasing or decreasing population trend.
Stand	A silvicultural term for an area of trees that is or has been treated as a single management unit.
Start	An incomplete cavity.
Strategic recruitment	Placement of recruitment clusters in locations strategically chosen to enhance the spatial arrangement of breeding groups. Breeding groups aggregated in space rather than isolated are beneficial to population dynamics and viability.
Stochasticity	Random events.
Support population	All known populations not designated a primary or secondary core are designated support populations. Support populations (other than essential supports) are defined by ownership rather than biological boundaries. There are three classifications for support populations: 1. Essential support populations are those populations, identified in recovery criteria, that represent unique or important habitat types that cannot support a larger, core population. They are located on federal and state lands and two private properties. 2. Significant support populations are populations, not identified in recovery criteria, that contain and/or have a population goal of 10 or more active clusters. They are located on federal and state lands and on private lands enrolled in agreements with the U.S. Fish and Wildlife Service. 3. Important support populations are populations, not identified in recovery criteria, that contain and have a population goal of less than 10 active clusters. They are located on federal and state lands and on

	private lands enrolled in agreements with the U.S. Fish and Wildlife Service.
Take	As defined by the Endangered Species Act, take means to “harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct” (Section 3.18 of the Act). Habitat destruction and alteration are considered forms of take, following a Supreme Court ruling on this issue (Sweet Home vs. Babbitt).
Taxonomy	Hierarchical classification system for all life forms.
Territory	A region within an animal’s home range that is defended from conspecifics.
Thinning	A silvicultural treatment removing some trees in a stand to reduce tree density.
Translocation	The artificial movement of wild organisms between or within populations to achieve management objectives. Originally, translocation referred to the movement of animals from captive to wild populations, but the term has been expanded to include movements (by artificial means) within and between wild populations.
Two-aged management	A silvicultural method designed primarily for timber production, in which trees of two age/size classes are present in the same stand. The forest is regulated by developing equal areas in each age/size class.
Uneven-aged management	A silvicultural method designed primarily for timber production, in which trees of at least three age classes are present in the same stand. Stands are regulated by size class structure or volume.
Viability	The ability of a population or species to persist over time.

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APPENDIX 1. PERMITS, TRAINING, AND COMPLIANCE REQUIREMENTS

The objectives of the permitting and compliance program are to: (1) identify, standardize, and, as needed, modify training/certification procedures to ensure the safety of and minimize death and injury to red-cockaded woodpeckers; (2) standardize permit reporting requirements; (3) ensure compliance with all permit requirements, including reporting; (4) ensure that a coordinated specimen disposal program exists, and (5) facilitate distribution of research findings resulting from permit activities. The permit process is an important component of adaptive management. Permitted activities may be modified or eliminated based on research findings and/or an evaluation of their biological costs versus conservation benefits. The primary objective of establishing certification procedures, including "hands-on" protocols, is to minimize the potential for injury or death. Ultimately, it is our responsibility as individuals and as federal and state agency regulators to ensure that biological and ethical protocols are established and followed when conducting activities that have the potential to harm or harass red-cockaded woodpeckers.

The following activities associated with the monitoring and management of red-cockaded woodpeckers require an exemption from the prohibitions of Section 9 of the Endangered Species Act. This exemption is usually authorized via a Section 10(a)(1)(A) permit. The U.S. Fish and Wildlife Service considers that these activities have the potential to harass or result in death or injury to an individual red-cockaded woodpecker or to raise concern about possession of endangered wildlife contrary to laws and regulations.

1. installation and/or modification of artificial nesting cavities.
2. installation of cavity restrictors.
3. manipulation (removal or modification) of red-cockaded woodpecker cavities or cavity trees, including installation of SNEDs, SQEDs, cameras, etc.
4. capturing and handling (for any purpose, including banding or color marking) nestling and adult birds.
5. placing radiotelemetry devices on red-cockaded woodpeckers.
6. visual examination of active cavities with a mirror and droplight or a video probe (“peeper”).
7. salvage of addled eggs, and/or determining viability of eggs.
8. collection and retention of red-cockaded woodpecker specimens or their body parts (including eggs, blood or feathers) for scientific and other purposes consistent with the species' conservation strategy.
9. interstate commerce of dead or living birds or their body parts, including sale or bartering for financial gain.
10. translocation and/or temporary confinement of adults, fledglings, chicks, or eggs.
11. any other activity or practice that may be construed to harm or harass red-cockaded woodpeckers during any life stage.

In addition, the following activities involving red-cockaded woodpeckers are likely to require a Section 10(a)(1)(A) permit unless you are an employee or agent of the

U.S. Fish and Wildlife Service, any other federal land management agency, or a state conservation agency who is designated by his agency for the following purposes:

1. aid to a sick, injured, or orphaned specimen.
2. disposal of a dead specimen.
3. salvage of a dead specimen which may be useful for scientific study.

(Federal or state employees and agents must notify the U.S. Fish and Wildlife Service, Division of Law Enforcement within 5 days of undertaking these activities and must receive concurrence from the U.S. Fish and Wildlife Service on the disposition of these specimens.)

Those individuals placing aluminum bands and/or auxiliary markers (including colored leg bands) on red-cockaded woodpeckers, require a permit (in addition to a U.S. Fish and Wildlife Service Section 10(a)(1)(A) permit) for each of those activities from the U.S. Geological Survey, Biological Resources Division's National Bird Banding Lab, Route 197, Laurel, Maryland 20708; telephone: (301) 498-0428. Most, if not all, states harboring red-cockaded woodpeckers also require permits for some of the activities listed above, including translocating birds from and to their state. Contact state wildlife agencies for endangered/threatened species permit requirements. Each permit has a specific purpose and provides important information to the agency legally responsible for issuing the permit.

Reporting Requirements

Every Section 10(a)(1)(A) permit requires an annual report to the U.S. Fish and Wildlife Service. The Annual Report fulfills this requirement, and must be completed and submitted to the Recovery Coordinator (original) and the U.S. Fish and Wildlife Service's Regional Office (copy) annually by January 31st. Agencies or individuals not submitting completed reports will not have their permits re-authorized. This reporting system ensures that this critical recovery program is evaluated annually for its conservation value, and is modified as needed in response to new information.

Training

Prior to issuing any Section 10(a)(1)(A) permit, the U.S. Fish and Wildlife Service must meet several criteria, including the determination of the applicant's ability to successfully accomplish the authorized activities. Because of the potential for direct injury or death to red-cockaded woodpeckers from the above activities, all individuals involved in any of these activities must be trained and certified for each activity prior to receiving a permit or sub-permit under someone else's permit. Potential applicants must be trained by an individual who has the proper permits for and extensive experience in the activity in question. Several federal and state biologists, consultants, and researchers are considered "trainers" or "certifiers" by the U.S. Fish and Wildlife Service for one or more of the above activities. Upon satisfactory completion of training (as determined by the trainer and the Service), the trainer certifies in writing to the Service that the individual is competent and qualified to perform the activity or activities in question. Contact the Red-cockaded Woodpecker Recovery Coordinator to arrange training with certified trainers.

Training for Installation of Artificial Cavities and Restrictors

Training prior to installation of artificial cavities and restrictors is considered adequate if the following criteria are met:

a. A period of apprenticeship is completed under the direction of a person that has held appropriate permits for at least three years and has been involved in the activities in question throughout that time.

b. The apprentice has installed at least 10 restrictors, 10 drilled cavities, 10 starts, and 10 inserts under direct supervision of the permit holder.

c. The apprentice has learned the maintenance and inspection procedures for cavities and restrictors.

d. The permit holder has certified in writing to the U.S. Fish and Wildlife Service Regional Permits Coordinator and the Red-cockaded Woodpecker Recovery Coordinator that the apprentice completed the required training. If the permit holder determines that additional training of the apprentice is necessary or that the apprentice should not be issued a permit, he or she should certify such in writing to the apprentice and the coordinators listed above.

Training for Monitoring, Capture, Banding, Etc.

Safe and accurate monitoring of red-cockaded woodpeckers requires skill, normally acquired through years of experience with red-cockaded woodpeckers and their habitat. Apprenticeship training by a recognized expert in the biology of red-cockaded woodpeckers can accelerate the acquisition of appropriate monitoring skills. The Red-cockaded Woodpecker Recovery Coordinator maintains a list of recognized experts who are willing to serve as trainers. Persons seeking the endangered species and bird banding permits necessary for red-cockaded woodpecker monitoring will document their *need* in writing to the Red-cockaded Woodpecker Recovery Coordinator and the Regional Permits Coordinator. If both Coordinators concur that the monitoring need is legitimate and that the permit applicant is the appropriate entity to conduct the monitoring, the applicant will be referred to the list of qualified trainers. In reaching the referral decision the Recovery Coordinator or Permits Coordinator may conduct background inquiries as they deem necessary.

The applicant will select a red-cockaded woodpecker trainer from the provided list, contact that person, and arrange for training to occur. The cost of training will be borne by the applicant. The red-cockaded woodpecker expert will personally supervise the training of the applicant. The training period will be at the discretion of the trainer, but will not be less than:

a. 50 cavities correctly assessed for stage and activity,

b. 15 cavity trees climbed and cavity contents checked,

c. 10 adult red-cockaded woodpeckers captured and banded (with appropriate data taken) without injury to the birds,

d. 20 nestlings captured, aged and banded (with appropriate data taken) without injury to the birds,

e. 20 free ranging red-cockaded woodpeckers correctly identified by color-bands,

f. 10 sub-adults translocated without injury or mortality (including all associated activities such as feeding during transport, etc.), and

g. 10 red-cockaded woodpeckers treated for any other handling technique (such as bleeding, etc.).

Once at least the minimum amount of training, as described above or as otherwise dictated by the Recovery Coordinator, is accomplished to the satisfaction of the trainer, he or she will certify such in writing to the Recovery Coordinator and the Regional Permits Coordinator. The trainer will only conduct training and certification in areas of expertise in which he or she is certified. The trainer is under no obligation to certify anyone if in his or her opinion the applicant has not completed training adequately. If such is the case, the trainer will document the deficiencies in writing to the applicant, the Recovery Coordinator and the Regional Permits Coordinator, and recommend either more training or permit denial. Certification may be issued for some techniques and withheld for others. A person receiving certification cannot in turn train and certify other individuals until he or she has at least 3 years of experience in the certified techniques, has all required permits in good order and has been placed on the Recovery Coordinator's list of red-cockaded woodpecker trainers.

APPENDIX 2. PROTOCOL FOR MONITORING REPRODUCTIVE SUCCESS, GROUP SIZE, AND GROUP COMPOSITION (COLOR-BANDING)

Monitoring reproductive success and group size is accomplished by periodic visits to the nest, color-banding all nestlings and unbanded adults, conducting fledgling checks and/or late-nestling checks, and identifying all banded adults throughout the breeding season. This appendix provides information on: (1) nest checks, (2) aging nestlings according to Ligon age characteristics, (3) capturing and color-banding nestlings, (4) capturing and color-banding adults, (5) fledgling or late nestling checks, (6) color-band observation, (7) determining group composition, and (8) data management.

1. Nest Checks

Nest checks consist of repeated visits to the cluster on a 7 to 11 day cycle until a nest is found. More frequent nest checks subject the birds to unnecessary disturbance for little additional information. Less frequent nest checks greatly increase the likelihood that nestlings will be too old to band when found, and nest failures may go undetected.

Each active cavity tree in the cluster is a potential nest site, although nests are typically found in the most active cavity tree and often in the most recently completed cavity. Locate nests by observing adult behavior (e.g., flushing from a cavity during the day, tending nestlings) and/or inspecting contents of active cavities using Swedish ladders or a video probe. Once a nest is located, observe and record contents, including number of eggs or nestlings and nestling age (see below), as well as other relevant information such as date, time, and cavity, cavity tree, and cluster identification numbers. Schedule the following nest visit by optimal banding age (see below). If a discovered nest contains eggs, return to the cluster in 7 to 11 days. After nestlings are banded, it is not necessary to return to the site until the late/nestling check or fledgling check, whichever is used (see below).

If a nest fails before nestlings have fledged, return the cluster to the nest check cycle to detect renesting. If no nest is observed within a cluster, conduct a morning follow of group members (3A) and survey for new cavity trees within suitable habitat in and near the cluster (3A).

During nest checks, identify all adults present by color-band observation and record their color-band combination and activity (e.g., incubating, feeding nestlings, conflicting with other adults). This information is important to determining group composition (see below).

2. Aging Nestlings

Nestlings are aged according to descriptive characteristics set out by Ligon (1970; Table 20). Aging of nestlings is done with extreme care and attention to detail.

TABLE 20. Nestling characteristics indicative of nestling age, in number of days.

Nestling Age	Character	Description
DAY 0	SKIN	Loose and pink
	BILL	Mandible roughly 2mm longer that maxilla; diamond-shaped egg-tooth on maxilla
	WINGS	Permanently extended and used to remain upright
	RETRICES	Bumps
	FEET	Heel pad greatly enlarged
	SIZE	Appears small enough to fit back into egg
DAY 1	SIZE	Appears that the body would fit back into shell, but not the head
DAY 3	REMIGES	Dots visible
DAY 4	SKIN	Tail darkening
	BILL	Turning black except for egg tooth
	TRACTS	Back, wing, and scapular tracks visible
DAY 5	SKIN	Skin darkening
	TRACTS	Crown, lower neck, and most of spinal, femoral, and ventral tracks visible
DAY 6	BILL	Maxilla almost as long as mandible
	EARS	Open
	RETRICES	Bristles visible
DAY 7	TRACTS	Crural tracts visible
	FEET	Increasing in size
DAY 8	SKIN	Darker
	BILL	Maxilla and mandible are about equal in length
	RETRICES	Protruding
	REMIGES	Quills protruding from skin
	FEET	Darkening
DAY 9	EYE	Opening
	RETRICES	Exposed short distance
	FEET	Extended toes 34 mm
DAY 10	REMIGES	Quills showing
	TRACTS	Well developed; feather tips exposed at tail, rump, slightly on breast, and on lower abdominal tract. Quills of middle and lesser coverts, humeral tract, and spinal tract showing.
	FEET	Feet and tarsi dark, heel pads light, losing knobs and tubercles
DAY 11	BILL	Maxilla slightly longer than mandible, culmen 11 – 12 mm
	REMIGES	1^{st} secondary 8mm, 2^{nd} primary 7 mm
	TRACTS	Feather tips of spinal, scapulars, anterior ventral and crural tracts showing
	BEHAVIOR	Call changes to more adult-like
DAY 13	RETRICES	Quills 6.5 – 7.5 mm
	REMIGES	Outer primary quills about 25 mm; longest primary 18 – 25 mm

Table continued next page.

TABLE 20 (cont.). Nestling characteristics indicative of nestling age, in number of days.

Nestling Age	Character	Description
DAY 15	RETRICES	Quills 16 – 18 mm
	TRACTS	Feathers still largely sheathed
DAY 16	BILL	Culmen 14 mm
	REMIGES	Longest primary 27 mm (sheath 20 mm)
	TRACTS	Erupted feathers covering much of body surface
DAY 17	TRACTS	Feather sheaths on pileum of males broken away except for those of red crown patch
DAY 19	RETRICES	Longest feather 29 mm and quills beginning to break away
	REMIGES	Longest primary 45 mm and quills beginning to break away
	TRACTS	Body covered with feathers except for abdomen and flanks
	BEHAVIOR	Active and pecking at observer’s hand

3. Capturing and Color-banding Nestlings

Nestlings are banded between the ages of 5 to 10 days old. Banding nestlings older than 10 days in age is prohibited because of greatly increased risk of injury and mortality. Banding nestlings younger than 5 days old is not possible because they cannot accommodate three color-bands on one leg. In southerly parts of the range, nestling 5 or 6 days in age may not be large enough to wear three color-bands. In these regions, narrow the window of banding opportunity to 7 to 10 days in age.

Nestlings are captured and carefully removed from the nest cavity using a soft noose liberally lubricated with cornstarch (Jackson 1982). Nestlings must be kept warm and dry, and out of direct sunlight, while out of the nest.

Each individual is banded with a unique combination of color-bands (size XB) and a U.S. Geological Survey aluminum band (size 1A). Nestlings and adults (see below) are banded with three color-bands on one leg and the aluminum band, with or without an additional color-band, on the other leg. Birds are not to be banded with one or two color-bands alone on a leg, because color-bands that move excessively can cause injury to toes. Birds are not to be banded with more than a single color-band on the leg carrying the aluminum band. Therefore, we recommend that both legs be banded. If only one leg is banded, color-band combinations are reduced to a single color-band and the aluminum band.

Once nestlings are banded, check the accuracy of the band combination several times. Record necessary data on banding sheets. Return nestlings to the cavity.

4. Capturing and Banding Adults

Adults are captured for banding or color-band replacement following the breeding season, or at any time other than the breeding season, unless the bird in question cannot be caught except during breeding (e.g., a female without a roost cavity). Aluminum bands are never replaced, and are only removed if the band is causing injury. Color-bands may sometimes need replacement, but capture of adults should be minimized to the fullest possible extent.

Adults are typically captured at the roost cavity at dawn or dusk with a net attached to a telescoping pole. Adults will not be caught at night, except those captured for translocation that evening and for specific research needs with appropriate permits. Adults will also not be caught during wet weather; handling wet birds can kill them. Adults are banded in the same way as nestlings: three color-bands on one leg, and the aluminum band with or without an additional color-band on the other leg.

5. Fledgling or Late Nestling Checks

Fledgling checks or late nestling checks are performed to determine how many nestlings survived to fledging, and the sex of those individuals. Fledgling checks are preferable to late nestling checks because the accuracy of survival estimates are improved and because fledgling checks are an important time to identify adult members of the group. However, late nestling checks may be substituted if time and personnel are constrained.

Conduct fledgling checks for each banded nest between 2 and 14 days after the projected fledging date (26 days after estimated hatching date). Fledgling checks last a minimum of one hour or until all nestlings banded are seen as fledglings. Record number of fledglings, their color band combinations, and their sex. Determine sex by unobstructed views of the fledgling's entire crown: females have a black crown and males have a red crown patch. If a banded nestling is not detected as a fledgling during the one-hour fledgling check, conduct a second check within ten days. If no fledglings are detected in these two checks, examine active cavity trees for an additional nest attempt.

Conduct late nestling checks before the 21st day after estimated hatching date. If nestlings are disturbed at age 21 days or older, they may fledge prematurely. During a late nestling check, identify, count, and sex all nestlings and record these data.

6. Color-band Observation

Using spotting scopes, identify and count adults whenever they are encountered. Most observations are made during nest and fledgling checks. Do not count birds by sound alone. Record color-band combinations, cluster, date, and behavioral data such as tending young or conflicting with other adults present. Verify unexpected color-band combinations.

7. Determining Group Composition

Group composition is determined using color-band observations described above. Breeding male status can be assigned to a male if any one of the following criteria are met: (1) he is the only male in the group, (2) he is the oldest male in the group, (3) he roosts in the nest cavity, or (4) he was the breeding male in the previous year. Once the breeding male has been determined, other adult males present are assigned helper status if they are on their natal territory or if they were seen incubating, tending young, or interacting peacefully with other adult members of the group. Breeding female status is assigned to a female if (1) she is the only female, (2) she is the oldest female in the group, or (3) she was the breeding female in that group in the previous year. Other adult females are assigned helper status only if they are on their natal territory.

Birds that are observed in conflict with group members are intruders from a nearby group or non-breeding adults without a group (floaters). Extra adult females that peacefully interact with a group, but are not on their natal territory, sometimes occur. The role of these auxiliary females deserves further research.

In cases where group composition or individual status remains uncertain, conduct a morning follow (3A) or roost check. This will enable determination of which bird roosts in the nest cavity as well as locate breeders or helpers not seen previously. Old breeding males, for example, may be especially hard to observe during nest and fledgling checks. If it appears that an old breeding male is no longer present, a morning follow or roost check is recommended to verify his disappearance.

8. Data Management

We recommend that data be stored using database management software rather than spreadsheets or other software types. Of course, data management will vary according to research and species management needs.

However, for monitoring reproductive success and group size, it is useful to keep at least these two separate data sets: (1) the first containing one record for each individual in each breeding season, and including information such as color-band combination, age or minimum age, status (e.g. helper or breeder), cluster, and year; and (2) the second containing one record per group per year, including information such as the number of eggs, nestlings, and fledglings produced, whether or not a nest was attempted, and group size. Group size should not include fledglings. Managers may consider creating a third data set that contains one record for every time a bird was observed, although this is time-consuming. Other data sets can be created as needed.

APPENDIX 3. PROTOCOL FOR TRANSLOCATION EVENTS

This appendix describes general protocol for confirmation of cluster status and the capture, transport, and release of birds for the purposes of translocation. Translocation guidelines (8H) must be followed for all translocation events. If a bird is being translocated to a cluster containing a solitary bird (mate provisioning), solitary status in the recipient cluster is to be confirmed by a morning follow (i.e., morning roost check, see 3A) just prior to the translocation event.

Part A. Confirmation of Cluster Status

1. Confirm status of the recipient cluster one to three days before the translocation event, by a morning follow (i.e., morning roost check; see 3A). This is conducted in all clusters receiving birds, to determine:

a. if the cluster is inactive, for translocations of potential pairs;
b. if the cluster contains a solitary bird, for translocations of potential mates;
c. if the cluster contains a potential breeding group, contrary to expectations;
d. the suitability of cavities and cluster habitat structure.

If the intended recipient cluster contains a potential breeding group, or does not have suitable cavities and habitat structure, cancel the translocation. If cluster status is confirmed as expected and the translocation can proceed, ensure that the cluster and target cavity trees are easily found at night and flag a route if necessary.

2. Confirm status of potential donor clusters one to three days before the translocation event, by a morning follow (3A). Ensure, for all clusters donating birds, that the birds intended for translocation are actually available. Follow guidelines for bird availability given in 8H. Have several potential donor clusters for every one bird to be translocated, in case a bird cannot be captured or bird availability status has changed.

Part B. Capture, Transport, and Release of Individuals

1. Plan the capture of the birds based on transport time.

1. Observe roosting of the birds to be translocated. Capture the birds that night or the following morning with a net and telescoping pole. Birds should be trapped at night if transport time is not expected to exceed 5 or 6 hours, and in the new cavity by midnight; if not, morning captures are used. Double-check the aluminum band numbers to ensure that the correct birds were captured.

2. Transport the birds in covered, well-ventilated cages placed in the interior of unheated and quiet vehicles. Never transport more than one bird in each cage. Be certain that you

always know the location of each captured bird, but keep disturbance to an absolute minimum. Feed crickets and mealworms to birds every 45 to 60 minutes if transported during daytime.

3. Put the birds safely, quickly, and quietly into recipient cavities. Screen cavity entrances with ½in hardware cloth tacked firmly but lightly so that the screen can be easily removed in the morning. Drop a string from the screen to the ground so that the screen can be removed without climbing. If the cluster contains a solitary bird prior to translocation, take care not to flush it.

4. Arrive at the cluster at first light. If a solitary male roosts in the cluster, release the translocated potential mate when the resident male exits his cavity. If a potential pair has been moved, wait until both are pecking at the screen, and release them simultaneously. Have ladders present in case the tree has to be climbed to remove the screen.

5. A cassette of red-cockaded woodpecker calls played just after release may help increase the likelihood that birds encounter each other.

6. Once the birds are released, wait at least one week before returning to the cluster for any follow-up check. Follow-up checks are not necessary; no further observations are required until the next breeding season. During the next breeding season, the cluster and surrounding clusters should be monitored to determine the presence of potential breeding groups and the location of translocated birds. In populations undergoing translocation for the purpose of population augmentation (i.e., receiving birds from donor populations), all clusters are monitored for group size and reproductive success (Appendix 2).

Part C. Other Methods of Translocation

Other techniques for the translocation of individuals may prove more successful than current methods (e.g. Wallace and Buchholz 2001), but are not approved for general use at this time.

APPENDIX 4. SURVEY PROTOCOL

Guidelines for Surveys to Assess Potential Project Impacts to Red-cockaded Woodpecker Nesting and/or Foraging Habitat

Surveys are used to determine whether the nesting and/or foraging habitat of a red-cockaded woodpecker group will be adversely impacted by a proposed project, such as a timber sale or development activity, on a particular tract of land. This is an important part of the conservation and management of this endangered species, and therefore the Fish and Wildlife Service has developed standard survey and analysis procedures for such determinations. These determinations must be undertaken prior to the initiation of any project within the southeastern United States that calls for removal of pine trees 30 years or older; typically such trees will be at least 25.4 cm (10 in) dbh or larger. The procedure is also used following new land acquisition by state and federal agencies in the southeast or any other circumstance in which the presence or absence of red-cockaded woodpeckers is to be assessed.

The first step in the survey procedure is to determine if suitable nesting or foraging habitat exists within the area to be impacted by the project. If no suitable nesting or foraging habitat is present within the project impact area, further assessment is unnecessary and a "no effect" determination is appropriate. If no suitable nesting habitat is present within the project impact area, but suitable foraging habitat is present and will be impacted, potential use of this foraging habitat by groups outside the project boundaries must be determined. This is accomplished by identifying any potential nesting habitat within 0.8 km (0.5 mi) of the suitable foraging habitat that would be impacted by the project. Any potential nesting habitat is then surveyed for cavity trees. This procedure is described in greater detail below. If no active clusters are found, then a "no effect" determination is appropriate. If one or more active clusters are found, a foraging habitat analysis is conducted (see 8I) to determine whether sufficient amounts of foraging habitat will remain for each group post-project.

For nesting and foraging habitat surveys within project impact areas and within 0.8 km (0.5 mi) of the project site, potential habitat is assessed at the level of the stand. A stand is a term often used to refer to a wooded area receiving past or current silvicultural treatment as a single management unit. Here we expand the term to include any subset of a tract of wooded land, divided by biological community type, management history, or any other reasonable approach. A small tract of land may be considered a single stand.

Identification of Suitable Foraging Habitat

For the purpose of surveying, suitable foraging habitat consists of a pine or pine/hardwood stand of forest, woodland, or savannah in which 50 percent or more of the dominant trees are pines and the dominant pine trees are generally 30 years in age or older. These characteristics do not necessarily describe good quality foraging habitat (see 2E, 8I); rather, this is a conservative description of potentially suitable habitat.

Identification of pine and pine/hardwood stands can be made using cover maps that identify pine and pine/hardwood stands, aerial photographs interpreted by standard techniques, or a field survey conducted by an experienced forester or biologist. Age of stands can be determined by aging representative dominant pines in the stands using an increment-borer and counting annual growth rings. Stand data describing size classes may be substituted for age if the average size of 30 year-old pines is known, i.e., at least 25.4 cm (10 in) dbh or larger, for the local area and habitat type.

If no suitable foraging habitat is present within the project area (that is, no pines 30 years or older will be impacted), then further evaluation is unnecessary and red-cockaded woodpeckers are considered absent. If the project area contains any suitable foraging habitat that will be impacted by the project, that habitat, if it contains any 60 year old trees or older, and all other suitable nesting habitat within 0.8 km (0.5 mi) of the project site, regardless of ownership, must be surveyed for the presence of red-cockaded woodpeckers.

Identification of Suitable Nesting Habitat

For the purpose of surveying, suitable nesting habitat consists of pine, pine/hardwood, and hardwood/pine stands that contain pines 60 years in age or older and that are within 0.8 km (0.5 mi) of the suitable foraging habitat to be impacted at the project site (see above). Additionally, pines 60 years in age or older may be scattered or clumped within younger stands; these older trees within younger stands must also be examined for the presence of red-cockaded woodpecker cavities. These characteristics do not necessarily describe good quality nesting habitat (see 2D, 8E, 8F); rather, this is a conservative description of potential nesting habitat.

Determination of suitable nesting habitat may be based on existing stand data, aerial photo interpretation, and/or field reconnaissance. All stands meeting the above description, regardless of ownership, are surveyed for cavity trees.

Surveying for Red-cockaded Woodpecker Cavity Trees

Once suitable nesting habitat is identified (above), it must be surveyed for cavity trees of red-cockaded woodpeckers by personnel experienced in management and/or monitoring of the species. Potential nesting habitat is surveyed by running line transects through stands and visually inspecting all medium-sized and large pines for evidence of cavity excavation by red-cockaded woodpeckers. Transects must be spaced so that all trees are inspected. Necessary spacing will vary with habitat structure and season from a maximum of 91 m (100 yards) between transects in very open pine stands to 46 m (50 yards) or less in areas with dense midstory. Transects are run north-south, because many cavity entrances are oriented in a westerly direction, and can be set using a hand compass.

When cavity trees are found, their location is recorded in the field using a Global Positioning System (GPS) unit, aerial photograph, and/or field map. Activity status, cavity stage (start, advanced start, or complete cavity), and any entrance enlargement are assessed and recorded at this time. Again, it is extremely important to have all surveys and cavity tree assessments performed by experienced personnel.

If cavity trees are found, more intense surveying within 457 m (1500 ft) of each cavity tree is conducted to locate all cavity trees in the area. Cavity trees are later assigned into clusters based on observations of red-cockaded woodpeckers as described in 3A. Any cavity trees or other evidence of red-cockaded woodpecker activity is reported to the Fish and Wildlife Service, at either a local office or the Clemson Field Office, Clemson, South Carolina.

APPENDIX 5. PRIVATE LANDS GUIDELINES

Private landowners have different responsibilities than do public land managers for endangered species conservation under the Endangered Species Act. Because of this, we provide specific guidance here for private landowners to follow on lands occupied by red-cockaded woodpeckers. However, private landowners are strongly encouraged to follow general guidelines for red-cockaded woodpecker management given in section 8 of this document.

Here, we first list activities that have the potential for harass and/or harm under the definition of "take" in the Act. These activities cannot be conducted within clusters and foraging habitat of red-cockaded woodpeckers without concurrence and/or a permit (see 4A) from the U.S. Fish and Wildlife Service. We then present guidelines for the management of foraging habitat on private lands. Finally, we give guidance on monitoring the activity status of red-cockaded woodpecker clusters specific to private landowners.

Potentially Harmful Activities

Because of the potential for harass and/or harm under the definition of 'take' in the Endangered Species Act, the following activities require concurrence and/or a permit from the U.S. Fish and Wildlife Service.

1. Removing any red-cockaded woodpecker cavity tree, through cutting, bulldozing, or any other activity.

2. Damaging an active cavity tree which results in the death of that tree. Damage includes, but is not limited to, injury to the bole or root system (generally due to heavy equipment use), exposure to herbicides, and fire scorch to the crown due to inadequate protective measures during prescribed burning. Pines are best protected from damage by intense fires through frequent low-intensity prescribed burns (see 8K).

3. Using insecticides on any standing pine tree. Prevention and control of disease and insect infestations is encouraged. Infestations of insects such as southern pine beetles are best prevented by maintaining open structure and adequate spacing between pines (see 8J). Control of active infestations often includes the cutting of infested trees. If such control will result in losses of trees below recommended foraging guidelines (below), or in the removal of cavity trees, the U.S. Fish and Wildlife Service must be contacted prior to the action.

4. Constructing roads and utility rights-of-way within a cluster. Use of existing roads, improved or unimproved, generally does not adversely affect red-cockaded woodpeckers and therefore is permitted. If, in the landowner’s opinion, there is no reasonable alternative to construction of new roads, either improved or unimproved, or if there is no reasonable alternative to placing a utility right-of-way within the cluster, the U.S. Fish

and Wildlife Service must be contacted before construction or clearing activities are initiated.

5. Construction of facilities including, but not limited to, buildings, campgrounds, recreational developments, residential dwellings, and industrial or business complexes. If, in the landowner's opinion, extenuating circumstances require a facility to be constructed in an active cluster, the U.S. Fish and Wildlife Service must be contacted during the planning phase and prior to any construction activity.

6. Planting of shrubs and/or ornamental plants that will exceed 2.1 m (7 ft) in height within 15.24 m (50 ft) of active and inactive cavity trees. If cavities are 3.05 m (10 ft) or less in height, planting any shrubs within 15.24 m (50 ft) of cavity trees may adversely affect red-cockaded woodpeckers. Construction equipment and construction material cannot be stored within 61 m (200 ft) of cavity trees. Landscaping within clusters should be accomplished with hand tools or lightweight power equipment rather than tractor-mounted equipment.

Foraging Habitat

We present two sets of guidelines for the management of foraging habitat. The first, named the recovery standard, is presented in 8I, and scientific reasoning underlying these guidelines is explained in 2E. However, because of differing responsibilities of private landowners and public land managers under the Endangered Species Act, it may be unreasonable to expect that private landowners manage their foraging habitat at the same level of quality at which public land managers are expected to manage their lands. Populations on public lands are required to be increasing, whereas many populations on private lands are managed for stability. For those private landowners that wish to increase the size of their population, we strongly encourage that the recovery standard be followed. However, we present an alternative set of foraging guidelines for groups in populations on private lands managed to maintain existing population size. Because our understanding of foraging requirements is not yet sufficient to identify the specific level of foraging resources at which a population changes from stable to increasing (see recovery task 5.8.), these guidelines are based on existing minimum amounts of foraging resources of groups known to be surviving and reproducing over at least short time periods.

Red-cockaded woodpeckers can benefit by the establishment of lower guidelines for populations in which only stability rather than increasing trends is required, because lower guidelines can encourage private landowners to enroll in conservation agreements and participate in active management. Flexibility in guidelines, within appropriate boundaries, is an important component of successful conservation on private lands because it fosters cooperation rather than resentment (see 4A). But, these guidelines are presented with a caveat: stability of small populations cannot be attained without additional management (such as use of artificial cavities and/or translocation; see 3B, 3D, 8E, 8H). Additionally, the standard for managed stability is not designed to increase population size nor is its wide-scale implementation within a population adequate to maintain that population's viability over the long-term. It does not provide future nesting habitat or suitable, i.e., good quality, foraging habitat over the long-term. Its wide-scale implementation will result in population fragmentation with subsequent problems related to demographic stochasticity and perhaps genetic variability. Again, private landowners are strongly encouraged to manage at or toward the recovery standard, and should provide at least the standard for managed stability. The standard for managed stability is as follows:

1. Provide each group of red-cockaded woodpeckers a minimum of 689 m^2 (3000 ft^2) of pine basal area, including only pines $\geq$ 25.4 cm (10 in) dbh.

2. Provide the above pine basal area on a minimum of 30.4 ha (75 ac).

3. Count only those pine stands in suitable habitat that, for this standard only, has each of the following characteristics:

   a. Stands that are at least 30 years old and older.

   b. An average pine basal area of pines $\geq$ 25.4 cm (10 in) between 9.2 and 16.1 m^2/ha (40 and 70 ft^2/ac).

   c. An average pine basal area of pines < 25.4 cm (10 in) less than 4.6 m^2/ha (20 ft^2/ac).

   d. No hardwood midstory or if a hardwood midstory is present, it is sparse and less than 2.1 m (7 ft) in height.

   e. Total stand basal area, including overstory hardwoods, less than 23.0 m^2/ha (80 ft^2/ac).

   f. We recommend that all land counted as foraging habitat be within 0.4 km (0.25 mi) of the cluster, and that any stand counted as foraging habitat be within 61 m (200 ft) of another foraging stand or the cluster itself.

   g. Frequent prescribed burning of foraging habitat, especially during the growing season, is strongly recommended. Development and protection of herbaceous groundcovers facilitates prescribed burning and benefits red-cockaded woodpeckers.

As stated above, the standard for managed stability can benefit red-cockaded woodpeckers on ownerships not legally required to recover the species, because it encourages cooperation between landowners and the U.S. Fish and Wildlife Service. Previous guidelines for privately owned lands facilitated the development of successful

Safe Harbor Agreements and Memoranda of Agreement (see 4A). Again, research to date does not adequately support the designation of foraging habitat that will result in stable vs. increasing populations, so these guidelines have been developed using minimum observed values for successfully reproducing groups. For the most part, the standard for managed stability reflects previous guidelines for private lands. Changes include requirements of slightly more minimum acreage, lower maximum pine densities, and higher minimum pine densities. These modifications were made based on results of recent research described in detail in 2E.

We stress the importance of adequate stand structure. Stands cannot be considered suitable as foraging habitat unless they have an "open" character. A pine stand that is 30 years in age and has an average tree diameter of 25.4 cm (10 in) or more does not necessarily qualify as suitable foraging habitat. If such a stand has not been prescribed burned (or otherwise treated to control hardwood midstory) and has not been thinned to a basal area of 16.1 m^2/ha (70 ft^2/ac) or less, it will not satisfy the "open" condition criterion. Dense stands of young pine and pine/hardwood are typical of unmanaged plantations and natural regeneration areas (particularly loblolly seedtree harvests) that have not been thinned or frequently burned. Such stands cannot be considered suitable foraging habitat simply because they have the required total and stand basal area and average stem diameter. Stand quality, as measured by an open structure, is a critical factor determining suitability and use of foraging habitat and must be considered when acceptable foraging habitat is identified.

Development, with concurrence from the U.S. Fish and Wildlife Service, can occur within the 0.8 km (0.5 mi) radius surrounding the cluster. However, the level of development cannot reduce the available foraging substrate below the required standard of managed stability. Although residential and commercial facilities and their associated infrastructures (roads, right-of-way, parking areas, recreational complexes, etc.) are permitted, all reasonable measures will be taken to minimize the impact of these developments on the foraging habitat available to the red-cockaded woodpecker. In other words, developments will strive to minimize clearing for rights-of-way, road widths, residential dwellings, and commercial and/or industrial complexes. If development would result in foraging habitat losses below the recommended guidelines, a permit (see 4A) is required. Landscaping, whenever possible, should use existing natural vegetation and will not involve extensive hardwood tree plantings.

Monitoring Activity Status of Clusters

Private landowners are encouraged to monitor the number of active clusters on their property and report this information annually to the Red-cockaded Woodpecker Recovery Coordinator. A description of monitoring number of active clusters, and further information concerning the Annual Report, is given in 3A. Private landowners are not responsible for the protection and maintenance of inactive or abandoned clusters, but must adequately document that a cluster is no longer active. This section defines inactive and abandoned clusters and explains how to adequately document cluster activity status.

For the purposes of these private lands guidelines, an abandoned cluster is one that has not shown any evidence of activity by red-cockaded woodpeckers for three years or more. An inactive cluster is one that is not currently supporting any red-cockaded woodpeckers and shows no evidence of red-cockaded woodpecker activity.

Declaring a cluster inactive or abandoned requires the expertise of a knowledgeable biologist or other individual familiar with the identification, life history, and ecology of red-cockaded woodpeckers. The individual must have ample experience with red-cockaded woodpeckers to recognize, and interpret, the sometimes confusing and subtle differences associated with cavity status. One visit is not sufficient to determine activity status, because of several of the species' life history traits. Therefore a cluster-specific monitoring program must be established for at least each cluster in question, and preferably for all clusters on the property.

The objective is to determine whether any red-cockaded woodpeckers are using any cavities within the cluster. Clusters are monitored for red-cockaded woodpecker activity during early morning and/or early evening hours. The number of monitoring days and/or periods (morning/evening) required to document the use or non-use of the cluster by red-cockaded woodpeckers will depend on several factors.

These factors include, but are not limited to,

1. The existing number and condition of cavities. If at least one cavity tree has fresh resin, the cluster is active. If all cavity trees appear as if abandoned for several years, one additional visit at dawn or dusk is generally sufficient to verify the absence of red-cockaded woodpeckers. In contrast, if the cluster appears possibly active, or active within the last few months, several visits may be necessary to document the presence or absence of birds.

2. Distance from, and numbers of, other known active clusters. Active clusters nearby (within a few km, or mi) increase the probability that the cluster in question is active. The number of visits to the cluster should be increased if there are active clusters nearby.

3. Time of year that cluster status is determined. Red-cockaded woodpeckers may not spend as much time in the fall and winter on cavity and resin well maintenance; additionally, resin flow is not as vigorous during the non-growing season. Both of these factors should be considered if cluster status is being determined during the fall/winter period.

Ultimately, a significant amount of professional judgment is required when deciding upon an acceptable monitoring strategy. In general, the monitoring program should be designed to meet individual needs, to the degree necessary, to accurately determine whether or not red-cockaded woodpeckers are using the cluster. Landowners are encouraged to obtain the assistance of red-cockaded woodpecker biologists, consultants, and other qualified individuals to help them certify the status of their particular cluster(s).

As general guidance, when it is not obvious that the cluster has been abandoned for a long time (several to many years), monitoring for either: (1) an extended period of consecutive days, with a mix of morning and evening periods or (2) a series of randomly selected days, spread over several weeks or months, will be necessary to determine the cluster's status. If new evidence, such as a change in appearance of cavities or resin wells, arises during the monitoring period, even though red-cockaded woodpeckers were not observed, the existing monitoring strategy must be revised to include additional visits to the cluster.

Because of the variability and uncertainties associated with individual red-cockaded woodpecker behavior, no single monitoring strategy can be designed for all situations. Strategies will be developed on a case-by-case basis and discussed with the Red-cockaded Woodpecker Recovery Coordinator for adequacy and acceptability. Flexibility in design and implementation of red-cockaded woodpecker cluster status monitoring programs is important and will be emphasized with each landowner.