Longleaf Pine Restoration Assessment:

Conservation Outcomes and Performance Metrics

Final Report

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By R. Kevin McIntyre, PI, Joseph W. Jones Ecological Research Center

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EXECUTIVE SUMMARY

This report summarizes the results of a collaborative effort between the National Fish and Wildlife Foundation (NFWF) and the Joseph W. Jones Ecological Research Center (Jones Center) to lead development of wildlife habitat metrics for the Longleaf Stewardship Fund grant program. These metrics reflect current understanding of preferred habitat for species of conservation concern associated with longleaf pine ecosystems. As goals for longleaf habitat restoration, the metrics can serve as evaluative milestones to assess the relative merit of proposed projects in moving restoration sites toward these conditions, thus maximizing benefits to wildlife species of interest.

There has been a groundswell of interest in restoration of longleaf pine ecosystems in recent years. Longleaf pine ecosystems are some of the rarest natural communities in North America, and longleaf is now a higher priority for governmental natural resource agencies, nongovernmental conservation organizations and private landowners. The unique suite of wildlife species associated with longleaf pine is frequently cited as a primary rationale for the increased emphasis on longleaf restoration. However, restoration plans are typically stated very broadly, with measurable objectives for wildlife habitat structure seldom correlated with restoration projects. This project seeks to articulate restoration goals and more closely link them with restoration actions for those with longleaf-associated wildlife as a primary management focus.

A steering committee was formed to help guide the project and included representatives from the NFWF, the Jones Center, the U.S. Forest Service (USFS), and the U.S. Fish and Wildlife Service (USFWS). We also brought in representatives from three related projects as collaborators (East Gulf Coastal Plain Joint Venture Open Pine Decision Support Tool, USFWS Southern Pine Desired Forest Condition project and NatureServe USFS Longleaf Ecological Integrity Assessment). A draft list of candidate wildlife species of interest was narrowed to eight potential species and a literature review was conducted for each species. A final suite of four species was chosen that represents both biological and program funders' priorities; Northern bobwhite quail, Bachman's sparrow, red-cockaded woodpecker and gopher tortoise.

Literature review confirmed that these four species (indeed all eight reviewed) shared preferences for parameters of major elements of habitat structure, including basal area, canopy cover, midstory cover and understory cover and composition. These preferred ranges of habitat structure were then incorporated into a prototype Bayesian model using Netica® software.

Metric	Parameters
Basal Area	40 – 70 square feet per acre
Canopy Cover	40 – 60 percent
Midstory Cover	Less than 20 percent
Understory Cover	Greater than 65% contiguous herbaceous; at least 20% grasses

Wildlife response was modeled by developing condition classes for a site using a binary matrix table that incorporated all possible combinations of the four habitat structural elements either meeting or failing to meet the desired range of values. Wildlife response was then projected for each combination of possibilities using a likelihood of occupancy, i.e. presence or absence.

The model used four of the most common restoration practices as well as costs for these practices. These costs, along with other factors, were weighed against projected wildlife responses to calculate a relative value of a project, not unlike a cost/benefit analysis.

Practice	Cost Range/acre ($)	Cost Average/acre ($)
1) Prescribed Fire	15 – 45	24
2) LLP Establishment (Reforestation)	150 – 355	238
LLP Establishment (Afforestation)	150 – 367	234
3) Midstory Treatment (Mechanical)	80 – 675	288
Midstory Treatment (Herbicide)	40 – 170	88
4) Thinning	45 – 180	100

Spatial context (development pressure, wildlife source populations) and temporal stage of stand development for a longleaf restoration site were also built into the model. Spatial context is critical for recolonization of restored habitats and temporal stages must be factored in because of the long development time and frequent management interventions required for longleaf restoration. Spatial context was evaluated using the East Gulf Coastal Plain Joint Venture (EGCPJV) Open Pine Decision Support Tool and temporal development was projected utilizing a transition matrix that incorporated eleven possible developmental stages from early successional habitat to mature, uneven-aged structure.

The prototype model was built for two of the four species to demonstrate how the model would function if fully developed. The prototype has the potential to be refined into a full-fledged decision support tool if resources were available to support further work. Importantly, the model also served as a conceptual framework for a stakeholder workshop that was held to solicit input for this project. While the model is not fully developed at this point, conservation outcomes for any of the four species can be estimated. Once the number of acres that the LSF has moved into condition classes that support a given species' presence is calculated, dividing this number by the average density for the species as reported in the literature provides a reasonable estimate of population impact.

Species	Average Density
Bachman's sparrow	10 acres/pair
Bobwhite quail	40 acres/covey (average 12 birds)
Gopher tortoise	3 acres/tortoise
Red-cockaded woodpecker	150 acres/group (average 3-4 birds)

The stakeholder workshop was held in July 2012 and included representatives from Federal agencies (USFS, USFWS, NRCS), State agencies, conservation NGOs and academia. There was broad consensus on wildlife species chosen, habitat parameters and the conceptual basis and structure of the model.

Participants provided valuable input and suggested refinements for the data presented above and for future iterations of the model. In addition, participants were surveyed for their perspectives on strategic programmatic priorities for the LSF. Nineteen participants were asked how they would deploy a hypothetical five million dollar fund for longleaf conservation (total $95 million).

Strategy	Dollars (million)	Percent of Total
Improve existing degraded longleaf	22.50	24
Land protection/conservation	16.65	18
Management/maintenance/enhancement of existing longleaf	15.40	16
Technical assistance/demonstrations (e.g. fire teams, restoration demos)	14.55	15
Training and outreach to private landowners (e.g. workshops, training)	14.15	15
Research/monitoring/policy	7.25	8
Restoration/reforestation	4.50	5

Beyond the habitat metrics and wildlife "accounting" strategy, major recommendations from this project are summarized below.

- Focus expenditures on sites that are likely to persist in the conservation estate. Because of the long time required for preferred elements of longleaf habitat structure to develop, sites that are dedicated to long-term management as wildlife habitat will be required to fully realize wildlife impact.
- Prioritize improvement of existing longleaf. It is much easier to improve or maintain existing longleaf ecosystems than to reassemble them.
- Refine understanding of existing longleaf and wildlife populations through spatial analyses and focus expenditures in locations with the greatest chance of lasting success. Spatial context is critical for wildlife responses and long term management of longleaf with fire.
- Invest in lasting, place-based prescribed fire capacity rather than individual prescribed burns.
- Require more detailed assessment of existing conditions at restoration sites from grant applicants. Employ filters to penalize sites with lower chances of success (e.g. invasives, agricultural legacies) and prioritize sites with higher conservation value or chances of success (e.g. sites with isolated wetlands and associated fauna).
- Continue to refine metrics in an adaptive management model and explore application to different species and types of longleaf pine communities. Encourage or require post-restoration monitoring to better understand wildlife responses and lessons learned.
- Invest in capacity. Successful implementation of the rangewide conservation plan for longleaf pine will be a grassroots effort requiring local capacity, collaboration and leverage. No one agency or organization can fund a conservation plan of this magnitude from the top down.

Ecosystem restoration is a complex undertaking, with restoration of longleaf pine ecosystems more challenging than most. Wildlife species of interest in these systems are most commonly associated with advanced seral stages of development and mature habitat characteristics. Because of the long time scales at which these systems function and their dependence on frequent, low-intensity fire, restoration of desired habitat structure for this faunal group is a long term process that requires an ongoing commitment to management interventions in the form of prescribed burning. Unlike some ecological systems such as streams or wetlands, where structure and function can often be reestablished by discrete restoration actions, with faunal responses following relatively soon, these same results often take decades to unfold in longleaf ecosystems.

This project was intended as a start to better defining structural objectives for wildlife habitat in the context of the rapidly growing longleaf restoration movement. As such, it represents a step forward from the generic goal of establishing more acres of longleaf by beginning to define specific objectives for those interested in managing for longleaf-associated wildlife. However, our collective knowledge of wildlife responses to longleaf restoration is incomplete and it is hoped that this work will be but one step in an iterative and ongoing process. The NFWF is to be acknowledged for initiating this important dialogue in the longleaf conservation community and for their commitment to longleaf conservation through the efforts of the Longleaf Stewardship Fund.

INTRODUCTION

Interest in conservation and restoration of longleaf pine ecosystems in the southeastern U.S. has never been greater, driven in large part by the diverse wildlife values associated with these ecosystems. Many rare, declining and endemic species of wildlife are strongly associated with longleaf pine. Given that longleaf pine forests today occupy as little as 4% of their historic range and that a significant portion of what remains is in need of some form of restoration treatment, many wildlife species that are considered habitat specialists associated with mature, open, grass-dominated longleaf forests are similarly diminished.

In 2012, the National Fish and Wildlife Foundation (NFWF) launched the Longleaf Stewardship Fund (LSF), a three-million dollar annual grant program intended to accelerate achievement of the goals of the Rangewide Conservation Plan for Longleaf Pine. Building on the successes of the Longleaf Legacy grant program sponsored by NFWF and the Southern Company, the LSF expands the geographic scope, contributing partners and available resources to enhance longleaf pine conservation and restoration across its historic range. The LSF is a public-private partnership that includes the U.S. Department of Defense, the USDA Forest Service, the U.S. Fish and Wildlife Service, the Natural Resources Conservation Service and the Southern Company.

With the LSF, the NFWF seeks to benefit longleaf-associated wildlife populations through funding of habitat improvement and establishment. The 2009 Rangewide Conservation Plan for Longleaf Pine outlines an approach to longleaf conservation that includes “Acres to Maintain” (maintenance of existing high-quality sites), “Acres to Improve” (improvement of degraded sites) and “Acres to Restore” (establishment of new acreage). The NFWF is a critical partner in the broader longleaf conservation partnership and has aligned the priorities of the LSF with those of the conservation plan and the partnership.

For many of the agencies and organizations working to restore longleaf pine communities, a primary goal is to increase habitat and populations of longleaf-associated wildlife, yet often short-term and long-term restoration goals are not explicitly linked to wildlife responses. A more clearly articulated definition of restoration goals for the ecosystem, actions and objectives to achieve those goals, and a synthesis of our best understanding of wildlife responses to these goals and actions would provide a better roadmap and more tangible metrics to assess progress for those interested in longleaf-dependent wildlife.

Early in 2012, the NFWF approached the Joseph W. Jones Ecological Research Center about collaborating on an effort to shape their Business Plan for the LSF. The preliminary plan for this effort included background work to identify:

- Elements of habitat structure that comprise quality habitat for longleaf-associated wildlife
- A suite of wildlife species representative of the longleaf ecosystem
- Restoration treatments that move longleaf habitat toward desired conditions
- Projections of conservation outcomes (species response)

These topics formed the basis for a workshop that was held in July 2012 to solicit further input from a diverse group of stakeholders from the longleaf conservation community.

The broader longleaf partnership recognizes and promotes the linkages between longleaf restoration and the unique wildlife community characteristic of longleaf ecosystems. However, there has been relatively little discussion beyond wildlife professionals of actual parameters of habitat structure that are important for wildlife species of interest and the degree to which these structural parameters are an end goal for longleaf restoration efforts. Given the NFWF's primary goal for the LSF of benefitting longleaf-associated wildlife, the objective of this project was to identify desired habitat metrics and conservation outcomes as a way to improve the prioritization process for proposed restoration projects, thereby improving the efficacy of resources expended. In addition, the NFWF should be acknowledged for bringing this important issue to a broader group and fostering dialogue about one of the primary drivers of *why* we are restoring the longleaf ecosystem.

The surge of interest in longleaf pine over the last 5-10 years has brought together a diverse constituency of stakeholders with different interests and objectives for longleaf restoration. One of the keys to the success of the longleaf partnership has been that all perspectives and contributions to restoration of the longleaf ecosystem are valued. It is important to acknowledge that the purpose of this project is to identify specific objectives for longleaf habitat structure that are important *for those for whom wildlife habitat is a primary management goal*, including, but not limited to, the NFWF. Others that may have different objectives, or combinations of objectives, will hopefully take from this what is useful for their purposes and know that their overall contribution to longleaf restoration is valued.

BACKGROUND

Prior to European settlement, longleaf pine ecosystems comprised one of the most extensive forest types in North America. Structured by frequent low-intensity fire, small-scale disturbance events, episodic regeneration and variation in hydrology and topography, these forests were described by early observers as open, park-like landscapes. Longleaf ecosystems occurred over a wide range of edaphic conditions, from xeric sandhills to wet flatwoods and were represented by a diversity of community types. Natural longleaf forests typically consisted of multiple age classes (seedlings to 400+ years), with the majority of the volume in larger diameter stems. The gap-phase dynamic driven by the small-scale disturbance/mortality, periodic masting events and frequent, low-intensity fire resulted in a forest that continually regenerated itself through time.

Over millennia, a diverse faunal community evolved to thrive in conditions of relatively open woodlands with grass-dominated understories. As most of the primary longleaf forests were harvested in the late 19th and early 20th century, many of these species of wildlife began to decline in numbers and spatial extent. The growing popularity of intensive short-rotation forestry practices after World War II continued the negative trends for longleaf-associated wildlife.

With listing of the red-cockaded woodpecker in 1970 and the revision of the Endangered Species Act in 1973, increased attention was focused on the unique assemblage of wildlife species associated with longleaf pine ecosystems, many of which were declining. Renewed interest and focus on these species, their autecology and habitat requirements led to new insights and understanding of longleaf habitat structure and wildlife relations. As a group, most wildlife species of conservation concern associated with longleaf pine ecosystems show an affinity for several common structural elements of the system. These species are most commonly found in mature, open-canopied woodlands with a low density of midstory structure and fairly dense, diverse, grass-dominated understories that were historically maintained with frequent fire. As interest in conservation of longleaf-associated wildlife grew, so did interest in restoration of longleaf ecosystems as habitat for this unique faunal community.

Opportunities for longleaf restoration include a range of starting conditions, from existing established longleaf with one or more compromised structural elements to afforestation projects that begin with bare ground. In the case of the former, wildlife responses to restoration actions can, in many cases, be expected fairly quickly; for the latter, decades of development through several structural phases may be necessary before adequate ecosystem structure and associated wildlife responses can be expected. Any approach to assessing or projecting wildlife responses to restoration actions should incorporate these temporal considerations.

Similarly, there is a spatial context for wildlife responses to restoration. Source populations of desired species must be located within dispersal distances of the restoration site for those species to recolonize sites on their own or managers must be prepared to undertake active translocation to establish new populations. Thus we suggest there are three critical elements to assessing project efficacy and wildlife response once target species are chosen; 1) identification of preferred structural characteristics of habitat, 2) assessment of restoration actions and developmental time needed to achieve these conditions and 3) assessment of spatial context for wildlife recolonization of a site.

These three elements form the core of a prototype model that was developed to serve as a framework for discussions and input at the July 2012 workshop. With further development, this model could serve as a decision support tool for assessment and prioritization at the project scale and provide information to help inform assessment at the program scale. Background information for the workshop included synthesis of three related and ongoing projects, a literature review conducted by the Jones Center and a survey of longleaf restoration practitioners across the region to assess costs of various restoration treatments

LONGLEAF-ASSOCIATED WILDLIFE SPECIES AND LITERATURE REVIEW

One of the goals articulated by the NFWF for this project was to review species of conservation need associated with longleaf pine ecosystems and make recommendations for a small set of focal species for the LSF. The desire was to balance biological, sociopolitical and pragmatic considerations. This was not intended to be a scientific analysis of indicator species based on cross-taxon congruence or other formal criteria.

The conservation status of wildlife species of interest associated with longleaf pine ecosystems includes those that are sufficiently imperiled to warrant Federal listing under the Endangered Species Act, candidate species for Federal listing and other species identified by the conservation community as foci for stewardship. Broadly speaking, this suite of species can be divided into those that are found primarily in pine-dominated, non-wetland (preferably, but not necessarily, longleaf) communities and those that are associated with a landscape mosaic of pine matrix and other community types such as ephemeral wetlands or hardwood-dominated systems.

Because the LSF is focused on restoration of upland longleaf pine communities, wildlife species that are primarily associated with these communities were chosen for further analysis. Other factors that were considered in narrowing the list of potential focal species included:

- Species of conservation concern but yet still common enough that responses to restoration treatments can reasonably be expected given adequate proximity to source populations
- Representative of different classes, i.e. not only birds
- Distribution across a large portion of the range of longleaf pine
- Permanent resident, not migratory
- Demonstrated association with higher quality longleaf pine habitats
- Potential to be considered “umbrella” species (e.g. red-cockaded woodpecker)
- Potential to be considered “flagship” species (e.g. Northern bobwhite)
- Given the LSF focus on upland longleaf restoration, species that are associated with upland pine sites rather than embedded wetlands
- Public trust species for Federal partners and/or priorities for LSF principals (red-cockaded woodpecker, gopher tortoise)
- Monitoring is practical, e.g. relatively easy to locate
- Sufficient knowledge of species is available to adequately make assessments

Following is a list of species of conservation concern associated with longleaf pine ecosystems, their status and longleaf communities in which they are found. (Taken from Rangewide Conservation Plan for Longleaf Pine).

Listed Species

- Red-cockaded Woodpecker U, F, SV, SH, M
- Gopher Tortoise* U, F, SH
- Indigo Snake U, F, SV
- Flatwoods Salamander U, F, SV
- Gopher Frog* U, SV
- Mississippi Sandhill Crane SV

Candidate and Species of Conservation Interest

- Gopher Tortoise* U, F, SH
- Striped Newt U, SH
- Black Pine Snake U, SH
- Louisiana Pine Snake U, SH
- Southern Hognose Snake U, SH
- Gopher Frog* U, SV

- Eastern Diamondback Rattlesnake U, F, SH
- Camp Shelby Burrowing Crayfish F,
- Swallow-tailed Kite SV

Migratory Birds of Conservation Interest

- Bachman's Sparrow U, F, SV, SH, M
- Chuck-wills Widow U, F, SV, SH, M
- Red-headed Woodpecker U, F, SV, SH, M
- Brown-headed Nuthatch U, F, SV, SH, M
- Henslow's Sparrow F, SV
- Southeastern American Kestrel F, SV, SH
- Loggerhead Shrike F, SV
- Red Crossbill M

Wildlife of Interest in State Wildlife Action Plans

- Florida Black Bear U, F, SV
- Northern Bobwhite U, F, SV, SH, M
- Wild Turkey U, F, SV, SH, M
- Eastern Fox Squirrel SH
- Short-tailed Snake SH
- Southeastern Pocket Gopher SH
- Florida Mouse SH
- Eastern Spotted Skunk SH

* Status in portion of species' range
(U = Upland, F = Flatwoods, SV = Savannas, SH = Sandhills, M = Montane)

Our goal was to choose 4 – 6 species that were representative of the LSF stakeholders' interests as well as the considerations listed above. The Jones Center conducted literature reviews for the following species:

- Bachman's sparrow
- Brown headed nuthatch
- Red-cockaded woodpecker
- Northern bobwhite quail
- Sherman/Southern fox squirrel
- Gopher tortoise
- Pine snake spp.
- Southern hognose snake

For some of these species, the USFWS had conducted reviews of literature through the year 2007 to support the development of species profiles for their fire program. For those species, we included the USFWS species profiles as part of our literature review in addition to later citations through 2011. We ultimately chose four species that seemed to best represent a balance of the range of considerations listed above; Bachman's sparrow, Northern bobwhite, red-cockaded woodpecker and gopher tortoise. Literature reviews for the eight species are included in Appendix 2.

All of the species chosen show an affinity for high-quality mature longleaf habitat. However, Bachman's sparrow and Northern bobwhite also utilize, to some degree, early successional habitat such as conditions found in recently-established longleaf pine. These species are also fairly well-distributed across the range of longleaf pine and sufficiently abundant that a positive response to habitat restoration could be expected without translocation. Because of its popularity for recreational hunting, Northern bobwhite also attracts a community of support beyond those interested primarily in longleaf conservation. The gopher tortoise and red-cockaded woodpecker were of particular interest because of their protected status and relative concentration on Federal lands. Red-cockaded woodpecker also represents a classic umbrella species; if habitat structure is suitable for this species, then it is suitable for a suite of longleaf-associated species. However, for most restoration sites, both of these species will require active translocation unless they are located relatively close to source populations and neither is likely to utilize afforested/reforested sites in their early successional stages.

RELATED PROJECTS: SYNTHESIS AND DESCRIPTIONS

Early in the project, it was recognized that there were other relevant efforts in progress that could contribute substantively to this work as well as benefit individually from greater coordination with other related projects. Leaders from three projects were identified and they enthusiastically agreed to participate. Their contributions to this work were substantial and this turned out to be a very productive collaboration. A brief description of each project provided by the project leader follows.

<u>NatureServe</u>

NatureServe and the USFS have partnered to produce a draft metrics-based approach that will help land managers better understand plant community ecological integrity in the "ground"/herb layer, in the midstory and in the canopy of longleaf dominated forests. This approach is especially important to land managers interested in tracking number of acres in high, medium and low quality since the metrics-based approach assigns a condition value at each of the three levels (canopy, midstory, ground) and an overall condition value for the area being assessed. This approach complements existing stand-level canopy assessments and has been designed so that users can make changes and updates to the metrics as we collect more data and refine our understanding of the best indicators of ecological health. For instance, the dividing line between "good" and "fair/poor" habitat may change with new data or new research suggesting that a different cutoff on a particular metric may be more appropriate for measuring habitat quality. Longleaf dominated communities vary greatly in terms of moisture regime, topography, soil substrate and geography, so NatureServe's approach splits the longleaf dominated communities into five main ecological groupings and applies the metrics to each grouping in different ways. Our latest report summarizes our findings from our 2011 metric development and data collection exercise. In 2012, we began working with the East Gulf Coastal Plain Joint Venture to find opportunities to combine our more vegetation-based approach with their desired future condition for wildlife habitat *approach to create a tool that landowners throughout the Southeast can use to assess ecological integrity and wildlife habitat value of stands.*

Southern Pine DFCs

The East Gulf Coastal Plain Joint Venture (EGCPJV) is leading an effort with multiple partners to develop desired forest conditions (DFCs) for wildlife habitat in southern pine ecosystems. Principally, the intended purpose is to provide technical recommendations for restoration and management of fire-maintained, pine-grasslands to support priority wildlife species. These recommendations are designed to be voluntarily implemented by landowners and land managers endeavoring to improve wildlife habitat. This effort's success relies on the participation of biologists, foresters and researchers representing myriad federal and state agencies, nongovernmental and industrial organizations and universities. Major goals of this effort include the following:

- *Strategic Goal: Develop Desired Forest Conditions for Wildlife Habitat in Southern Pine Ecosystems*
- *Tactical Goal: Develop a Framework to Explicitly Link Priority Species' Habitat Needs to Management Actions*
- *Operational Goal: Develop Management Recommendations that Facilitate the Achievement of Desired Forest Conditions*

East Gulf Coastal Plain Joint Venture Decision Support Tool

The East Gulf Coastal Plain Joint Venture (EGCPJV) is leading the development of a decision support tool (DST) that will enable strategic conservation of open pine habitats. This DST is intended to guide decisions about where, when, how and why conservation actions should be undertaken based upon a comprehensive landscape analysis and the application of key conservation biology principles to maximize conservation benefits for birds and other wildlife. Additionally, the fundamental elements of this DST have applicability beyond the EGCP. This DST is stimulating additional collaboration with neighboring Joint Ventures with planning boundaries and bird conservation priorities intrinsically linked to conservation of longleaf pine systems.

EGCP habitat conservation efforts are rooted in the basic assumption that habitat availability, condition and configuration are principal factors limiting the abundance of birds in the EGCP. Thus, through widespread restoration of pine habitats to more 'natural' open conditions, the EGCP assumes a corresponding increase in numbers of birds associated with open pine ecosystems.

MODEL DEVELOPMENT

To assimilate information from the literature review and the related projects as well as develop a conceptual model for discussions at the workshop, a synthesis working group was formed consisting of Barry Grand and Amy Salvano (Alabama Cooperative Fish and Wildlife Research Unit), Randy Wilson (USFWS), Rickie White (NatureServe) and Kevin McIntyre (Jones Research Center). A prototype model was developed by Barry Grand and Amy Salvano, with input from the group, using the Netica® software program. This is a Bayesian Decision Network that allows transparent representation of relationships and assumptions in the model as well as incorporation of uncertainty. In addition to the temporal development and spatial context of a potential longleaf restoration site, the model incorporates the most essential elements of habitat structure (basal area, canopy cover, midstory cover and grass cover in the understory), cost factors of restoration actions and projected wildlife responses of the four target species.

Spatial Considerations

The spatial arrangement of landscape elements plays a critical role in wildlife community dynamics. Population viability, movement patterns, metapopulation dynamics and genetic diversity are just a few examples of wildlife ecology that are strongly influenced by landscape pattern and structure. Most relevant to this project, the ability of a species to recolonize a restored site is highly dependent on a number of spatial variables. Examples include the proximity of the restoration site to a source population of a given species, barriers to movement between the source population and the restored site and related patterns of current land use and future land use change. Put simply, not all locations are created equal and some have much more potential value in regard to wildlife responses to habitat restoration.

To incorporate spatial context in assessment of longleaf restoration projects, the model takes the geographic location of a proposed project and inputs data from the rangewide version of the EGCPJV Open Pine DST that is currently under development. Specifically, the issue of source populations is dealt with by using spatially explicit density estimates of species as well as a stewardship value, or proximity to conservation lands. Threats from land use change, inability to conduct prescribed burning and barriers to wildlife movement are characterized using an index of urban density to inform relative value.

Temporal Considerations

The temporal stage of development of a longleaf stand is another critical driver that structures wildlife communities. Because of the wide range of starting conditions, land use histories/legacies and ongoing management interventions that are necessary to maintain this system, a comprehensive catalog of possible scenarios does not lend itself to this type of modeling. To capture the temporal dynamics of longleaf stands, we utilized a transition matrix of 11 possible states that was developed from historical imagery and data collected from approximately 800 plots of pine-dominated stands (not necessarily longleaf) from the piedmont and coastal plain regions of Alabama. This matrix projects annual transition probabilities from one state to another, based on the above dataset and restoration actions that are input to the model. The transition matrix is the core of the model and involves varying degrees of assumptions about the effects of restoration actions; the results of some actions are well known, while others have more uncertainty or variation in their end results.

The 11 possible states are:

- Agricultural (AG)

- Open (OPEN)
- Early Successional Habitat (PINE ESH)
- Pine Saplings (PINE SAP)
- Pine Poles (PINE POL)
- Pines Greater than 12” DBH (PINE GT12)
- Two-aged Pine (PINE 2A)
- Uneven Aged Pine (PINE UA)
- Mixed Pine Hardwood (MIXED)
- Uneven Aged Hardwood (HDWD UA)
- Developed (DEVEL)

Because of software limitations, we were only able to use three time steps or states in the prototype model; present (S0), seven years from present (S7) and 100 years from present (S100). This arrangement allowed us to capture the most significant variants of structure in a longleaf restoration pathway of reforestation/afforestation scenarios, namely early successional characteristics of the establishment phase, closed-canopied conditions of the plantation phase and the open woodlands of mature phases. However, the long time span between S7 and S100 introduces significant amounts of uncertainty to projections. Future development of the model that allowed more frequent time steps could capture a wider range of states and greatly facilitate incorporating the presence or absence of frequent fire through time as a structuring process. Refinement of the transition matrix is also needed to make it more specific to longleaf pine. While the existing matrix provided a reasonable starting point that was based on real-world data, the lack of specificity to longleaf pine does not fully capture the unique dynamics of these systems.

The three states chosen also represent the most discrete, i.e. predictable, stages of longleaf development relative to wildlife responses. We know that all four species considered in this exercise utilize the mature stage of development and that two (NOBO, BACS) will utilize the early successional phase. While the closed canopy structure of the plantation phase will receive little use by any of the longleaf species of interest, it is a necessary step along the path to more mature conditions and has some degree of intrinsic value as such. The developmental process that begins with initial thinning of the plantation phase and ultimately brings us to mature habitat structure is a much more nuanced progression of structural characteristics with many unanswered questions about wildlife utilization. Research and monitoring of the development of longleaf plantations that are managed through time and their associated wildlife responses will aid in our predictive accuracy and understanding of best practices going forward.

<u>Habitat Parameters</u>

A wide range of habitat structural elements were examined in the Jones Center literature survey, as well as the Southern Pine DFC and NatureServe projects. The major elements of habitat structure that emerged were remarkably congruent between projects. Habitat parameters between longleaf community types were also fairly consistent for primary structural elements, with the exception of wet longleaf savannas. The most significant elements driving wildlife responses for the four taxa were pine stocking and structure (basal area and canopy closure), midstory cover and understory cover, particularly the grass component.

Basal Area

Preferred basal area ranged from 40 to 70 square feet per acre. Wildlife species of interest associated with longleaf ecosystems prefer a moderate basal area with a component of larger, mature trees. But, basal area in isolation is a poor indicator of forest structure, needing another metric such as trees per acre, tree age or diameter distribution guidelines to more accurately describe desired forest structure. A given basal area can be comprised of many small trees or fewer large trees. For this reason, and because of software limitations on the number of variables, this metric was not used in the prototype model. However, because of its familiarity to foresters, basal area, along with another metric to further define size distribution of trees should be incorporated into future iterations of the model if developed further.

Canopy Closure

Canopy closure is a better metric for overstory structure relative to wildlife responses. A relatively open canopy allows adequate sunlight to penetrate to the forest floor to sustain a robust groundcover community. However, there should be sufficient stocking of overstory pine to provide fine fuels for prescribed fire in the form of pine litter. Insufficient fuel levels can allow release of midstory hardwoods and degrade wildlife habitat values. Optimal canopy closure is between 40 and 60 percent.

Midstory Cover

Most species reviewed, including all four of the focal species, showed preferences for sparse to nonexistent midstory hardwoods. Twenty percent coverage was deemed an upper threshold of optimal conditions for this element of habitat structure. While not considered in development of the model, we suggest that there should also be consideration or discussion of a lower limit, i.e. acknowledgement that a complete absence of hardwoods is not necessarily a desirable condition because of their general value for wildlife, including some longleaf specialists. Recruitment and presence of midstory hardwoods is believed to be directly related to canopy coverage and fuels/fire behavior.

Understory Cover

One of the hallmark characteristics of high-quality longleaf pine ecosystems is a species-rich herbaceous groundcover dominated by grasses. Not only is this an important structural element for wildlife, but grasses play a critical role as a fine fuel and driver of fire behavior. Desired conditions for understory were an herbaceous community of 65% or greater contiguous cover with at least 20 percent graminoid composition.

<u>Restoration Actions</u>

As might be expected given the wide range of potential starting conditions for longleaf pine restoration scenarios, there are numerous possibilities for restoration pathways and specific treatments. Of all the possibilities, the synthesis working group identified prescribed fire, midstory treatment, thinning and afforestation/reforestation as the most commonly used actions to elicit positive wildlife responses. Active understory restoration (introduction of native plant material in the form of seeds or plugs) and treatment of invasive plants are two other practices that were considered, but ultimately not incorporated into the model at this time. Active understory restoration success has proven difficult to predict and regional seed supplies are not available for implementation at operational scales. Invasive treatments are highly specific to individual sites and thus lend themselves poorly to predictive modeling.

Prescribed Fire

Longleaf pine ecosystems and their faunal communities evolved for millenia under a regime of frequent, large-scale, low intensity fire of both natural and anthropogenic origin. Fire sustained the species-rich, grass-dominated understories, restricted hardwood encroachment into the midstory and was essential to many aspects of the life history of the longleaf pine itself. Today, prescribed fire is our modern surrogate for these historic fires that swept across the landscape at 1 – 3 year intervals. Fire is an ecological imperative for longleaf and is *the* critical management tool for longleaf conservation and restoration.

Currently, we struggle to achieve adequate application of prescribed fire to maintain the longleaf that exists in good condition. For many of the acres classified by the Rangewide Conservation Plan as “Acres to Improve”, reintroduction or increased frequency of prescribed fire is the most important restorative action needed on those sites. The creation of additional longleaf acreage at the aggressive scale envisioned by the Rangewide Conservation Plan will require even more fire. The longleaf conservation community will need both more resources and greater capacity to meet those needs.

Midstory Treatments

Midstory encroachment by hardwoods is a consistent characteristic of degraded longleaf sites. In addition to alteration of forest structure in ways that negatively impact wildlife, midstory encroachment suppresses and eliminates understory communities, further exacerbating wildlife impacts. These situations have often progressed to the point that fire alone cannot restore them to the desired structure.

Fortunately, these conditions can be addressed using mechanical or chemical treatments, often in combination. When midstory treatments are followed with regular application of prescribed fire, desired condition for wildlife species of interest can be achieved relatively quickly, especially compared to the time required for those conditions to develop under reforestation or afforestation scenarios.

Thinning

Management strategies that focus on timber production or economic returns are often significantly different than those for which wildlife habitat is the primary objective. Timber-oriented management strategies often carry higher stocking of trees for longer periods of time than is optimal for wildlife and some economic trade-offs may be involved if desired conditions for wildlife habitat are to be achieved more quickly. Incentive payments to thin earlier and heavier may be required to mediate economic differences between timber and wildlife objectives and motivate landowners to incorporate more of a focus on wildlife.

Afforestation and Reforestation

Approximately 4 million acres of new longleaf will need to be established to meet the Rangewide Conservation Plan goal of 8 million acres. Obviously, afforestation on lands not currently in forest cover and reforestation of cutover land will be a critical action. However, it should be acknowledged that wildlife responses will often involve significant lag times between establishment of new longleaf stands and the development of desired forest structure. Other than temporary utilization of early successional conditions in longleaf plantations during the period between seedling establishment and canopy closure by species such as Northern bobwhite and Bachman's sparrow, most wildlife responses will take decades to realize.

Costs

Economic efficiency is an important consideration in decision-making for natural resource conservation. In an era where needs far outpace available resources, cost-benefit criteria are essential for leveraging those resources. An average cost was factored into the model for each restoration action. Costs were estimated from an informal survey of longleaf restoration practitioners across the range as well as data provided by the NFWF from past project proposals. The survey provided data from all states except Florida, Texas and Louisiana. NFWF data provided several estimates from Florida as well as one from Louisiana. Texas is not represented in these data. The model was built using estimates that the synthesis working group generated before results from the survey were complete. The model estimates were consistent with the survey for prescribed and establishment costs but were lower than the survey reported for midstory treatment and thinning incentives. Future iterations of the model will incorporate updated data from the survey.

Practice	**Cost Range/acre ($)**	**Cost Average/acre ($)**
1) Prescribed Fire	15 – 45	24
2) LLP Establishment (Reforestation)	150 – 355	238
LLP Establishment (Afforestation)	150 – 367	234
3) Midstory Treatment (Mechanical)	80 – 675	288
Midstory Treatment (Herbicide)	40 – 170	88
4) Thinning	45 – 180	100
* Understory Planting	160 – 600	272

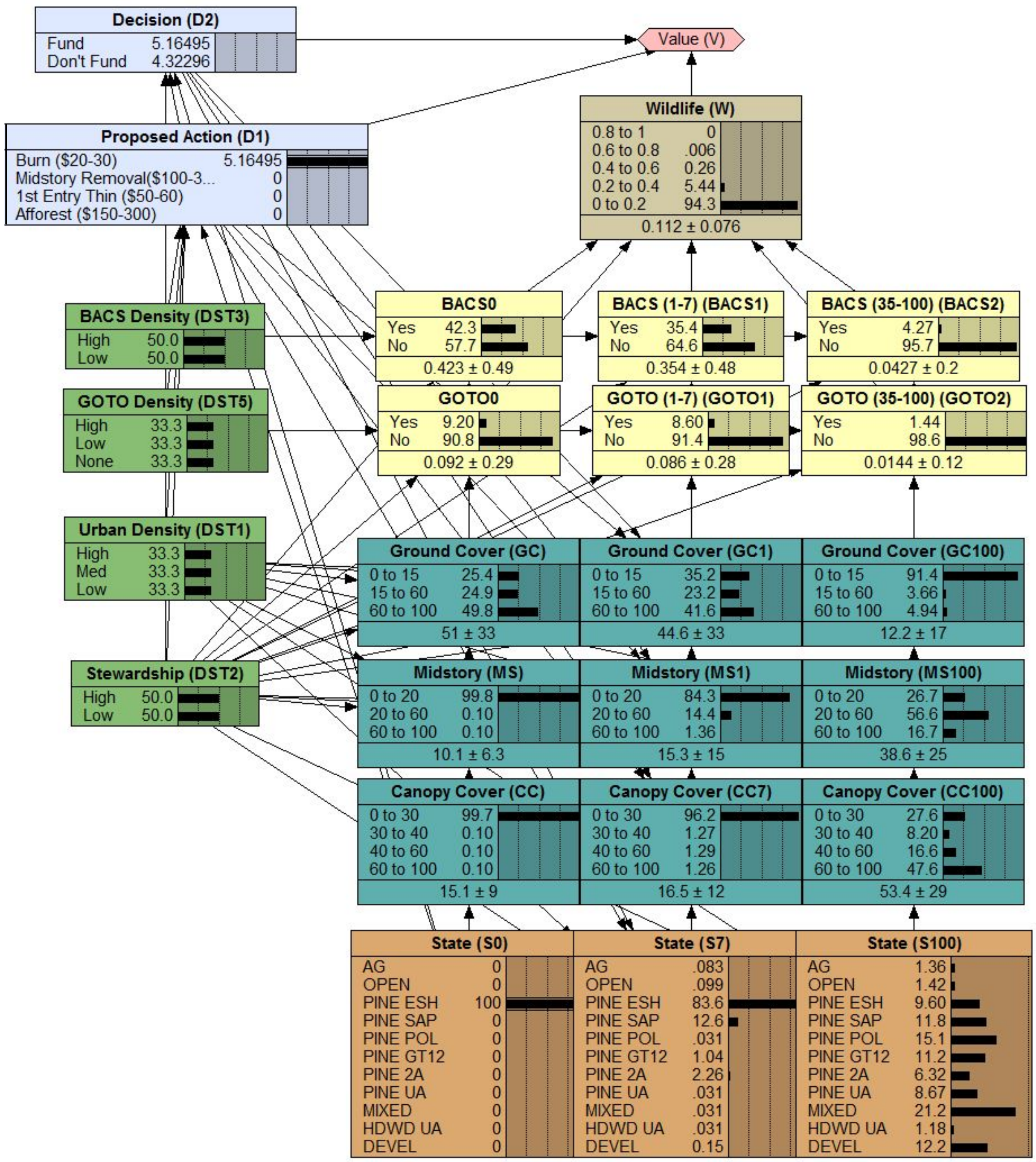

Figure 1. Example run of prototype Netica model for gopher tortoise and Bachman's sparrow. This model run illustrates a stand that is starting with recently planted longleaf pine (PINE ESH) and projecting response from proposed burning. Color codes: rust nodes = temporal state/structural phase of site at time S, teal nodes = habitat elements, green nodes = spatial context from Open Pine DST, yellow nodes = wildlife response, blue nodes = utility functions, light brown node = wildlife response summed over time, pink node = value.

WORKSHOP

A workshop of leaders and resource experts from the longleaf conservation community was held at the Jones Research Center in July 2012. Participants included representatives from Federal, State, Academia, NGOs and private industry. The goals of the workshop were to review and solicit input on the synthesis of habitat parameters, the prototype model and its conceptual basis, implementation priorities for longleaf restoration and the overall investment strategy for the NFWF. See Appendix 3 for a list of participants and represented organizations.

The workshop opened on the afternoon of day one with an introductory session designed to give an overview of the goals of the project and objectives for the workshop. Dan Petit from the NFWF gave a presentation on the business plan concept that their organization uses to structure individual programs. This was followed by overview presentations by principals from each of the three related projects (EGCPJV Open Pine DST, Southern Pine DFC, USFS NatureServe).

Day two began with a presentation by Kevin McIntyre on the synthesis of the three projects and the literature review. He outlined the conceptual basis for the model, including temporal and spatial considerations, focal species selection, habitat parameters and restoration actions. The core of the morning session followed, with a presentation by Barry Grand that reviewed a prototype of the Netica model that had been developed for two of the four focal species. A group discussion of the model structure and focal species followed.

Consensus points:

- General agreement on validity of model structure
- Refinements should minimize uncertainty and retain simplicity
- Extremely difficult to incorporate fire into model
    - Uncertainty of predicting variation in response
    - Fire functions as process through time rather than single event
    - System changes rapidly once fire removed as structuring process
- General agreement on focal species
    - Concern about GOTO and RCWO responses – will likely require translocation
- Model is useful but should not be used in isolation from other analytical tools/considerations
    - Site history and conditions
    - Assessment of landscape context and potential for connectivity
    - Likelihood of permanence/persistence of restoration trajectory, capacity for management (especially fire)
- Groundcover condition is very important element of wildlife habitat
- “Filters” for proposal prioritization that weighted positive/negative aspects of agricultural legacies, embedded wetlands and project size would improve process

Dissenting points:

- Some felt that active groundcover restoration should be included in restoration actions
- Agricultural legacies (altered soils, invasive grasses) are not adequately captured
- Conservation value of ephemeral wetlands are not adequately captured

Discussions after lunch focused on draft parameters for habitat structure. There was some debate on parameters for basal area. The group generally agreed that while some high quality examples of longleaf communities such as wet savannas are sometimes characterized by very low stocking, in the 10 – 20 BA range, this low stocking is inappropriate as a restoration goal. Others suggested consideration of 80 as an upper limit for those who also place emphasis on timber production. Another area of discussion centered around the groundcover component of the model, with suggested modifications for those parameters. This section ended with a discussion of how to estimate overall wildlife responses for the LSF program.

Consensus points:

- Metric objectives represent an average target; individual parameters may move in and out of range through management activities but should strive for range as goal.
- Basal area (BA) target of 40 – 70 is good, but needs complementary metric to better define structural definition, such as trees per acre or diameter distribution guidelines. Canopy closure and midstory cover parameters in the model greatly diminish the need for inclusion of BA, but future iterations of the model that include BA should include complementary metrics.
- Agreement on canopy cover, midstory ranges.
- Groundcover should be modified to 65% contiguous groundcover, with 20% cover of graminoids.
- Need to refine model in future to accommodate distinctions between five categories of longleaf ecosystem.
    - Need further crosswalk between USFWS DFC and USFS NatureServe projects.
- With available information, estimates will represent potential habitat with projections of wildlife response based on average density and home range data that is available for focal species.
- More precise prediction of population responses will require further development of model, monitoring of wildlife response and additional data
- Gopher tortoise response will likely be challenging to predict due to their slow response to changing habitat structure, tolerance of disturbed habitat and limited capacity for dispersal.

Dissenting points:

- Maintaining structural elements within these parameters may represent economic opportunity costs that discourages some private landowners.
- Upper limit of basal area may be too low for more economically-oriented landowners, especially on higher productivity sites.

The next session was lead by Dan Petit (NFWF) and reviewed potential strategies for LSF investment. This was a higher-level look at potential areas of programmatic emphasis that solicited input from the group on what they saw as priorities. Dan outlined a number of potential areas of emphasis that the NFWF had considered and surveyed the group by posing a question: “How would you spend $5 million on longleaf?” Nineteen participants were polled (total of $95 million to “invest”), with answers falling into one of the six categories Dan had proposed, as well as another category (*) that arose organically.

The categories of investment strategies are listed below, along with total expenditures per category and the percentage of the hypothetical $95 million pool of funding.

Strategy	Dollars (million)	Percent of Total
Improve existing degraded longleaf*	22.50	24
Land protection/conservation	16.65	18
Management/maintenance/enhancement of existing longleaf	15.40	16
Technical assistance/demonstrations (e.g. fire teams, restoration demos)	14.55	15
Training and outreach to private landowners (e.g. workshops, training)	14.15	15
Research/monitoring/policy	7.25	8
Restoration/reforestation	4.50	5

DISCUSSION

Recommendations

This section outlines recommendations from this project, including input from the stakeholder's workshop. While there was general agreement at the workshop on many topics, alternative views were sometimes presented and we have tried to capture these objectively.

Persistence

Priority should be given to proposals in which there is greater assurance that restoration investments will persist through time. Because of the long time scales at which longleaf ecosystems function, projected wildlife responses may take decades to be realized, especially under afforestation or reforestation scenarios. Sites that will stay in the "conservation estate", whether public or private, will have the greatest potential for development of desired conditions for longleaf-associated wildlife. These include Federal, State and local government holdings managed for natural resource values as well as private lands under some type of formal protection such as conservation easements.

Improving Degraded Longleaf

Projects that target improvement of existing longleaf sites should be prioritized. There are sites that may meet or be close to some, but not all, desired parameters of habitat structure and these represent the best opportunities for achieving desired habitat structure in the near term. In many of these cases, restoration actions can establish desired parameters of habitat structure relatively quickly compared to afforestation or reforestation scenarios, thus eliciting desired wildlife responses more rapidly.

Spatial Analyses

Project efficacy relative to wildlife responses could be greatly improved with better understanding of spatial aspects of existing longleaf, putative source populations of wildlife and opportunities for functional connectivity. Designation of Significant Geographic Areas (SGA) in the Rangewide Plan was intended as a starting point for more detailed and comprehensive mapping for conservation planning. Standardized protocols, detailed mapping and habitat assessment would facilitate objective spatial prioritization for longleaf restoration within SGAs. The NFWF might consider earmarking funding to move this process forward and leverage their future investments by deploying resources where they are most likely to bring about desired wildlife responses. Successful longleaf restoration will do little to benefit wildlife if suitable habitat and source populations are not located within effective dispersal ranges for wildlife species of interest. While translocation is certainly an option and will sometimes be necessary, there are significant expenses associated with these situations and this should be factored into cost/benefit analyses and comparisons of competing projects.

Prescribed Fire

Prescribed fire is essential for maintaining and restoring the longleaf pine ecosystem and its faunal elements. The critical role of fire is well-established and was reiterated by all participants at the workshop. However, this is also one of the greatest challenges that the longleaf conservation community faces. More fire is needed and this will require more resources, capacity and policy support for prescribed fire.

Frequent fire that develops and maintains the habitat structure required for wildlife species of interest should be thought of as a process rather than an event. Individual fires will do little to improve or sustain longleaf ecosystems if they are not part of a larger continuum of fire through time. Therefore, a culture of practice must be created that ensures that prescribed fire will continue to be a part of ongoing management of longleaf pine ecosystems. No one agency, organization or funding source can be expected to support a fire program at the scale of the range of longleaf pine. This will of necessity need to be a bottom-up approach that establishes prescribed fire as an assumed component of a management strategy rather than a series of singular events.

Furthermore, it is difficult to predict or measure the impact of a single fire in terms of wildlife response; fire must be a constant process to realize wildlife values. NFWF funding that is directed at fire should focus on creating sustainable prescribed fire programs throughout the range of longleaf pine by building capacity and leveraging other available funding opportunities. Priority should be given to proposed restoration projects that are more likely to be managed with fire based on established track records of strong and sustainable prescribed fire programs as well as likelihood of future fire capacity.

Filters

Two points of discussion from the workshop highlighted the opportunity to employ filters for characteristics of proposed applied restoration projects that would improve the likelihood of success and conservation outcomes.

The first point dealt with issues surrounding longleaf restoration on former agricultural lands. Modified soil characteristics from typical farming practices, such as elevated fertility and altered pH, can have deleterious effects on establishment, survivorship and development of longleaf. Similarly, these sites are prone to problems with invasive plants, particularly sod-forming pasture grasses such as Bermuda and Bahia, as well as persistent undesirable weedy ruderals. These concerns could be addressed, and impacts largely avoided, by assigning a lower prioritization for sites that fall into this category and are thus likely to face greater challenges to successful restoration. If resources are available on the part of the grantor or the grantee, verification of agricultural soil legacies or invasive species issues would give the most accurate and fair appraisal.

Many of the species of greatest conservation need are those that depend on landscapes with a matrix of longleaf pine uplands and embedded ephemeral wetlands. There was some concern that because the LSF is primarily focused on restoration of upland longleaf habitat itself rather than the historic landscape mosaic, these species may not receive benefits from LSF-funded restoration projects. The NFWF should consider some mechanism in the prioritization process that recognizes the conservation benefit of sites with embedded wetlands and assigns a higher prioritization for these projects. Other attributes of a project, such as higher-quality groundcover communities, could also be recognized in a similar way. Again, detailed knowledge and documentation of a site will be required for complete assessment of site characteristics and conservation value.

Assessment of Current Site Conditions for Proposed Restoration Projects

Both of the issues outlined above regarding the value of filters for prioritization of projects also point out the value of more detailed assessment of individual projects. The LSF would benefit from solicitation of more information from applicants on the current condition of project sites than is currently required. More detailed information on current conditions of habitat structure and spatial context would allow more informed decisions by the NFWF, ultimately leading to enhanced wildlife impacts. Most organizations applying for funding should have the needed expertise on staff to provide this information. Another option would be to have a NFWF staff person that conducts site reviews of proposed projects. While this is obviously more labor intensive and would involve more cost, the benefits might justify the expense, especially given the size of this funding program and its anticipated growth.

Post Implementation Monitoring

Longleaf ecosystem restoration is a relatively new field of practice. Development of best practices has, up until recently, been largely focused on tree seedling establishment. As challenges with seedling establishment have been met, the longleaf conservation community naturally begins to look at the broader aspects of holistic ecosystem restoration, including wildlife responses to ecosystem restoration. Most of our assumptions of wildlife response to longleaf ecosystem restoration are based on habitat models derived from measurements of wildlife utilization of higher-quality longleaf sites that are already within the ranges of desired habitat condition. We have relatively little in the way of research or empirical data that demonstrates wildlife responses to different seral stages or structural phases in the lengthy developmental pathway that is an inherent part of longleaf restoration.

The NFWF has a unique opportunity to facilitate acquisition of these needed data by establishing a monitoring component for funded projects. Monitoring could be encouraged or required as a component of individual projects that is performed by grantees. The NFWF may also consider contracting third party monitoring of a representative sample of its projects.

Capacity building

Increased capacity among restoration practitioners, both natural resource professionals and private landowners, will be a critical component of achieving the goals of the Rangewide Conservation Plan at scale across the range of longleaf pine. At the workshop, a wide range of activities was discussed to facilitate increased capacity, including training opportunities, workshops, field days, web-based educational programs and publications. However, several people also expressed concern with the historical difficulty of evaluating on-the-ground impact from these types of efforts. It was noted that a "train the trainer" model for some of these activities would leverage impact.

<u>Further Model Development</u>

The initial concept for the Netica model was to develop a prototype of a coarse-scale model that incorporated stand-level habitat structure, landscape-level spatial context and temporal development of longleaf pine. Restoration actions, associated costs and projected wildlife response were then factored in for the primary purpose of assessing the relative value of a given proposal as well as relative ranking and prioritization of groups of project proposals. The prototype model was a useful tool for the workshop in that it provided a framework for discussion and a common vision for the major drivers of longleaf systems. The model has great potential to be used as a more robust decision support tool with further development, but there are limitations in its current state.

The prototype was built to include analyses for two of the four suggested focal species. There was a limited amount of time available for development of the model and while it is "up and running" and as a whole performing as it should, there are individual parameters and responses that need refinement. Further work on the prototype would improve its ability to more accurately reflect dynamics of longleaf systems as well as accommodating all four (or potentially more) focal species. Another area for refinement is the binary occupancy matrix in which a species is assumed to be either present or absent based on a given combination of conditions. Refinement of this matrix as a likelihood of occupancy expressed as a percentage, would improve the accuracy of projections.

A second issue arose regarding limitations of the software package. The desire, or need, to incorporate a series of time steps quickly ran up against the limits of the software capacity. There are supporting software programs, such as Matlab, that would allow the model to be more fully developed. Additional time steps would allow more accurate representation of recurring treatments such as prescribed fire and temporal development of longleaf without introducing more complexity in the basic model structure. The capacity to incorporate more detail could allow inclusion of variables such as additional habitat parameters, multiple treatments, etc., but should be balanced with the potential liability of introducing more uncertainty as complexity increases.

As discussions with NFWF staff evolved during the planning and preparation for the workshop, the utility of a model that could evaluate a portfolio of conservation investments and estimate species' response and conservation outcomes program-wide became apparent. The current prototype model, even if fully developed, will have limitations in this regard and while able to achieve this end result, does so in a roundabout way by summing the outputs of individual projects. A portfolio-based model that was developed specifically for a program-wide scale would be a more appropriate way to approach this, and the NFWF should consider the potential benefits of engaging in this effort.

Conservation Outcomes

For the purposes of this project, conservation outcomes are defined as the actual response of wildlife species of interest to the various conservation actions that the NFWF funds through the LSF. For clarification, we use the term conservation action to describe the full range of activities that the LSF funds and the term restoration actions to describe actual on-the-ground efforts, particularly those included in the model. Conservation actions can be as diverse as the ecosystems they seek to restore and protect, with wildlife response serving as the ultimate common denominator for the NFWF to measure the success of those actions. The NFWF is interested in assessing wildlife response at two scales; on a project-by-project scale to evaluate relative value of proposed projects and at a programmatic scale to assess wildlife response to LSF investments.

The prototype model was designed to estimate potential wildlife responses at the project level. The model uses 1) a given starting condition, 2) proposed restoration actions, 3) temporal transitions, 4) spatial context and 5) costs to give a relative value of the proposed project. The core of the model, factors 1 – 3, is the basis for estimating the area of suitable habitat that results from the proposed restoration action. To calculate wildlife response or conservation outcome, we then take the estimated area of suitable habitat (i.e. within the desired range of habitat parameters) resulting from the project divided by the average density for each species in good habitat. Note that these projections are simply the *potential* response to new acres of suitable habitat; future refinements of the model could more fully incorporate probabilities of occupancy, density and productivity, thus improving accuracy.

Estimates of wildlife utilization that were used in the model are niche-based projections of habitat suitability where the species in question is assumed to be either present or absent depending on habitat suitability (see Table 1 from Appendix 1 below).

Table 1. Vegetative characteristics used as indicators for the likely presence of longleaf pine associated wildlife species.							
Vegetative characteristic (DFC)				Species			
BA	CC	MS	GC	BACS	NOBO	RCWO	GOLPOL
1	1	1	1	1	1	1	1
1	1	1	0	0	0	1	0
1	0	1	0	0	0	1	0
1	0	1	1	0	1	1	1
0	1	1	0	0	0	0	0
0	1	1	1	1	1	0	1
0	0	1	1	0	1	0	1
0	0	1	0	0	0	0	0
1	1	0	1	1	1	0	1
1	1	0	0	0	0	0	0
1	0	0	0	0	0	0	0
1	0	0	1	0	1	0	1
0	1	0	0	0	0	0	0
0	1	0	1	1	1	0	1
0	0	0	1	0	1	0	1
0	0	0	0	0	0	0	0

On the left side of the table, the four structural habitat elements of Basal Area (BA), Canopy Cover (CC), Midstory Cover (MS), Ground Cover (GC) are represented as a binary function, i.e. either in (1) or out (0) of the desired range. On the right side of the table, species response to the particular combination of habitat characteristics is also represented as a binary function of presence (1) or absence (0).

For projections of species responses, we are suggesting the following draft estimates of average density in good habitat gleaned from the literature and expert opinion.

Species	Average Density
Bachman's sparrow	10 acres/pair
Bobwhite quail	40 acres/covey (average 12 birds)
Gopher tortoise	3 acres/tortoise
Red-cockaded woodpecker	150 acres/group (average 3-4 birds)

As an example, with the current draft matrix presented above, 4 of the 16 possible combinations of habitat elements are projected to provide suitable Bachman's sparrow habitat. Thus, if LSF-funded projects moved 10,000 new acres into those four condition classes, potential habitat has been created for 1000 pairs of Bachman's sparrow.

Two of the four focal species chosen present unique challenges in regard to species response to restoration. While the red-cockaded woodpecker and the gopher tortoise are two of the most iconic species of the longleaf ecosystem, the former is one of the rarest and the latter is one of the least vagile. However, both are priorities for the longleaf conservation community and are considered umbrella species for the broader faunal community associated with longleaf pine. Each of these species, if not already present on a site or very close to it, will likely require translocation to utilize restored habitat and this should be factored into projections of these species' response. In discussions about this issue at the workshop, it was suggested that one way of looking at this would be to factor in translocation costs in assessment of conservation value for these species.

Estimates of actual costs for translocation for these two species are difficult to come by, but some data are available. For gopher tortoise, translocation costs were analyzed by the Florida Fish and Wildlife Conservation Commission for the September 2012 update of their gopher tortoise management plan. Direct costs were estimated at $903 per tortoise and included expenses for survey, capture, transport and fencing at recipient sites. This figure does not include expenses associated with permitting, recipient site fees or other indirect costs. For red-cockaded woodpecker, data are also available from a recent Section 6 grant through FL FWCC in which the Jones Center partnered on translocating six birds. Estimated costs were $1667 per bird and included pre-movement survey, cavity installation, actual translocation and post-movement monitoring. Figures for both species are preliminary, come from single sources and could be refined with additional data.

In practical application for typical LSF funded projects, the following assumptions about utilization of restored longleaf pine can, in most cases, be reasonably made.

- Given a source population in the area, early successional habitat characteristic of newly planted longleaf pine can potentially provide habitat for BACS and NOBO.
- Once canopy closes in planted longleaf stands (~7-8 years), none of the four species are likely to utilize these stands. However, this does not mean that they have no wildlife value as the state of development represented by these stands is a necessary step towards higher quality habitat.
- After first thinning (18-20 years), BACS and NOBO can be expected to utilize these stands again.
- If a stand is within typical foraging distance for RCWO (~0 .5 mi from cluster center), some degree of utilization by RCWO could be expected after first thinning, although these stands are unlikely to meet definitions of suitable foraging habitat for some time.
- RCWO will not be able to utilize stands for nesting until trees are large enough to accept a cavity insert (14-16 in. DBH). Translocation will be required unless restoration sites are relatively close to established populations.
- Translocation will be required for GOTO unless a restoration site is adjacent or very close to established populations.
- All of the above assume regular application of prescribed fire.
- Wildlife responses to individual prescribed fires are extremely difficult to project.

In the absence of a more sophisticated projection tool or model, wildlife responses for the LSF at the program level can be estimated on a project-by-project basis and then rolled up for a program total in a given grant cycle or over a period of years. As mentioned above, preliminary discussions have occurred regarding the development of a broader portfolio model more tailored to program-level assessment.

This could potentially incorporate a broader menu of conservation actions above and beyond the on-the-ground restoration actions included in the current prototype project-level model.

CONCLUDING THOUGHTS

Projecting wildlife responses to ecosystem restoration has many challenges under the best of circumstances. Longleaf pine, because of the long time scales and continuous management interventions required for reaching and maintaining desired habitat structure, presents even greater challenges than most ecosystems. In some ecosystems, for example streams or wetlands, a single engineering intervention may be able to drastically change the structure and function of the system rather quickly, with subsequent rapid responses from wildlife. These scenarios tend to cast restoration in a binary light, i.e. either degraded or restored and often lend themselves to relatively simple assessments of wildlife before and after restoration. In contrast, longleaf restoration is typically a lengthy advance through a continuum of progressively changing states, driven by multiple management interventions or restoration actions, with a similarly paced gradual transition in wildlife community composition over a relatively long period of time. Indeed, it should be recognized that, unlike many types of ecological restoration, longleaf restoration may actually require that wildlife habitat conditions get worse before they get better, e.g. the closed-canopy “plantation” phase of longleaf reestablishment.

The work presented here is intended as a start to an iterative process of better understanding the relationship between wildlife population dynamics and longleaf pine ecosystem restoration. Most of the tentative conclusions presented are in reality assumptions based on our knowledge of how wildlife utilizes existing higher quality habitat. There is actually very little in the way of empirical data on wildlife responses to restored habitat, particularly habitat that is “in process”, i.e. slowly improving on a restoration trajectory. Because there is still much to be learned about this subject, we caution that projected wildlife responses should be viewed as estimates rather than literal figures. However, we suggest that the recommendations presented here represent a significant step forward in refining the metrics that the NFWF used for the initial round of grants under the LSF and will significantly improve the program’s long-term impact on wildlife populations.

With the growing emphasis on longleaf restoration over the last ten years, there are now hundreds of thousands of acres of developing longleaf across the landscape. This presents a unique opportunity to better understand wildlife responses to longleaf restoration and to refine best practices for those for whom wildlife is a primary management objective. We strongly recommend that the NFWF view the metrics used for the LSF as an adaptive process that incorporates new information from on-the-ground monitoring of actual wildlife responses to real-world restoration projects.

Appendix 1. Detailed Model Description (Barry Grand, author)

A Description of the Technical Basis for the NFWF Longleaf Pine Prototype Decision Model

PROBLEM STATEMENT

The National Fish and Wildlife Foundation (NFWF) wishes to improve the metrics they use to prioritize projects proposed for funding longleaf ecosystem establishment or restoration and to better assess conservation outcomes of these projects. Although they are interested in restoration of the longleaf ecosystem as a whole, they are specifically interested in improving the cost-effectiveness of their funded projects by maximizing the expected wildlife response per unit cost. These proposals are solicited annually by the NFWF via a request for pre-proposals (RFP).

Concurrent with the NFWF's interest in developing improved metrics for their longleaf programs, three other relevant projects are in varying stages of development.

- The East Gulf Coastal Plain Joint Venture (EGCPJV) Open Pine Decision Support Tool is the most fully developed and has a strong emphasis on the spatial aspects of conservation and restoration.
- The U.S. Fish and Wildlife Service is developing Desired Forest Conditions (DFC) for Southern Pines, focusing on habitat structure for wildlife species characteristic of southern pine ecosystems.
- NatureServe is developing structural metrics for the U.S. Forest Service to classify longleaf stands on National Forests.

While unique in the specific purpose for which they are being developed, these projects are complementary and have many common attributes and areas of agreement. To synthesize this work, we have developed a prototype model using the Netica® software package. This prototype model can serve as a framework in the decision process for NFWF longleaf pine programs and could be developed into a more robust decision support tool in the future.

The resulting decision process in the prototype model takes into account the current state of the project site and long-term value of the project. The value of each project is determined by comparing cost and the expected increase in wildlife populations that are representative of longleaf ecosystem function on the project site over the next 100 years. For this analysis, these species include but are not limited to Bachman's sparrow (BACS), Northern bobwhite quail (NOBO), red-cockaded woodpecker (RCWO) and gopher tortoise (GOTO). Given equal cost and expectations for increases in respective populations, projects that benefit the greatest number of species are considered most valuable. However, projects that are of great value to even a single species may be more valuable than projects that have little value to multiple species. Estimating the expected increase in wildlife population includes uncertainties related to environmental variation (likelihood of future conditions as a result of climate, weather, geography, etc.), ecological knowledge (e.g. uncertainty regarding wildlife habitat relationships and future habitat conditions), observation error and bias (e.g., detectability) as well as persistence or permanence (likelihood of implementation, maintenance and stability of the site's primary use as wildlife habitat).

This model is a prototype for one that could be used in a hierarchical decision process. The recommendation to fund is based on whether or not implementing the proposed activity is likely to increase the value of the project site. The relative degree of value of implementing any project provides a means of ranking or comparing projects.

MODEL DESCRIPTION AND OBJECTIVES

Prior information

We assume that from the proposal, at a minimum, NFWF staff will be able to determine the land use, size (acres), location, proposed costs and activities proposed for the project site. Additional information from the Open Pine Decision Support Tool (OPDST) reduces uncertainty regarding the impacts of spatial context on the value of the proposed project. Data potentially derived from OPDST includes the mean and standard deviation of the regional density of development, proximity to land in long-term conservation and putative source populations for representative species for the project area. Estimates and standard errors for current conditions of parameters of habitat structure of a proposed project, such as basal area, canopy closure, mid-story cover and graminoid ground cover will also be used to reduce uncertainty regarding expected value. If all or some of these data are not available, those parameters remain uninformed in the decision analysis, and value is assigned based on average expected conditions or an uninformed prior condition. These data could either be supplied by the applicant or obtained by site visits as part of the NFWF proposal evaluation process.

Objectives

The fundamental objectives for estimating the value of a given project are the projected costs and responses of wildlife populations associated with longleaf ecosystems. In this prototype, we measured cost per acre on a relative scale, including uncertainty based on the range of expected costs. Future refinements should include more accurate representation of costs.

Ideally, the measurable attribute (value) of the wildlife population objective is a composite of the expected **number** of BACS, RCWO, NOBO, GOTO produced on the project site over time. For this prototype, we use the expected area of suitable habitat divided by the average density for each species in good habitat over the 100 years following initiation of the project. In the prototype, we estimated these values as the probability of meeting critical DFC requirements. Future refinements should include species-specific models that predict either probability of animal density or probability of use divided by expected density (e.g., probability of use by a breeding pair divided by territory size and associated uncertainty), or the expected number of individuals produced (population growth rate). Expected population responses are summed across species because we assume that NFWF wants to maximize the value to all of the representative species, and they are willing to accept tradeoffs among species on sites that provide exceptional value for one or more of them. These values are summed over time because we assume that NFWF is interested in not only populations in the future, but maintaining or improving existing populations.

We assume that responses by wildlife populations will be conditional upon state parameters that describe site characteristics including land cover type, OPDST parameters described above, relevant DFC parameters and proposed management or restoration activity. We allow for each species to have a unique response to each state variable (e.g., canopy cover). Further, we assume that future project (site) characteristics including land cover type, OPDST parameters and DFC parameters are conditional upon the current site conditions as well as the proposed restoration activity. We also assumed that site characteristics are dynamic and predictable (see system model below).

Alternatives

The alternatives are based on the suite of actions that are eligible for funding and NFWF's alternatives to fund or not fund any one of them. In this prototype we considered four actions: prescribed burning, afforestation, mid-rotation thinning and mid-story control. A more comprehensive list of actions based on the list in the RFP of restoration activities eligible for funding should be developed for future versions of this model. These actions have immediate or likely effects on one or more of the state variables that affect wildlife responses.

Modeling consequences

System model

This model requires transition matrices for each of the state variables including land cover and DFC characteristics (basal area, canopy cover, ground cover, mid-story cover). Cost, projected wildlife species responses and actions do not require transition matrices because their future states are not affected by their states at prior times. We started by constructing a matrix (**A**) for each variable composed of the annual probabilities (rates) of residency and change from one state to every other potential state of the variable (a_{ij}), conditional upon the prior state of the variable. The prior state can be known or it may be a vector (**S**) describing the probability (or composition) of each state. Multiplying the transition matrix by the vector of prior probabilities estimates the state of that variable one year later. We estimated conditional probability of the state of each variable at 7, 25 and 100 years in the future using:

$$\mathbf{S}_{t+n} = \mathbf{A}^n \mathbf{S}_t \,,$$

where t is the time period for which the state variable is predicted, and n is the number of years the state variable is to be projected into the future.

Transition matrices

<u>Land cover.</u> – We estimated rates of change among land cover types from those developed for several other projects underway at the Alabama Cooperative Wildlife Research Unit. The states include: AG (row crops), OPEN (pasture, road sides, rights-of-way), PINE ESH (clear cuts), MIXED (pine-hardwood

forest), PINE SAP (even-aged pines < 4"dbh), PINE POL (4"< even-aged pines < 12" dbh), PINE GT12 (even-aged pines >12" dbh), PINE 2A (two-aged pine), PINE UA (uneven-aged pine), HDWD UA (hardwood forest) and DEVEL (developed areas). Alternative matrices were developed to emulate:

status quo (Alt0) – land cover changes and forest succession with no interventions,

maintenance (Alt1), – status quo with use of prescribed fire to prevent succession of pine types to MIXED and HDWD,

improve (Alt2) – adds the effect of mid-rotation thinning (PINE POL and PINE GT12 → PINE 2A, PINE 2A→PINE UA) to Alt1,

restore (Alt3) – adds conversion of AG and OPEN to PINE ESH to Alt2

<u>Basal area (BA), Canopy cover (CC) and Mid-story cover (MS)</u>. – We estimated rates of change in these parameters from Forest Vegetation Simulator (FVS) output based on simulated conversions of existing MIXED and PINE GT12 to Pine UA with a Pro-B thin and 10 year re-entry frequency (Grand unpubl.).

<u>Grass-cover (GC)</u>. – Grass cover was estimated as a fixed percentage of ground cover (Wilson pers. comm). Ground cover was estimated using a BBN to learn the conditional relationships based on field studies conducted at over 700 sites in Alabama (Grand unpubl.).

Species models

For this prototype, we use a simplified approach to niche-space modeling. We first decided to limit the number of potential species to four and the vegetative parameters to BA, CC, MS, GC. We then elicited a binary matrix of indicators by asking, "If one or more of the vegetative parameters is within DFC limits at a site, which species are likely to be present?" Since there were only four vegetative parameters under consideration, there were sixteen possible combinations for the presence or absences of DFCs (Table 1).

Table 1. Vegetative characteristics used as indicators for the likely presence of longleaf pine associated wildlife species.							
Vegetative characteristic (DFC)				Species			
BA	CC	MS	GC	BACS	NOBO	RCWO	GOLPOL
1	1	1	1	1	1	1	1
1	1	1	0	0	0	1	0
1	0	1	0	0	0	1	0
1	0	1	1	0	1	1	1
0	1	1	0	0	0	0	0
0	1	1	1	1	1	0	1
0	0	1	1	0	1	0	1
0	0	1	0	0	0	0	0
1	1	0	1	1	1	0	1
1	1	0	0	0	0	0	0
1	0	0	0	0	0	0	0
1	0	0	1	0	1	0	1
0	1	0	0	0	0	0	0
0	1	0	1	1	1	0	1
0	0	0	1	0	1	0	1
0	0	0	0	0	0	0	0

Cost

For the prototype, we elicited a range of cost estimates for each action as follows:

Table 2. Range of costs and relative cost of management actions.

Actions	Lower	Upper	Scaled lower	Scaled upper
Plant	$150	$300	0.46	1.00
Burn	$20	$30	0.00	0.04
1st Entry Thin	$50	$60	0.11	0.14
Midstory	$100	$300	0.29	1.00

Decision

Values are calculated based on the sum of the species responses (Pr(habitat is in DFC | Species requirements)) across each time interval based on the equation:

$$U\ (w_{11} \ldots w_{ti}, E, B) = \Sigma(w_{it})+(E*B),$$

Where w are the species responses for the i species at t times, B is the proposed cost of the action, and E is an indicator to fund or not. The decision in this prototype is sequential in nature. The first 'decision' is the proposed action. Normally, this information will be included with the proposal. Thus, it could be considered a state variable. However, treating this as a decision allows calculation of the value of alternative actions. The second decision is whether or not the project under consideration should be funded. Once an action is selected, the values reflect the benefit of implementing the alternative or not doing so.

Tradeoffs

Tradeoffs occur among species as indicated above (sum of species responses). Individual weights could be assigned to species. Weights may be assigned based on various criteria including degree of imperilment, distance to population objectives (continental, regional or local). Tradeoffs also occur over time. Thus high values in the future could outweigh low current value and vice-versa. Perhaps the most significant tradeoff is in cost versus wildlife response. Also known as willingness to pay, we need to assess risk tolerance based on the tradeoff between cost of projects and their expected value to wildlife.

Uncertainties

We need to identify how and document where the following sources of uncertainty influence the decision:

- Environmental – stochastic events and events related to local conditions
- Ecological – variable hypotheses regarding system function and response
- Observational – biases associated with models and monitoring responses (e.g., observability)
- Partial Controllability – ability to implement actions (aka likelihood for success). These are somewhat accounted for in the transition models, at least for land cover.

Monitoring

Ideally, all system states are periodically measured on at least a sample of projects and unfunded proposals. However, we may be able to identify critical elements for a monitoring program that will have the greatest impact on reducing the uncertainty in decision making and increasing the accuracy of predicting outcomes through sensitivity analysis and assessing the value of perfect information.

Appendix 2. Jones Center Literature Review

Bachman's Sparrow (*Aimophila aestivalis*)

	Description	Source
Current Range	Breeding bird populations range from Central Florida, north to Southern Virginia, west to Tennessee, Kentucky and Missouri to eastern Oklahoma, and eastern Texas	Dunning 2006
Habitat Variable		
Habitat - Preferred	In general, there are 2 preferred habitat types: (1) mature (50-80 yrs. or older), frequently burned pine savannas, with dense herbaceous understory; (2) early successional stands that were recently cutover (1-5 yrs. post clearing); regenerating pine stands	
	Mature, frequently burned, open pine savannas >80 years old	Dunning and Watts 1990
	Frequently burned, longleaf pine, >50 years old	Tucker et al. 2004
	Early successional, stands recently cutover, >1 year old but <5 years	Dunning and Watts 1990
	Regenerating pine stands during the 6-10 years post planting	Stober and Krementz 2006
	Bachman's sparrows tend to occupy stands managed for Red-cockaded woodpeckers, however, some sites managed for RCWs may not be suitable habitat for Bachman's sparrow because they are too small	Conner et al. 2002; Provencher et al. 2002; Wood et al. 2004; Brooks and Stouffer 2011
	Fire-maintained longleaf pine-scrub oak forests, with little to no midstory, and herbaceous understory	Allen et al. 2006
Habitat - Avoided	Bog or wetland stands with a few trees OR closed canopy of pines are avoided	Brooks and Stouffer 2011; Czapka and Kilgo 2011
	Middle-aged stands with a midstory; ~25-30 years old	Brooks and Stouffer 2011; Stober and Krementz 2006
	Stands with high tree densities b/c canopy closure reduces the cover, density, and species richness of the herbaceous layer	Brooks and Stouffer 2010
	Stands with very dense herbaceous layers may not be suitable because too much herbaceous vegetation hinders ability to forage and nest	Brooks and Stouffer 2010

	Young restored longleaf and loblolly stands with presence of a midstory and high shrub densities	Novak, M.S. Thesis 2011
	Young and middle-aged stands with a pine understory	Dunning and Watts 1990
	Clearcuts replanted with pines that are >5 years old are typically avoided because they become too overgrown with pines	Dunning and Watts 1990
Habitat Patch (Size & Spacing)	Habitat patches should be at least 3.5 hectares in size	FWS publication
	Patches should be spaced <0.5 km apart; <3 km from an occupied patch	FWS publication
Forest Stand Structure		
Canopy	Maintain open pine canopy with canopy cover <60%	Dunning and Watts 1990; Wood et al. 2004
	Basal area ~11-14 m^2/ha; mature longleaf pine Canopy cover ~40%	Tucker et al. 2004; Wood et al. 2004
	Basal area 10 m^2/ha (pine); 1.1 m2/ha (hardwoods); Pine (>40cm dbh) = 28.2 stems/ha; Pine (20-40 cm dbh) = 45.7 stems/ha	Cox and Jones 2007
	Longleaf and loblolly pines >25 yrs old; Canopy cover=70-85%	Novak 2011
	Canopy cover (dominated by longleaf pine) = 65%	Allen et al. 2006
	Loblolly, longleaf, and shortleaf pines >50 years old; Canopy Closure = 30%	Howell et al. 2008
Midstory	Reduce/maintain woody midstory cover - <20%	Dunning and Watts 1990
	Prefer stands with low volume of vegetation, that is 2-4 meters above ground level	Dunning and Watts 1990
	Little to no midstory >1 m; allow 2-5 midstory trees (<12m) per 250 acres for perching	Fire Management Species Profile
Ground Cover	Maintain dense bunchgrass and forb understory cover (<1 meter tall) at 65-90% cover	Dunning and Watts, Plentovich et al. 1998
	Bunch grasses=25-30%; Other grasses=10%; Forbs=25-40%	Novak 2011
	Grasses=13%, Forbs=13%, and Woody=21% Grass Height= 0.56m	Cox and Jones 2009
	Grasses >65%; Forb >20%; Vines <20%	Tucker et al. 2004
	Herbaceous understory – 23% grasses, 15% shrubs, 4% forbs	Allen et al. 2006
	Total understory cover = 61%; grasses=20%; forbs=15%, woody=25%	Wood et al. 2004

	Patchy (but dense) distribution of herbaceous understory is preferred as opposed to a uniform distribution	Dunning and Watts 1990; Brooks and Stouffer 2011; Novak 2011
	Bachman's sparrows were more abundant in native groundcover sites dominated by wiregrass (*Aristida stricta*) compared to sites with disturbed groundcover dominated by broomsedge (*Andropogon* spp.) and silk grass (*Pityopsis* spp.)	Rutledge and Conner 2002
Shrub Cover	Shrub cover should be maintained at low cover; Brooks and Stouffer (2011) reported a negative correlation between sparrow abundance and shrub cover	Brooks and Stouffer 2011
	Shrub cover <1m should be patchy	Cox and Jones 2009
	Shrub cover = 45-65%	Tucker et al. 2004
Litter	In general, litter depth 0.5-1 inch; litter cover 60-90%	
	Litter depth should be reduced to <0.5 inches	Cox and Jones 2008
	Percent litter cover was consistently high (60-90%) on Bachman's sparrow habitat throughout the southeast	Haggerty 2000
	Litter depth = 0.8 inches; Litter Cover = 70%	Allen et al. 2006
	Litter Cover = 20-30%	Tucker et al. 2004
	Litter Cover >80%	Novak 2011
Bare Soil	Expose bare mineral soil in patches over at least 10% of area	Cox and Jones 2008
	Bare ground = 52% Positive correlation between bare ground and winter sparrow abundance	Cox and Jones 2009
	Bare ground = 16% cover	Allen et al. 2006
	Bare ground = ~1%	Tucker et al. 2004
	Bare ground <25%	Novak 2011
Snags and Down Wood	Downed wood = 2% cover	Allen et al. 2006
	Root balls from blown down trees as a result of Hurricane Katrina were used as refugia by possibly providing tunnels and holes for Bachman's sparrows to escape from predators	Brooks and Stouffer 2010
	Stand occupancy estimates of Bachman's sparrows increased with abundance of downed tree crowns as a result of blow downs from Hurricane Katrina, because birds were attracted to downed trees to use as song perches.	Brooks and Stouffer 2010
	Bachman's sparrows clumps of shrubs and debris piles for singing perches and cover from predators	FWS Publication; Meanley 1959

Stand Disturbance		
Fire	In general, frequent fire ≤ 3 years (fire return interval) and growing season burns will be most beneficial for vegetation structure	
	Optimal fire return interval is ≤ 3 years	Tucker et al. 2004, Tucker et al. 2006, Stober and Krementz 2006, Cox and Jones 2007, Cox and Jones 2009, Brooks and Stouffer 2010, Brooks and Stouffer 2011; Plentovich et al. 1998
	Growing season burns may be most beneficial for maintenance of vegetation structure associated with open longleaf pine forests	Allen et al. 2006
	Bachman's sparrows may abandon areas if fire is excluded for more than 3 years because of change in vegetation structure (i.e. dense herbaceous ground cover, grass standing crop, woody vegetation start to invade)	Cox and Jones 2007
	Sites left unburned for ≥4 yrs. host few to no breeding sparrows and it appears that breeding productivity is low among birds that do settle in those habitats	Tucker et al. 2006
	Season of burn had little to no effect on density and breeding ecology of Bachman's sparrows, therefore growing season burns may be most beneficial because it promotes fire-adapted vegetation (i.e. wiregrass and other species that thrive with growing season fire)	Cox and Jones 2004; Perkins et al. 2009; Tucker et al. 2006
	Bachman's sparrows select grasslands that were burned the previous growing season for winter habitat	Cox and Jones 2009
	Nest success did not differ between growing season and dormant season burns but support the use of growing season burns	Howell et al. 2008
Hurricanes	Hurricanes are important for maintaining coastal pine savannas by mediating patch dynamics of trees through gap creation that is suitable for longleaf pine regeneration. This gap creation promotes the uneven-aged stands characteristics of old-growth pine savannas	Brooks and Stouffer 2010
	Temporal scales are different for hurricanes and fire. Disturbance associated with hurricanes (or other storms) takes place on a decadal time scale rather than ~3 years for fire	Brooks and Stouffer 2010

Home Range	Mean breeding season home-range size is between 1.5 and 4.8 ha and varies with time since fire, timber age, and vegetation structure	Haggerty 1998; Stober and Krementz 2006; Cox and Jones 2007
	Mean home range size based on 95% fixed kernel = 3.1 ha	
	Mean home ranges size across all habitats was 3.3 ha for males and 2.2 hectare for females.	Stober and Krementz 2006
	Home ranges were larger in mature pine stands (4.8 ha) compared to home ranges in early successional stands; 4-year old stands (3.0 ha) and 2-year old stands (1.5 ha)	Stober and Krementz 2006

Dispersal & Movement	Mean movement of Bachman's sparrows within a year = 172.8 m	Cox and Jones 2007
	It is suggested that Bachman's sparrows can disperse 3-6 km from source patch but varied depending on site and population density declined as distance for source patch increased.	Dunning et al. 1995
	Daily movements of Bachman's sparrows reflected home range sizes; smaller home ranges were associated with shorter daily distances moved. Mean daily distance moved in mature pine stands (106.6 m) was greater than in 4-year old (88.8 m) and 2-year old (61.0 m) stands	Stober and Krementz 2006

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Brown-headed Nuthatch (*Sitta pusilla*)

Habitat Variable	Description	Source
Habitat - Preferred	In general, brown-headed nuthatches prefer mature or older-aged pine forests with open understories, relatively large trees, and an abundance of snags	
	Mature pine dominated or mixed pine-hardwood forests (≥60 years old)	USFWS (Species Profile)
	Fire-maintained longleaf pine-scrub oak forests, with little to no midstory, and herbaceous understory	Allen et al. 2006
	Fire maintained, sub-mature to mature (>45 years old) longleaf pine savanna, with low midstory and understory densities	Dornak et al. 2004
	Open, mature pine forests in which fire has kept the understory open and created snags for nesting/roosting. Most abundant in longleaf-slash and loblolly-shortleaf pine forests.	Withgott and Smith 1998
	Managed loblolly pine plantation, 1st year after thinning of stands 13-16 yrs. old (1st thinning) and 22-26 yrs. (2nd thinning). Detection of brown-headed nuthatch declines with time after thinning	Wilson and Watts 1999
	Open mixed pine forests (longleaf, loblolly, shortleaf)	O'Halloran 1984; O'Halloran & Conner 1987; Conner et al. 1983; Wood et al. 2004
	Fire-maintained upland loblolly-shortleaf pine forests and old-growth and even-aged slash pine forests, longleaf pine forests, or loblolly pine forests	Cox and Slater 2007; Conner et al. 2002; Sullivan 2011
	Mature longleaf pine forests	Novak 2011
	Hardwood-pine habitats	Herb and Burt 2000
	Fire-maintained loblolly dominated forests with scattered slash pine	Brittain 2009
Habitat - Avoided	In general, stands with a dense midstory are avoided by brown-headed nuthatches	
	Stands with dense midstory; especially hardwood midstory	O'Halloran 1984; O'Halloran & Conner 1987
	Young restored longleaf and loblolly stands with presence of a midstory and high shrub densities	Novak 2011
	Areas with dense sapling stage (5-16 cm dbh) pines, areas with a high number of shrub species and stems, and high number of tree species and density	Conner et al. 1983

Forest Stand Structure		
Canopy	In general, pine basal area should be in the 8-13 m^2/ha range (but have occupied areas up to 20 m^2/ha range) and hardwood basal area <1 m^2/ha. Canopy cover is wide-ranging 25-85%.	
	Pine dominated; **Canopy Cover** = 25-75%; **Pine Cover** = 50% of canopy cover	USFWS (Species Profile)
	Longleaf pine dominated; **Canopy Cover** = 65%	Allen et al. 2006
	Mature longleaf pine (>45 yrs); **Canopy Closure** = 30% **Pine basal area** = 10 m^2/ha; **Hardwood basal area** = 0.8 m^2/ha	Dornak et al. 2004
	Loblolly pine; **Canopy cover** = 77-83%; **Canopy Height** = 18-23 m; **Pine Basal Area**=8-12 m^2/ha; **Pine Density**= 160-287 stems/ha	Wilson and Watts 1999
	Longleaf, loblolly, and shortleaf pines (stand age ~45 yrs) – **<u>FORAGING AREAS</u> –** **Canopy Closure**=31%; **Canopy Height** = 15 m **Pine basal area** = 12 m^2/ha; **Hardwood basal area** = 0.3 m^2/ha **<u>NESTING AREAS</u>** – **Canopy Closure** = 15%; **Basal Area**=5.6 m^2/ha	O'Halloran 1984, O'Halloran & Conner 1987
	Mature pine forest - Loblolly and shortleaf pole stage pines (17-32 cm dbh and >32 cm dbh)	Conner et al. 1983
	Mature pine stands **>**70 yrs. old; **Canopy Cover**=26-50%; **Pine basal area**=13 m^2/ha; **Hardwood basal area**=0.6 m^2/ha	Wood et al. 2004

	Mature pine stands >65 yrs. old; **Canopy Closure**= 60-73%; **Pine basal area**= ~20 m^2/ha; **Hardwood basal area**= 0.1 m^2/ha; **Stand Height** = 25-27m	Conner et al. 2002
	Pines/Hardwoods– 82% of bird obs. occurred in pines; 18% in hardwoods **Total tree density**=24-76 trees/ha; **Pine density**=14-47 trees/ha; **Hardwood density**=10-60 trees/ha	Herb and Burt 2000
	Longleaf and loblolly pines >25 yrs old; **Canopy cover**=70-85%	Novak 2011
	Total Canopy Cover = 45%; **Pine Cover** = 42%; **Hardwood Cover**=3% **Pine Tree Height** = 30 m	Brittain 2009
Midstory	In general, little to no midstory with hardwood basal area ≤1 m^2/ha and midstory cover <30%	
	Open midstory; Hardwood BA ≤3 m^2/ha	USFWS (Species Profile)
	FORAGING AREAS – Pine BA=3.1 m^2/ha; Hardwood BA= 1.1 m^2/ha **NESTING AREAS** – Basal Area = 5.6 m^2/ha	O'Halloran 1984; O'Halloran & Conner 1987
	Midstory cover – 1-25%	Wood et al. 2004
	Hardwoods (5-14cm)= 0.1 m^2/ha; Hardwoods (15-32cm)= 0.1 m^2/ha	Conner et al. 2002
	Shrub/sapling cover = 31%; Shrub/sapling height = 3 m	Brittain 2009
	Pine basal area = 1.2 m^2/ha	Sullivan 2011
Ground Cover	In general, herbaceous cover is wide-ranging 10-80%	
	Herbaceous understory (grasses, forbs) = ≥40%	USFWS (Species Profile)
	Herbaceous cover – 10%	Dornak et al. 2004
	Herbaceous understory – 23% grasses, 15% shrubs, 4% forbs	Allen et al. 2006

	Ground cover density = 8 stems/m^2	Wilson and Watts 1999
	Negatively associated with number of shrub species and shrub stems	Conner et al. 1983
	Total cover (<1m) = 61%; Grasses=20%, Forbs=15%, Woody=25%	Wood et al. 2004
	Herbaceous cover = 15%	Sullivan 2011
	Herbaceous cover = 42% Herbaceous ground cover (height) = 0.7 m	Brittain 2009
	Bunch grasses=25-30%; Other grasses=10%; Forbs=25-40% Patchy (but dense) distribution of herbaceous understory is preferred as opposed to a uniform distribution	Novak 2011
	Grasses=20-28%; Ferns (dicot)=18-31%	Conner et al. 2002
Bare Ground	Bare ground = 9% cover	Dornak et al. 2004
	Bare ground <25%	Novak 2011
	Bare ground = 16% cover	Allen et al. 2006
Litter	Leaf litter cover = 29%	Dornak et al. 2004
	Litter Cover = 81%	Brittain 2009
	Litter Cover >80%	Novak 2011
	Litter depth = 0.8 inches; Litter Cover = 70%	Allen et al. 2006
Downed Wood	Downed wood = 2% cover	Allen et al. 2006
Stand Disturbance		
Fire	In general, stands should be burned during the growing season (after March nesting season) every 2-3 years to maintain open midstory/understory	
	Fire return interval 3-5 years	Dornak et al. 2004; Cox and Slater 2007; Conner et al. 2002
	Fire return interval 2-3 years; growing season	USFWS (Species Profile); Wood et al. 2004

	Lightning-season fire are most beneficial because brown-headed nuthatches nest early (March), thus dormant season fire may result in nest destruction and lower adult survival	Cox and Widener 2008
	Growing season burning is most beneficial for maintaining suitable habitat conditions (open, mature pine forests)	Allen et al. 2006
	Frequent fire required to keep understory open and create snags;	Withgott and Smith 1998;
	July-September = optimal time period for prescribed burning; density of nuthatches decrease over time following elimination of prescribed fire	Sullivan 2011
	Higher densities at Tall Timbers where fire-return interval is 2 yrs. versus 3-5 years at S. Florida sites	Cox and Slater 2007
Home Range	In general, minimum territory size is 4.5-5.0 ha	
	Tall Timbers R.S. – 0.33 territories/ha S. Florida sites – 0.08 territories/ha	Cox and Slater 2007
	Distance between nearest neighbor nests: Tall Timbers R.S. = 199 m S. Florida sites = 395 m	Cox and Slater 2007
	Mean territory size=7.4 ha (range=4.4-16.2 ha) Minimum territory size = 4.5-5.0 ha	Herb and Burt 2000
	Habitat Patch Size ≥5 ha; ≤300m spacing between suitable habitat patches	USFWS (Species Profile)
Movement	Mean distance of nest to the nearest foraging tree = 26.7 m	Herb and Burt 2000
	Dispersal events – males established territories or assisted at territories ≤300 m from parent territories	Cox and Slater 2007
	Mean distance of nest to open areas = 406 m	Sullivan 2011
Preferred Food	Insects and pine seeds (primary foods)	Withgott and Smith 1998; O'Halloran 1984; O'Halloran & Conner 1987
Nesting	≥5 snags/hectare; large diameter snags (≥13 cm dbh)	USFWS (Species Profile)
	Prefer snags 3.2 meters tall	Dornak et al. 2004
	Nest in cavities <3.7 meters tall	Wilson and Watts 1999

	Nest snag height=3.1 m; nest height= 2.4 m Nest sites in more open areas: 15% canopy closure; 5.6 m2/ha basal area	O'Halloran 1984; O'Halloran & Conner 1987
	Number of snags recorded in a 50m radius from nest site: **Small snags** (<15 cm dbh)=9; **Large snags** (>15 cm dbh)=4; **Mean nest snag diameter** = 25 cm Successful nests were located in areas containing many more small snags as opposed to areas with larger snags	Sullivan 2011
	Nest located in open areas; nested in natural and artificial cavities	Herb and Burt 2000

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Gopher Tortoise (*Gopherus polyphemus*)

	Description	Source
Current Range	Alabama, Georgia, Florida, Louisiana, Mississippi, South Carolina	
Habitat Variable		
Habitat - Preferred	Generally occupy sandhills, longleaf pine-turkey oak, and slash pine habitats but also occur in pine flatwoods, loblolly pine plantations, oak scrub, xeric hammocks and dry prairie habitats	USFWS (species profile); Hoctor and Beyeler 2010; Auffenberg and Franz 1982; Wilson et al. 1997; Smith et al. 1997; Wright 1982; Butler et al. 1995
	Southern ridge sandhills, scrubby flatwoods, and ruderal sites	Ashton et al. 2008; Hoctor and Beyeler 2010
	Longleaf pine stands and a relatively sparse canopy cover and understory and well-drained sandy soils	Baskaran et al. 2006
	Coastal strand (dune) and scrub habitats – hatchling tortoises used microhabitats within these habitats with dense ground cover and relatively tall vegetation	Pike 2006
	Military firing points (open, dense herbaceous ground cover) adjacent to mature pine forests that were fire suppressed until this study	Yager et al. 2007
	Commercially thinned loblolly and longleaf pine stands (20-25 yrs. old)	Wigley et al. 2012
	Fire-maintained longleaf pine-wiregrass habitat interspersed with patches of live oak	Eubanks et al. 2002
	Mature slash pine plantations with sparse hardwoods	Aresco and Guyer 1999; Diemer 1992
	Xeric uplands – longleaf, slash, turkey oak, and sand live oak overstory and herbaceous understory dominated by wiregrass, broomsedge, and forbs	Wilson et al. 1994
Habitat - Avoided	Wetlands and regions with clayey soils	Baskaran et al. 2006
Habitat Patch (Size)	60 hectares required for a population of 50 adult gopher tortoises	Eubanks et al. 2002

Forest Stand Structure		
Canopy	**Canopy Cover** ≤ 50%	Ashton et al. 2008
	Basal area < 70 m^2/ha	Baskaran et al. 2006
	Loblolly and slash pine; **Canopy Cover** = ~90% **Pine (BA)** = 17-20 m^2/ha **Pine Height** = 15-17 m **Pine dbh** = 18-21 cm **No. Pine Trees/ha** = 607-897	Wigley et al. 2012
	Pines, Pine-Hardwood Mix, and Hardwood; **Canopy Cover** = 0-60%	USFWS (species profile); Wilson et al. 1997
	Pine-Hardwood Mix **Canopy Cover** = 44-57% **Pine basal area** = 7-10 m^2/ha **Hardwood basal area** = <3 m^2/ha **Pine (trees/ha)** = 117-294 **Hardwood (trees/ha)** = 12-94 **Pine Height** = 14-19 m **Hardwood Height** = 9 m	Evans et al. 2010
	Mature pine forests with some oaks **Canopy Cover** = 30-50% **Total basal area** = 8-19 m^2/ha **Pine basal area** = 5-19 m^2/ha **Oak basal area** = <4 m^2/ha	Tuberville et al. 2007
	Mature slash pine with sparse hardwoods **Total basal area** = 51 m^2/ha **Pine basal area** = 31 m^2/ha **Hardwood basal area** = 5 m^2/ha **Total tree density** = 961 trees/ha	Aresco and Guyer 1999
	Oak scrub habitat = >50% OAK cover Oak Palmetto Scrub = 30-50% OAK cover Palmetto/Lyonia/Wax Myrtle = 0-30% OAK cover	Smith et al. 1997
	Slash Pine Overstory = 57.3 trees/ha	Wright 1982
	Native tree cover = 18-35%	McLaughlin 1990

	Non-native tree cover = 1-47%	
Midstory	**Midstory Cover =** 40% **Hardwood (BA)** = <1 m^2/ha **Hardwood Height** = 3 m **Hardwood dbh** = 7cm **No. Hardwood Trees/ha** = 37-55	Wigley et al. 2012
	Shrub Cover = <60%	USFWS (species profile)
	Woody Cover (trees, vines - 1-6 m) = 18%	Evans et al. 2008
	Slash Pine (20%) and Turkey Oak (80%) = 103.8 trees/ha	Wright 1982
Ground Cover	Dense herbaceous ground cover (grasses/forbs) – up to 80% or more cover	USFWS (species profile)
	Herbaceous Cover (grasses/forbs) =42% Woody Cover (trees, vines shrubs <1m) = 37%	Evans et al. 2008
	Herbaceous Cover = 90%	Yager et al. 2007; Wigley et al. 2012
	Total Herbaceous Cover = 30-45% Shrub Cover = 20-25%; Wiregrass = 2-30% Other Grass = 7-13% Legumes = 3-7% Other Forb = <2%	Tuberville et al. 2007
	Understory Vegetation Cover = <1 m Total Understory Cover = 28% Grass Cover = 11% Total Forb Cover = 8% Woody Vine Cover = 2% Arborescent Cover = 2% Non-Arborescent Cover = 5%	Aresco and Guyer 1999
	Edible Herbaceous = 18-46% Other Herbaceous = 3-11% Shrubs = 6-33%	McLaughlin 1990
	Shrubs dominant in understory of Sandhills and Flatwoods (due to years of prior fire suppression)	Ashton et al. 2008; Baskaran et al. 2006

	Ruderal areas consisting primarily of dense bahia grass (*Paspalum notatum*)	Ashton et al. 2008
Bare Ground	Bare Ground Cover = 9-40%; burrow densities increased with increasing amount of bare ground	Ashton et al. 2008
	Bare Ground Cover= 4%	Evans et al. 2008
Downed Wood	Debris Cover = 32%	
Soils	Well-drained sandy soils	Auffenberg and Franz 1982; Tuberville et al. 2007; Wilson et al. 1994; Wilson et al. 1997
	Probability of finding a burrow decreased as the clay percentage in the top soil layer increased.	Baskaran et al. 2006
	On sandy soils, 42% of burrows were active On loamy soils, 31% of burrows were active	Wigley et al. 2012
Stand Disturbance		
Fire	≤ 5 year fire return interval; in general, areas become unsuitable as gopher tortoise habitat if fire has been suppressed for 5-7 years or longer	Ashton et al. 2008
	Gopher tortoises returned to sandhills and flatwoods after re-introduction of fire to fire-suppressed areas; active burrow densities were highest in the most recently and frequently burned areas	Ashton et al. 2008
	Frequent and repeated prescribed fire to restore open longleaf pine habitat and reduce midstory hardwood cover – repeated burning for 4 years was not long enough to restore open pine forest conditions with dense herbaceous ground cover	Yager et al. 2007
	1-12 year fire return interval depending on habitat type	USFWS (species profile)
	Fire return interval = 1-2 years	Eubanks et al. 2002
	Fire return interval = 1-5 years depending on site; **Growing Season** burns optimal	Tuberville et al. 2007
	Fire return interval = 1-3 years; **Growing Season** burns optimal	Aresco and Guyer 1999
	Periodic fires beneficial for maintaining an open canopy and understory and promoting herbaceous understory	Hoctor and Beyeler 2010

Home Range	In general, home range is wide-ranging but is as large as 6.55 ha	
	Adult Males = 0.06-1.44 ha (Georgia) 0.23-2.88 ha (North Florida) 0.3-5.3 ha (Central Florida) 1.2-2.9 ha (South Carolina) 0.28-2.17 ha (Florida)	McRae et al. 1981; Diemer 1992; Smith et al. 1997; Wright 1982; McLaughlin 1990
	Adult Females = 0.002-1.44 ha (North Florida) 0.04-0.14 ha (Georgia) 0.16-1.18 ha (North Florida) 0.3-1.1 ha (Central Florida) 0.014-0.122 ha (Florida)	Smith 1995; McRae et al. 1981; Diemer 1992; Smith et al. 1997; McLaughlin 1990
	Subadults = 0.0037-0.52 ha (North Florida)	Diemer 1992
	Juveniles = 0.0004-0.25 ha (North Florida) 0.010-0.36 ha (South Florida) – **Mean** = 0.07ha	Diemer 1992; Wilson et al. 1994
	Hatchlings = 0.06-0.42 ha (North Florida) 0.0001-4.8 ha (Central Florida)	Butler et al. 1995; Pike 2006
	Males & Females = 0.05-6.55 ha	Yager et al. 2007
	Critical Area = **Males** = 2.3 ha **Females** = 1.0 ha	Eubanks et al. 2002
	Males (mean) = 0.47 ha (Range = 0.6-1.44 ha) **Females (mean)** = 0.08 ha (Range = 0.04-0.14 ha)	McRae et al. 1981
	Males (mean) = 1.05 ha (Range = 0.28-2.17 ha) **Females (mean)** = 0.06 ha (Range = 0.01-0.12 ha)	McLaughlin 1990
	Mean (both sexes) = 1.7 ha; **Males (mean)** = 1.9 ha (Range = 0.3-5.3 ha) **Females (mean)** = 0.6 ha (Range = 0.3-1.1 ha)	Smith et al. 1997
	Sample Size is only 3 **Males (n=2)** = 1.2-2.9 ha **Female (n=1)** = 0.7 ha	Wright 1982
	Females Only = 0.002-1.44 ha **Sandhill Habitat (Females) =** 0.48 ha **Old Field Habitat (Females)** = 0.11 ha	Smith 1995

Movement	Short-range annual migrations – up to 250 m; moved from more mesic sites to xeric site in the early spring and then back to mesic sites in the Fall/Winter	McRae et al. 1981
	Longest Distance moved (by an individual) = 744 m	Diemer 1992
	Mean distance moved = 15 m	Wilson et al. 1994
	Mean movement radii: **Males**= 47m; **Females**= 28m Movement from burrow was correlated with abundance of herbaceous ground cover; movement decreased with increasing herbaceous ground cover density	Auffenburg and Iverson 1979
	Feeding Activity (mean length) = 7.4 m (Range = 2-17 m) Nesting Forays (mean length) = 77.4 m (Range=11-142 m) Nest Distance from Burrow Entrance (mean) = 18.3 cm	Smith 1995
	Mean Feeding Radius: **Adults**= 13 m; **Juveniles**= 7.8 m	Wilson et al. 1997
Preferred Food	feed primarily on herbaceous plants (grasses and forbs) but may also consume insects	Hoctor and Beyeler 2010; Wilson et al. 1997
	Wiregrass, broomsedge, eupatorium, and prickly pear	Wright 1982
Burrows	Burrows were found in more open areas even though hatchlings used microhabitats with dense ground cover and tall vegetation	Pike 2006
	Density of burrows increased with increasing grass cover	Auffenburg and Iverson 1979

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Northern Bobwhite Quail (*Colinus virginianus*)

Habitat Variable	Description	Source
Habitat - Preferred	Open, upland pine forests with an open understory dominated by early successional plant species is ideal habitat type	
	Loblolly pine stands (>20 years old) with a diverse understory	Burke et al. 2008
	Burned and unburned loblolly pine stands (>60 years old) and oak/hickory midstory	White et al. 1999
	Longleaf-slash and loblolly-slash pine stands with some hardwood midstory encroachment	Bell et al. 1985
	Mature, open pine forests, mixed pine-hardwood forests, grass-brush rangelands, and agricultural fields and grasslands	Brennan 1999; Fies et al. 2002; Jones and Chamberlain 2004; Sisson et al. 2000
	Upland pine forests dominated by loblolly and slash pines in the overstory, with a smaller longleaf pine and live oak overstory component	Carver et al. 2001
	Preferred habitat characteristic of old agricultural fields undergoing succession	Dixon et al. 1996
	Upland pine forest (longleaf, loblolly, slash overstory), with scattered midstory of hardwoods, and understory containing early successional plant species	Terhune et al. 2006
	Upland pine forests and mixed pine-hardwood stands – 50-60 years old	Liu et al. 2002; Brennan et al. 1991
	Mature, fire-maintained longleaf pine stands (~60 years old), little to no hardwood midstory and a dense herbaceous understory dominated by wiregrass	Hill 1998
	Pine savannas, sandhills, flatwoods, and loblolly-shortleaf pine stands	Hunter et al. 1994
	Dry prairies –herbaceous low shrub communities similar to longleaf pine flatwoods, but lacking pines in the overstory	Singh et al. 2011
	Slash Pine Stand (40 yrs. old) and Longleaf Pine Stands (>50 yrs. old)	Repenning and Labisky 1985
	Mature, frequently burned loblolly and shortleaf pine forests interspersed with live oak	Smith et al. 1982
Habitat - Avoided	Wet prairie habitat – Florida	Singh et al. 2011
Habitat Patch (Size)	Manage for large contiguous blocks ≥ 3,000 ha (7 pairs/40 ha)	Hunter et al. 1994

Forest Stand Structure		
Canopy	Loblolly pine dominant (Stand age = 24-46 years) Canopy Closure = 71%	Burke et al. 2008
	Loblolly pine dominant (>60 years old) Canopy Closure = 73-88% Basal Area (trees ≥ 7.5 cm dbh) = 24-27 m^2/ha	White et al. 1999
	Ideal forest habitat – pine and mixed pine-hardwood stands Canopy Cover <50%	Brennan 1999
	Loblolly and slash pines (dominant); longleaf pine and live oak (smaller component) Basal Area = 5-15 m^2/ha	Carver et al. 2001
	Longleaf, loblolly, and slash dominated overstory Basal Area = 3-9 m^2/ha	Terhune et al. 2006
	Mixed pine-hardwood – loblolly and Virginia pines, oaks, tulip poplar, and maples	Fies et al. 2002
	Loblolly and shortleaf pines, oaks, hickories, and sweetgum Basal Area = 9-14 m^2/ha	Liu et al. 2002
	Pine Overstory Basal Area = 10-20 m^2/ha	Brennan 1991
	Mature, uneven-aged pine and pine-hardwood forests (75-85 yrs. old) Canopy Closure = 70-90% Pine Basal Area = 30 m^2/ha	Jones and Chamberlain 2004
	Pine Savanna (Basal Area) = 2-5 m^2/ha Sandhills, Flatwoods, and Loblolly-Shortleaf (Basal Area) =14-23 m^2/ha	Hunter et al. 1994
	Slash Pine Stands (40 yrs. old): Basal Area = 7 m^2/ha Tree Height = 16 m Tree dbh = 19 cm Tree Density = 260 trees/ha Canopy Cover = 55% **Longleaf Pine Stands (>50 yrs. old):** Basal Area = 30 m^2/ha	Repenning and Labisky 1985

	Tree Height = 20 m Tree dbh = 30 cm Tree Density = 52 trees/ha Canopy Cover = 52%	
Midstory	Oaks and hickories	White et al. 1999
	Scattered hardwoods including oaks, sassafras, black cherry and persimmon	Terhune et al. 2006
	Hardwood Basal Area = 40 m^2/ha	Jones and Chamberlain 2004
	Little to no midstory vegetation	Hunter et al. 1994
Ground Cover	Grasses = 16% Forbs = 21% Woody = 18% Vines = 8% Ferns = 4%	Burke et al. 2008
	Herbaceous cover = 17-39% Shrub Density (<7.5 cm dbh) = 1,229-2,225 shrubs/ha	White et al. 1999
	Early successional vegetation: broomsedge (*Andropogon* spp.), goldenrod, rubus, ragweed	Terhune et al. 2006; Brennan 1991
	Ferns, vines, woody spp., other herbaceous Maximum understory vegetation height = 0.84-1.1 m Mean understory vegetation height = 0.40 m Vertical obstruction height = 0.12-0.25 m Vines= 20-36% Ferns=4% Woody=21-30%	Jones and Chamberlain 2004
	grasses and forb dominated understory with sparse retention of shrub/scrub	Hunter et al. 1994
Bare Ground	Bare ground cover = 11%	Burke et al. 2008
	Bare ground cover = 17%	Carver et al. 2001
	Bare ground cover = 3.5%	Jones and Chamberlain 2004
Leaf Litter	Leaf Litter Cover = 10-23%	White et al. 1999
	Litter Depth = <0.1 cm	Jones and Chamberlain 2004

Downed Wood	Debris cover = 21%	Burke et al. 2008
	Debris cover = 66%	Carver et al. 2001
	Debris cover = 20-42%	Jones and Chamberlain 2004
Snags	Snag Density (≥ 7.5 cm dbh) = 37-94 snags/ha	White et al. 1999
Stand Disturbance		
Fire (& other)	Fire return interval is dependent upon habitat type but 1-3 years appears to be optimal for maintaining early successional understory vegetation	
	Prescribed burned during the growing season on a 2 year rotation and treated with imazapyr to reduce hardwood midstory and promote herbaceous understory	Burke et al. 2008
	Burned treatments – 3-4 year fire return interval during dormant season	White et al. 1999
	Frequent vegetation disturbance (fire or mechanical) – every 1-5 years	Brennan 1999
	Fire return interval = 2-3 years; growing and dormant season	Carver et al. 2001
	Disturbances to promote understory of early successional vegetation in upland pine forests include frequent prescribed burning, seasonal disking, drum-chopping and mowing	Terhune et al. 2006
	Fire return interval = 1-2 years to maintain early successional understory vegetation	Brennan 1991
	Burned annually in February or March	Smith et al. 1982
Home Range	Mean Home range is wide ranging – 3-88 ha	
	Juveniles = 26-41 ha Adults = 18-58 ha	Bell et al. 1985
	Mean = 11.1 ha (Range = 4.2-33 ha) Core Areas = 1.8-14.4 ha	Dixon et al. 1996
	Mean home range (translocated birds) = 17.4 ha (range = 4-48 ha) Mean home range (resident birds) = 17.0 ha (range = 8-34 ha)	Terhune et al. 2006

	<u>March Home Range:</u> Resident Birds = 11 ha; Relocated Birds = 6 ha **<u>Nesting Season Home Range:</u>** Resident Birds = 62 ha; Relocated Birds = 43-47 ha	Liu et al. 2002
	Mean Annual Home Range (both sexes) = 88.4 ha (Range=5.7-544.3 ha) Mean Annual Home Range: Males=91 ha; Females = 84 ha Mean Winter Home Range (both sexes) = 69.3 ha (Range=5.6-401.6 ha) Mean Winter Home Range: Males=74.6 ha; Females = 62.2 ha Mean Summer Home Range (both sexes)= 53.9 ha (Range=5.3-530.1 ha) Mean Summer Home Range: Males=55.3 ha; Females = 51.5 ha	Singh et al. 2011
	Mean Home Range (Supplemental Feeding) = 3-4 ha Mean Home Range (Not Fed) = 4-8 ha	Sisson et al. 2000
Movement	**<u>Mean daily movements (straight-line) by season:</u>** Winter = 272 m (Range = 191-332 m) Spring = 185 m (Range = 178-192 m)	Bell et al. 1985
	Mean home range (translocated birds)= 17.4 m (Range =4-48 ha) Mean home range (resident birds)= 17 ha (Range=8-34 ha) Mean daily movements (among resident & translocated birds)=128-171m Longest individual daily movement (translocated) = 475 m Longest individual daily movement (resident) = 446 m Movement between activity areas and trap/release sites (translo.) = 202m Movement between activity areas and trap/release sites (resid.) = 246m	Terhune et al. 2006
	Mean distance moved between winter and EARLY breeding season activity areas= 1,194m; Mean distance moved between winter and LATE breeding season activity areas= 1,644m 25% of bobwhites moved >2 km (classified as dispersers) Maximum distance moved by an individual = 13,500 m	Fies et al. 2002
	<u>Mean Breeding Season Dispersion:</u> Residents = 1.4 km; Relocated = 1.0 km **<u>Mean Distance Moved Daily (March):</u>** Residents = 182 m; Relocated = 123-134 m **<u>Mean Distance Moved Daily (April):</u>** Residents = 195 m; Relocated = 151-209 m	Liu et al. 2002

	Annual Distance Moved (Range) = 0-1,478 m **<u>Mean Annual Distances Moved:</u>** Adults = 177 m (Range = 0-972 m) Immature Birds = 215 m (Range = 0-1,478 m) Males = 230 m (Range = 0-1,478 m) Females = 191 m (Range = 1-1,203 m)	Smith et al. 1982
	<u>Mean Breeding Season Dispersal Distances:</u> Males= 1,576 m (Juveniles=1,339 m; Adults= 2,146 m) Females= 2,173 m (Juveniles=2,184 m; Adults=2,150 m) Both Sexes (Pooled)= 1,835 m (Juveniles=1,701 m, Adults=2,148 m)	Cook 1994
Preferred Food	Seeds and leaves of herbaceous vegetation (legumes, grasses, ragweed, etc.), fruits, insects	

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Pine Snakes – Black *(Pituophis melanoleucus lodingi)*
Florida (*Pituophis melanoleucus mugitus*)
Louisiana (*Pituophis ruthveni*)

	Description	Source
Current Range	**Florida pine snake –** Florida, southern Georgia, southern tip of South Carolina, and extreme southern Alabama	Miller 2008
	Black pine snake – southwestern Alabama through southern Mississippi, and into southeastern Louisiana	
	Louisiana pine snake – north-central and west-cental Louisiana and east-central Texas	Himes et al. 2006
Habitat Variable		
Habitat - Preferred	In general, fire-maintained pine forests with herbaceous ground cover and sandy soils	
	Most often associated with mixed pine-hardwood sites but other sites (hardwood, natural pine, pine regeneration and plantations, scrub/shrub, etc.) used when available	Miller 2008
	Xeric sites such as longleaf pine-xerophytic oak woodlands, sand scrub pine, pine flatwoods, and old fields on former sandhill sites	Franz 1992
	Longleaf pine or mixed pine forests (longleaf-slash or loblolly) with relatively open midstory and herbaceous ground cover	Baxley and Qualls 2009; Baxley et al. 2011; Rudolph and Burgdorf 1997
	Pine forests (loblolly, slash, and longleaf pine) with an herbaceous understory dominated by a diversity of grasses and forbs	Himes et al. 2006
	Longleaf pine savannas with sparse oaks in canopy, diverse herbaceous ground cover flora, and soils with high sand content	Ealy et al. 2004
	Fire-maintained, longleaf pine flatwoods, ground cover dominated by wiregrass and saw palmetto	Morin 2005
	Longleaf pine forests and ruderal habitats (open pastures)	Franz 2005
Habitat - Avoided	Not found in areas with cultivated crops, pasture and hay fields, developed areas, and roads	Baxley et al. 2011

	Avoided clearcut areas – perhaps due to scarcity of pocket gophers in these habitats	Himes et al. 2006
Forest Stand Structure		
Canopy	In general, 30-40% canopy cover	
	Pine/hardwood – 40% cover	Miller 2008
	longleaf pine or mixed pine (longleaf/slash or loblolly) – 41%	Baxley and Qualls 2009
	longleaf pine or mixed pine (longleaf/slash or loblolly) – 60%	Baxley et al. 2011
	loblolly, slash, and longleaf pine forests (canopy closure 21-25%)	Himes et al. 2006, Himes 2000
	longleaf pine with basal area 6-9 m^2/ha	Ealy et al. 2004
	longleaf pine; 35% canopy cover	Morin 2005
Midstory	Relatively open -- total cover = 14% (49% of the total cover = shrubs)	Baxley and Qualls 2009
	Total cover = 28% (31% of the total midstory cover = shrubs)	Baxley et al. 2011
	Midstory contained pines but lacked hardwoods	Himes et al. 2006
Ground Cover	In general, herbaceous vegetation 20-50% cover	
	25% grasses; 25% forbs	Miller 2008
	12% grasses; 6% forbs	Baxley and Qualls 2009
	21% grasses; 6% forbs	Baxley et al. 2011
	herbaceous ground cover with diversity of grasses and forbs	Himes et al. 2006; Ealy et al. 2004; Himes 2000
	understory dominated by wiregrass and saw palmetto with some gallberry, wax myrtle, and fetterbush	Morin 2005
Bare Ground	In general, 5-15% bare soil	
	~15% bare sand	Miller 2008; Morin 2005
	5% bare soil	Baxley and Qualls 2009
	17% bare soil	Baxley et al. 2011
Litter	In general, 50-90% litter cover	
	89% litter cover in the ground cover	Baxley and Qualls 2009
	74% litter cover in the ground cover	Baxley et al. 2011
	~60% leaf litter	Himes et al. 2006
	~50% leaf litter cover; leaf litter depth = 1.5 cm	Himes 2000; Morin 2005
	moderate to heavy leaf litter accumulation	Ealy et al. 2004
Downed Wood	~5% coarse woody debris	Miller 2008

	abundance of pine logs	Himes et al. 2006
	9% woody debris	Morin 2005
Stand Disturbance		
Fire	Frequent fire is beneficial for maintaining mixed pine-hardwood forests with an open canopy and herbaceous ground cover	Miller 2008
	Inner core area home ranges were burned within the previous 23 months	Baxley and Qualls 2009
	Snakes located in areas burned within the previous 45 months	Baxley et al. 2011
	Fire return interval 1-5 years	Ealy et al. 2004
Home Range	**In general,** male home ranges are larger than female home ranges; Louisiana pine snakes appear to require smallest home ranges among the 3 subspecies Mean across most studies: Males = 51 ha (or more); Females = 33 ha	
	Mean MCP – **Males**=70ha (range=25-157 ha); **Females**=38ha (range=19-81 ha) ** Maximum area used by an individual in 1 yr.–annual home range size	Miller 2008
	Mean 95% Kernel Density - Males=27 ha (range=20-36 ha); **Females**= 27 (range=20-42 ha) **Mean Fixed LoCoH – Males**=61 ha (range=22-136 ha); **Females**=29ha (range=19-52 ha) ** Kernal Density and LoCoH provide information on core areas used for habitat and resources	Miller 2008
	Mean home range = 53.2 ha; maintain an annual home range that includes areas used for forays and core areas used for habitat/resources	Franz 1986
	MCP (range) = 92-396 ha	Baxley and Qualls 2009
	Mean = 33.2 ha; **Range** = 7-108 ha	Himes et al. 2006
	Mean = 27.7 ha	Rudolph and Burgdorf 1997
	Mean = 57 ha; **Males** = 73 ha; **Females** = 14 ha	Franz 2005
Movement	Maximum distance moved = 28,541 meters	Franz 1986
	Maximum distance moved = 2,050 meters	Baxley and Qualls 2009
	Mean distance PER movement = 118 meters Maximum distance PER movement = 1159 meters	Himes et al. 2006
	Mean distance per day = 163 meters (range = 11-625 m)	Ealy et al. 2004

	Maximum distance traveled = 4,300 m; with maximum distances traveled during June and July	Franz 2005
Preferred Food	Mice, cotton rats, young cottontail rabbits, ground nesting birds (and eggs), and pocket gophers	Miller 2008; Franz 1992
Refugia	Use southeastern pocket gopher burrows for underground refuges	Miller 2008; Franz 2005; Franz 1992; Himes et al. 2006; Ealy et al. 2004; Himes 2000; Rudolph and Burgdorf 1997
	Most frequently used pocket gopher burrows but also used gopher tortoise burrows, and other burrows	Franz 1986; Franz 2005
	Primarily used pine stump holes – **Black Pine Snake** is NOT sympatric with pocket gophers	Baxley and Qualls 2009

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Red-Cockaded Woodpecker (*Picoides borealis*)

Habitat Variable	Description	Source
Habitat - Preferred	Longleaf pine stands with little to no midstory and an herbaceous understory	Novak 2011; Brudvig and Danschen 2011; Tuberville et al. 2007
	Fire-maintained longleaf pine-scrub oak forests, with little to no midstory, and herbaceous understory	Allen et al. 2006
	Mixed pine forests – Longleaf, loblolly, and slash pine (≤ 40 years but some older trees >40 years old)	Franzreb 2010, Franzreb 2008
	Loblolly and shortleaf pine stands (51-100 years – pine sawtimber)	Wood et al. 2008
	Sandhills – 2nd growth longleaf pine (51-90 years) with little to no hardwood or pine midstory and abundant grasses and forbs in the understory, dominated by wiregrass	Walters et al. 2002
	Longleaf, loblolly, slash pine forest with sparse oaks and sweetgum (≥60 years)	Kale 2008
	Loblolly/shortleaf pine stands and longleaf pine stands	Rudolph et al. 2007
	Loblolly/shortleaf pine stands (up to 85 years old)	Butler and Tappe 2008
Habitat - Avoided	Young restored longleaf and loblolly stands with presence of a midstory and high shrub densities	Novak 2011
	Pine regeneration stands (0-20 years old) and hardwood sawtimber stands (51-100 years old)	Wood et al. 2008
	Avoid stands or abandon clusters when hardwoods encroach as a result of fire suppression	Tuberville et al. 2007
	For foraging, avoid pine ≤30.5 cm dbh	Walters et al. 2002
Habitat Patch (Size)	32-51 ha of good quality open pine forest habitat provides sufficient habitat for foraging	Tuberville et al. 2007
Forest Stand Structure		
Canopy	Longleaf pines >25 yrs old Canopy cover=85% Basal Area = 292 m^2/ha	Novak 2011

	Dominated by Longleaf Pine Canopy cover = 65%	Allen et al. 2006
	Dominated by Longleaf Pine Optimal pine density (trees >36 cm dbh) = 35-80 trees/ha (trees ≤ 30.5 cm dbh) = <75 trees/ha	Walters et al. 2002
	Longleaf, loblolly, and slash pines (≥60 years) Pines (36 cm dbh)=5 m^2/ha Pines (25-36 cm dbh)=0-9 m^2/ha Pines(<25 cm dbh)=0-2.3 m^2/ha % Canopy Hardwoods = <30% Hardwoods (>10 cm dbh) = <5% of total basal area	Kale 2008
	Longleaf pine Canopy Cover = 42% Overstory Basal Area = 10.3 m^2/ha	Brudvig and Danschen 2011
	Loblolly and shortleaf pine (up to 85 years) Pine Canopy Cover = 45-51% Hardwood Canopy Cover = 3-21% Pine Basal Area (>25.4 cm)=10 m^2/ha Pines Basal Area (9-25.4 cm)=2 m^2/ha Hardwood Basal Area = 2 m^2/ha Mean Pine DBH = 34 cm Mean Hardwood DBH = 9-12 cm	Butler and Tappe 2008
	Longleaf (or other southern pine) stands (80-120 years old preferred for cavities) and ≥30 years for foraging habitat Preferred Cavity Trees ≥ 30 cm dbh	Tuberville et al. 2007
Midstory	Sparse hardwood midstory = <2.3 m^2/ha	Kale 2008
	Few to no midstory hardwoods	Tuberville et al. 2007
Ground Cover	Bunch grasses=25%; Other grasses=9%; Forbs=42%	Novak 2011
	Dense and diverse herbaceous understory with structure and diversity maintained by frequent fire	Brudvig and Danschen 2011

	Herbaceous ground cover = ≥40%	Kale 2008; Tuberville et al. 2007
	Grasses/sedges=29-34% Forbs = 5-16% Woody = 8-23% Vines= 4-13%	Butler and Tappe 2008
	Grasses = 23% Shrubs = 15% Forbs = 4%	Allen et al. 2006
	abundant grasses and forbs dominated by wiregrass	Walters et al. 2002
Bare Ground	Bare ground <25%	Novak 2011
	Bare ground = 16%	Allen et al. 2006
Leaf Litter	Litter Cover 80%	Novak 2011
	Litter Depth = 2.6 cm	Brudvig and Danschen 2011
	Litter Depth = 3 cm Litter Cover = 79-83%	Butler and Tappe 2008
	Litter Depth = 0.8 inches Litter Cover = 70%	Allen et al. 2006
Downed Wood	Woody debris = 16-19%	Butler and Tappe 2008
	Downed wood = 2%	Allen et al. 2006
shrubs	Shrub density = 3,064 stems/ha	Novak 2011
	Shrub density = 319 stems/ha	Brudvig and Danschen 2011
Snags	Snag density = 9.2 snags/ha	Novak 2011
Stand Disturbance		
	Fire return interval ≤3 years – Growing Season	Novak 2011; Kale 2008
	Growing season burns may be most beneficial for maintenance of vegetation structure associated with open longleaf pine forests	Allen et al. 2006

	Frequent, growing season burns	Walters et al. 2002
	Fire return interval = 2-3 years. No difference in red-cockaded woodpecker group size, clutch size, or number of fledglings between growing and dormant season burns	Lauerman 2007
	Fire return interval 1-5 years depending on stand condition; may require more frequent burning than every fifth year if hardwoods need to be controlled – Growing Season Fires Recommended	Tuberville et al. 2007
	Adaptive Kernel Home Range Mean Annual **=** 43.1 ha (Range = 14.4-201.5 ha) Mean Nesting = 24.1 ha Mean Non-Nesting = 43.7 ha **Minimum Convex Polygon Home Range** Mean Annual= 58.4 ha (Range = 3.6-252.8 ha) Mean Nesting=24.4 ha Mean Non-Nesting=39.1 ha	Wood et al. 2008
	Adaptive Kernel Home Range=83.6 ha (Range=56-129 ha) **Minimum Convex Polygon Home Range**=126.2 ha (Range= 84-231ha)	Walters et al. 2002
	~50 ha of good quality foraging habitat	Kale 2008
Foraging	**Mean Foraging Height** = 11.1 m (males); 9.8 m (females) **Mean Tree Height (foraging)** = 19.6 m (males and females) **Preferred Foraging Substrate =** trunk **Preferred Tree Age** = ≥ 30 yrs. old **Preferred Forage Tree** = longleaf pine (regardless of age or dbh) 98% of foraging observations occurred in Pine Trees 90% of observations (males and females) – foraging on LIVE trees	Franzreb 2010
	Preferred Pine Tree Characteristics: **Tree age** = >40 years old **Tree DBH** = >25.4 cm	Franzreb 2008
	Mean Forage Height: Loblolly trees = 20 m; Longleaf trees= 17 m **Mean Tree Height:** Loblolly/Shortleaf = 26 m; Longleaf trees= 25 m 94% of foraging observations occurred in pines trees Foraged most on trunk (in crown) and on live (vs. dead) portions of trees	Rudolph et al. 2007

	Mean Tree Height (foraging) = 21 m **Mean Tree Age** = 69 yrs. old **Mean Tree dbh** = 36 cm but **Prefer** pines >50.8 cm dbh 96% of trees used as foraging substrate = pines	Walters et al. 2002
Preferred Food	Species of arthropods and is primarily made up of wood cockroaches (*Parcoblatta* sp.) and/or ants (Formicidae)	Lauerman 2007; Rudolph et al. 2007

<u>References for Red-Cockaded Woodpecker</u>

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Sherman's Fox Squirrel (*Sciurus niger shermani*) – (Most information in this document is for this subspecies)

Southern Fox Squirrel (*Sciurus niger niger*)

Habitat Variable	Description	Source
	In general, preferred habitat for **Sherman's fox squirrels** is fire-maintained, mature pine forests with a small hardwood component (patches of oaks), open midstory with little to no vegetation, and a diverse herbaceous understory dominated by grasses (such as wiregrass) and forbs. **Southern fox squirrels** appear to tolerate a much greater hardwood component in the canopy.	
	Fire-maintained, mature open, longleaf pine stands with smaller, scattered oaks (turkey oak) and an herbaceous understory	Conner 2000; Weigl et al. 1989; Perkins et al. 2008; Conner and Godbois 2003; Perkins and Conner 2004; Kantola 1992; Conner 2001; Conner et al. 1999; FWC Publication 2010
	Mature longleaf pine sandhills and flatwoods from Central Georgia to Central Florida	Kantola and Humphrey 1990
Habitat - Preferred	Optimal habitat will have ~6 hardwood patches (each 0.02 ha) per 1 ha of mature pine savanna	Perkins et al. 2008
	Mature, upland pine and hardwood forests with <30% hardwoods; hardwoods being clumps of acorn-bearing oaks and hickories	Hilliard 1979
	Hardwood and mixed-pine hardwood stands; in particular Carolina bay, mixed runner, pine-hardwood, and hardwood runner habitat types characterized as containing both pine and hardwood – ECOTONAL areas are also very important to this species	Edwards 1986
	Southern Fox Squirrels - Barrier island – mature maritime forest (loblolly pine, live oak, laurel oak, southern magnolia and eastern red cedar) with a closed canopy, no midstory, understory dominated by saw palmetto	Dawson et al. 2009
	Southern Fox Squirrels - Sea island – mixed hardwood-pine, hardwood, and live oak habitats, with	
Habitat - Avoided	Hardwood forests, shrub/scrub, wetlands, agriculture, pine regeneration, and barren land/urban	Perkins and Conner 2004

	Monoculture pine forests because they do not provide the varied food required by fox squirrels	Kantola 1992
	Within a mature, upland pine-hardwood forest, large homogeneous areas of either very heavy ground cover or light ground cover	Hilliard 1979
	Marsh and low density pine habitat types, old fields, and agricultural areas	Edwards 1986
	Southern fox squirrels avoided pine habitat on a sea island	Lee et al. 2009
Habitat Patch (Size & Spacing)	Large habitat patch size required (several km^2) due to variability in food resources temporally and spatially	Kantola and Humphrey 1990
	maintain an area of at least 25 km^2 to support a population	Kantola 1992
Forest Stand Structure		
Canopy	Large, well-spaced pines; scattered oaks – size and spacing of pines and oaks are important habitat considerations	Weigl et al. 1989; Kantola and Humphrey 1990; Perkins et al. 2008; Perkins and Conner 2004; Kantola 1992; Conner 2001; Conner et al. 1999
	Fox squirrels most abundant in loblolly Pine-Oak; <30% hardwoods (but concluded that the longleaf pine-oak forests may be important in summer-fall for food resources)	Hilliard 1979
	General management recommendations = 12-21 m^2/ha basal area of mature pine; longleaf preferred but loblolly and slash acceptable and 2-7 m^2/ha of hardwoods	Hilliard 1979
	Retain at least 1 oak covert (0.05-0.1 ha) per 2 ha of pine	Hilliard 1979
	Optimum ratio for overstory trees in 7.6 (88.2%) mature pines to 1 (11.8%) hardwood; this yielded a 76% probability of use as fox squirrel home range	Perkins et al. 2008
	~6 hardwood patches per 1 hectare among mature longleaf pine appears to be optimum for Sherman's fox squirrel habitat	Perkins et al. 2008
	Large individual hardwood trees are important for loafing sites, daytime refugia, and nesting.	Conner and Godbois 2003; Kantola 1992

Midstory	open midstory, little to no vegetation	Perkins et al. 2008; Conner and Godbois 2003; Perkins and Conner 2004; Kantola 1992, Conner 2001; Conner et al. 1999; Hilliard 1979; Lee et al. 2009; Loeb and Lennartz 1989
Ground Cover	diverse herbaceous ground cover, dominated by wiregrass	Weigl et al. 1989; Kantola and Humphrey 1990; Perkins et al. 2008; Conner and Godbois 2003; Perkins and Conner 2004; Conner 2001; Conner et al. 1999
	diverse ground cover; mix of areas that were almost bare to areas of heavy cover with light cover areas used for foraging and moderate-heavy cover used for escape	Hilliard 1979
Stand Disturbance		
Fire	Frequent fire is necessary to maintain mature, open longleaf pine-oak forests by reducing abundance of hardwoods and promoting herbaceous understory	Weigl et al. 1989; Kantola and Humphrey 1990; Perkins et al. 2008; Conner and Godbois 2003; Conner 2001; Conner et al. 1999
	Burn during the growing season to prepare seedbed for longleaf pine regeneration	Kantola and Humphrey 1990
	2-3 year fire return interval to promote open pine forest, prevent hardwood encroachment, and prepare seedbed for pine regeneration	Perkins et al. 2008; Kantola 1992
	2-5 year return interval	Hilliard 1979
Home Range	**In general,** home ranges of males are greater than for females and **Mean Home Range (Upper Range for All Studies): Males~36 ha; Females~19 ha**	
	Composite home ranges for males = 37 ha and females = 21 ha	Conner 2000
	Home range varied by season and was larger during March-May (34.3 ha) than during January-February (5.9 ha); differences may be explained by food abundance and breeding behavior	Conner 2000

	Home range for males = 27 ha and females = 17 ha	Weigl et al. 1989
	Home ranges for males = 43 ha and females = 17 ha; Home ranges of males adjoined but did not overlap	Kantola and Humphrey 1990
	High variability in food supply in time and space may dictate need for large home range	Kantola and Humphrey 1990
	Range (**NOT home range**): Males=19 ha and Females=9 ha (mean=15 ha) Range is defined as all location points of collared squirrels, not just those used for foraging, mating, and caring for young	Hilliard 1979
	Ranged from 15.1-40.2 ha (no statistically significant difference between male and female home ranges)	Edwards 1986
	males = 9.6-37 ha females = 3.4-21 ha	Dawson et al. 2009
Preferred Food	Primary foods are longleaf pine seed and oak acorns (turkey and bluejack), with fungi, fruit, insects and staminate cones as secondary food sources. Will also consume live oak acorns when there is a turkey oak mast failure	Weigl et al. 1989, Kantola and Humphrey 1990; Perkins et al. 2008; Perkins and Conner 2004; Kantola 1992; FWC Publication 2010; Hilliard 1979; Loeb and Lennartz 1989
Refugia	Large individual hardwood trees are important for loafing sites, daytime refugia, and nesting. Large hardwoods may also provide protection from inclement weather	Conner and Godbois 2003; Kantola 1992
	Hardwood trees were 55.8% more likely to be used for refugia than were pines; therefore scattered hardwoods are important habitat component	Conner and Godbois 2003

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Southern Hognose Snake (*Heterodon simus*)

	Description	Source
Current Range	Coastal Plain – North Carolina, South Carolina, Georgia, Florida – may no longer occur in Alabama, Louisiana, Mississippi	Tuberville et al. 2000; Enge and Wood 2003
Habitat Variable		
Habitat - Preferred	Mature longleaf pine-turkey oak sandhills with well-drained sandy soils and little shrub cover may be the most important habitat type	Jordan 1998
	Also inhabits pine-wiregrass flatwoods, hardwood hammocks, old fields, dry river floodplains	Jordan 1998
	Upland sandhill, Pine forest, prairie/old field	Dorcas 2005
	Sandhills; widely spaced longleaf pines, sparse oaks in understory with a well-developed herbaceous layer;dense ground cover of grasses and forbs	Enge and Wood 2002;
	Southern hognose snakes were also commonly found in fragmented, ruderal communities that included old fields, improved pastures, and lawns	Enge and Wood 2002; Enge and Wood 2003
	Sand pine-rosemary scrub, longleaf pine-turkey oak, and xeric oak hammock but less frequently encountered in pine flatwoods, farmlands, fields, disturbed areas, and coastal beaches and dunes	Alabama Natural Heritage Report 2002
	Most commonly associated with fire-maintained Coastal Plain xeric habitats with sandy soils, and mixed-oak pine forests in North Carolina	Tuberville et al. 2002 (literature review)
Forest Stand Structure		
Canopy	Mature pine or pine-oak with 50-80% oak	Jordan 1998
	Longleaf pine (widely spaced, open)	Enge and Wood 2002; Alabama Natural Heritage Program 2002
Midstory	open with little to no woody or shrub cover	Jordan 1998
	sparse deciduous oaks	Enge and Wood 2002
Ground Cover	well-established herbaceous layer; preferably with a wiregrass component	Jordan 1998
	dense ground cover of grasses and forbs	Enge and Wood 2002
	dense ground cover of non-native grasses; grasses were short-statured	Enge andWood 2003

Stand Disturbance		
Fire	Frequent fire (2-3 yr. rotation) necessary to prevent hardwood encroachment and maintain adequate openings for nesting and hibernacula	Jordan 1998
	Growing season fires should be appropriate but research required	Jordan 1998
	Frequent fire and tree thinning to restore/maintain open longleaf pine woodlands and longleaf pine-scrub oak sandhills	Alabama Natural Heritage Program 2002
Preferred Food	Toads are preferred prey and it is thought that southern hognose snakes may have been observed frequently in ruderal habitats because prey might be more abundant or easier to capture in these habitats	Enge and Wood 2003
	Toads are preferred items but small vertebrates are also consumed	Tuberville et al. 2000
Refugia & Nesting	Slash piles and fallen trees should be retained where possible to provide refugia	Jordan 1998
	Open habitats are suitable for nesting which is likely the reason for high frequency of occurrence of juvenile hognose snakes on roads adjacent to lawns and pastures	Enge and Wood 2003

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Appendix 3. Participant List

PARTICIPANTS

National Fish and Wildlife Foundation Longleaf Pine Restoration Assessment Workshop
Joseph W. Jones Ecological Research Center
Newton, GA
July 16-18, 2012

Participant	Affiliation	E-mail address
Tim Albritton	NRCS	tim.albritton@al.usda.gov
Lindsay Boring	J.W. Jones Center	Lindsay.boring@jonesctr.org
Jim Candler	GA Power	WJCANDLE@southernco.com
Lamar Comalander	Milliken Forestry	comalander@millikenforestry.com
Vernon Compton	Longleaf Alliance	vernon@longleafalliance.org
Mike Conner	J.W. Jones Center	mconner@jonesctr.org
Kent Evans	NFWF	99kevans@gmail.com
Glen Gaines	USFS	ggaines@fs.fed.us
Patrick Glass	Southern Group of State Foresters	Patrick.Glass@forestry.alabama.gov
Barry Grand	USGS; AL Coop F&W Research Unit	grandjb@auburn.edu
Chuck Hunter	USFWS	Chuck_Hunter@fws.gov
Steve Jack	J.W. Jones Center	sjack@jonesctr.org
Chris Jenkins	Orianne Society	cljenkins@oriannesociety.org
Kay Kirkman	J.W. Jones Center	kkirkman@jonesctr.org
Kevin McIntyre	J.W. Jones Center	kevin.mcintyre@jonesctr.org
Rua Mordecai	South Atlantic LCC	Rua_Mordecai@fws.gov

David O'Neill	NFWF	David.ONeill@nfwf.org
Dan Petit	NFWF	Dan.Petit@nfwf.org
Beth Schlimm	J.W. Jones Center	Beth.schlimm@jonesctr.org
Suzanne Sessine	NFWF	Suzanne.Sessine@nfwf.org
Lora Smith	J.W. Jones Center	lora.smith@jonesctr.org
Atticus Stovall	NFWF	aes2aj@virginia.edu
Reggie Thackston	GA DNR and NBCI	Reggie.Thackston@dnr.state.ga.us
Russ Walsh	USFWS	William_Walsh@fws.gov
Nancy Walters	USFS	nwalters@fs.fed.us
Clay Ware	USFWS	Clay_Ware@fws.gov
Rickie White	NatureServe	rickie_white@natureserve.org
Randy Wilson	USFWS	Randy_Wilson@fws.gov

Appendix 4. Longleaf-associated wildlife species of conservation concern and management interest (from Range-Wide Conservation Plan).

Species	Status				LLP Communities				
	Listed Species	Candidate & Species of Conservation Interest	Migratory Birds of Conservation Interest	Wildlife of Interest in State Wildlife Action Plans	Upland	Flatwoods	Savannas	Sandhills	Montane
Bachman's Sparrow			x		x	x	x	x	x
Black Pine Snake		x			x			x	
Brown-headed Nuthatch			x		x	x	x	x	x
Camp Shelby Burrowing Crayfish		x				x			
Chuck-wills Widow			x		x	x	x	x	x
Eastern Diamondback Rattlesnake		x			x	x		x	
Eastern Fox Squirrel				x				x	
Eastern Spotted Skunk				x				x	
Flatwoods Salamander	x				x	x	x		
Florida Black Bear				x	x	x	x		
Florida Mouse				x				x	
Gopher Frog	x	x			x		x		
Gopher Tortoise	x	x			x	x		x	
Henslow's Sparrow			x			x	x		
Indigo Snake	x				x	x	x		
Loggerhead Shrike			x			x	x		
Louisiana Pine Snake		x			x			x	
Henslow's Sparrow			x			x	x		
Mississippi Sandhill Crane	x						x		
Northern Bobwhite				x	x	x	x	x	x
Red-cockaded Woodpecker	x				x	x	x	x	x
Red-headed Woodpecker			x		x	x	x	x	x
Short-tailed Snake				x				x	
Southeastern American Kestrel			x			x	x	x	
Southeastern Pocket Gopher				x				x	
Southern Hognose Snake		x			x			x	
Striped Newt		x			x			x	
Swallow-tailed Kite		x					x		
Wild Turkey				x	x	x	x	x	x