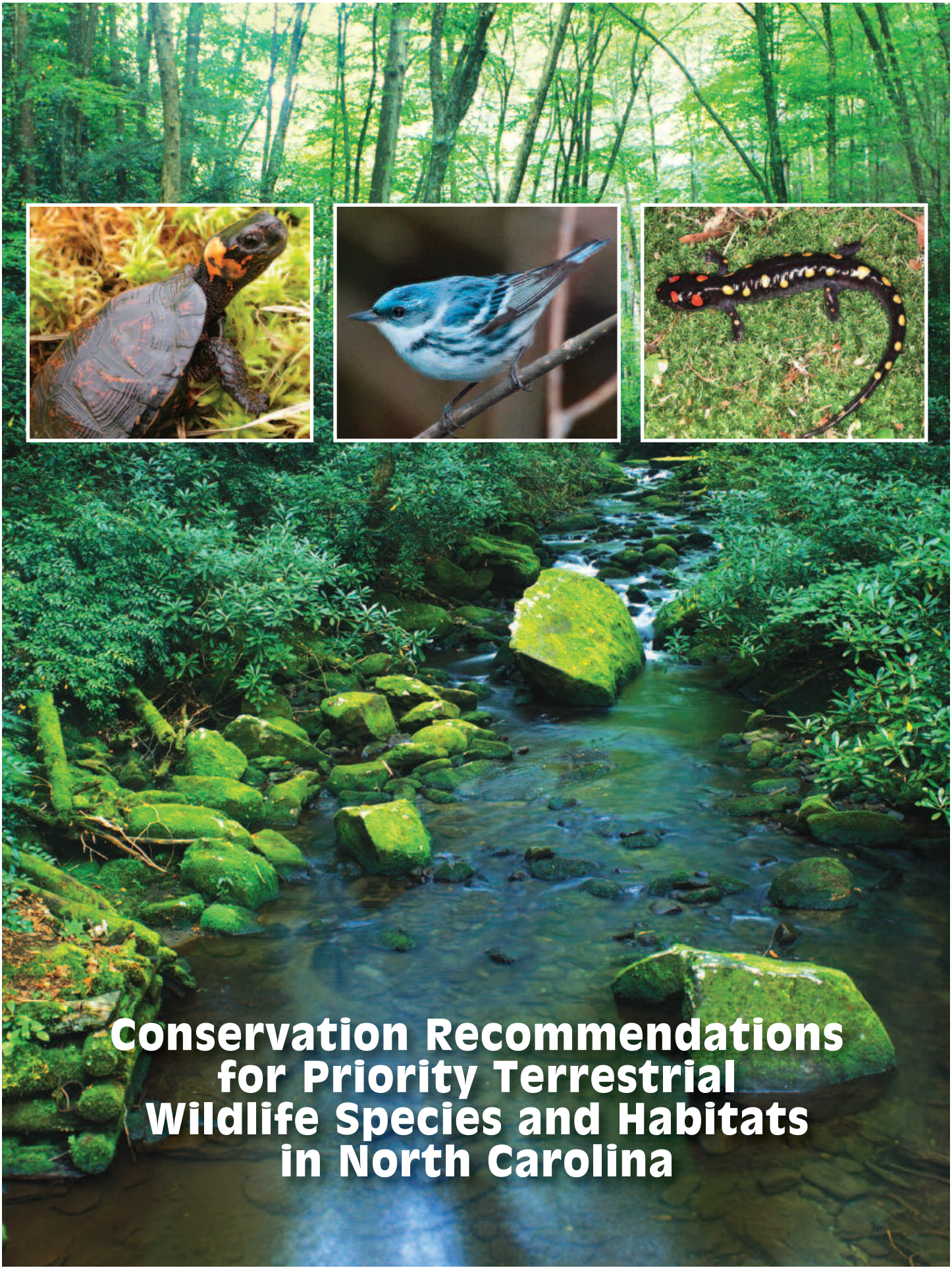

Conservation Recommendations for Priority Terrestrial Wildlife Species and Habitats in North Carolina

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forward

The North Carolina Wildlife Resources Commission (NCWRC) is proud to contribute a new resource to inform conservation decisions: "Conservation Recommendations for Priority Terrestrial Wildlife Species and Habitats in North Carolina." This document represents a compilation of the best available science on habitat thresholds and conservation needs for at-risk species. The recommendations are the result of an extensive review of scientific literature with review and compilation by a multi-agency team of natural resources professionals.

This document consolidates earlier guidance information and provides specific conservation recommendations for species and habitats identified as priorities in North Carolina's Wildlife Action Plan. This project grew out of a need to provide consistent, scientifically defensible recommendations to land use planners. The recommendations presented in this document were developed based on expert review of the responses of species and habitats to habitat changes and land-altering activities. Prior to this effort there did not exist a source that pulled together all available information to answer critical questions such as "How much habitat is enough?" for at-risk species in North Carolina.

The intent of this document is to make relevant information readily available to land use planners, natural resources professionals and land managers. The recommendations presented summarize existing studies and pull together information that NCWRC makes available through outreach efforts such as the Green Growth Toolbox. This document will provide consistency and efficiency for NCWRC recommendations. It is not a regulatory document and it is not the intent of this document to impose specific regulations. It is our intention that these recommendations be used to inform conservation, land use, and land management decisions, and it is our hope that it will help NCWRC and our partners to be more effective at protecting and enhancing the public trust wildlife resources of our state.

Gordon S. Myers, Executive Director
N.C. Wildlife Resources Commission
Raleigh, NC
July 25, 2012

This document was endorsed by a unanimous vote of the full North Carolina Wildlife Resources Commission at their meeting on Thursday, July 12, 2012.

contents

FRONT COVER, LARGE PHOTO: Joyce Kilmer Memorial Forest
INSETS: Bog turtle, Cerulean warbler, Spotted salamander

BOG HABITAT

BOG TURTLE

SECTION 1. INTRODUCTION

1.1 Background

Wildlife is a key component of healthy, functioning ecosystems in North Carolina. Healthy ecosystems produce the raw materials, such as clean air, clean water, food, and fiber, upon which our economy depends. The production of these economically valuable services relies in part on the daily activities and life cycle routines of native wildlife species. In the absence of native wildlife, ecosystems are more easily degraded and susceptible to disease and non-native species invasion. Decreases in ecosystem services and less opportunity for wildlife-based recreation, a growing base of tourist dollars for North Carolina, hurts the economy. To promote the economic benefits associated with healthy wildlife and ecosystems, efforts to protect them must be considered in our growth and economic development agenda. Likewise, protection of wildlife and ecosystems preserve opportunities for future generations to reap the benefits of abundant ecosystem services and to enjoy, view, and learn about the spectacular native species that live in our state.

Wildlife is a public resource. The North Carolina Wildlife Resources Commission is charged with conserving, protecting, restoring, and perpetuating the state's wildlife. Yet the agency does not have regulatory authority over most of the habitat on which these animals depend. Therefore, private landowners, local governments, and the public have a shared responsibility to protect and maintain wildlife resources for present and future generations.

Negative impacts associated with rapid development in North Carolina pose significant threats to wildlife species and habitats identified as conservation priorities in North Carolina's Wildlife Action Plan. When residential and commercial development occurs in a pattern that does not take the needs of wildlife into consideration, the result is a landscape with fragmented and degraded habitats that are unable to support populations of sensitive species.

In August 2002, the North Carolina Wildlife Resources Commission published a guidance memorandum[1] to assist local governments in addressing cumulative and secondary impacts associated with public projects. The 2002 guidance memorandum presents measures that, if adopted, will minimize cumulative and secondary impacts to threatened and endangered aquatic species (e.g., fishes and mussels) as well as terrestrial (land-based) species that are associated with riparian systems. In particular, the 2002 document was designed to improve the environmental review process, and help that process fully address cumulative and secondary impacts.

Because several groups of terrestrial species have habitat requirements that are not adequately addressed in the 2002 document, one goal of this document is to fill this information gap. This document is intended to supplement the 2002 guidance memorandum. However, this document also differs from the 2002 guidance memorandum in two ways. First, terrestrial species and habitats receive far less regulatory protection than aquatic species, so they are often not subject to the environmental review process. Second, this

1 N.C. Wildlife Resources Commission. (2002). *Guidance Memorandum to Address and Mitigate Secondary and Cumulative Impacts to Aquatic and Terrestrial Wildlife Resources and Water Quality.*

document does not just focus on cumulative and secondary impacts to these species and habitats; instead, this document presents conservation recommendations that can assist stakeholders in avoiding, minimizing, and mitigating for all types of impacts to terrestrial wildlife: direct, indirect, cumulative, and secondary.

1.2 Purpose

The purpose of this document is to present science-based recommendations that will assist local governments, developers, and other stakeholders in conserving and managing terrestrial wildlife habitats and species for future generations, particularly in North Carolina's urbanizing landscapes.

The document was created through a comprehensive review and synthesis of scientific literature, and will be updated as new science is made available. The recommendations presented in this document were developed based on expert review of what the best available science tells us about different "conservation thresholds." A conservation threshold is the minimum level of any characteristic of a species' habitat that is needed in order for local populations to persist over time.

The conservation recommendations in this document can be used to guide land use planning, land development, and natural resource management efforts across the state. Because the primary audiences are local governments and the development community, we did not conduct a comprehensive review of habitat management practices. We have included general management recommendations that can be used by natural resource managers, particularly in town and county parks and recreation departments. However, a full treatment of management recommendations was beyond the scope of this document. Where available, we reference publications that provide a synthesis of best management practices for each habitat type.

The recommendations, if implemented, should improve the probability that these habitats will support most of the priority species associated with them. Where it is impractical to follow all of the recommendations, there still will be a value in following them to the largest extent possible, though the probability of persistence for some of the more sensitive species will be reduced. The recommendations are intended to help North Carolina's decision makers compose proactive land use decisions that incorporate the needs of terrestrial wildlife. These recommendations are not regulatory.

1.3 Methods

The recommendations in this document, and the companion scientific justification document (Appendix C) are the culmination of an extensive review and synthesis of scientific literature. This process started in meetings of the advisory committee, which was composed of experts from the North Carolina Wildlife Resources Commission, U.S. Fish and Wildlife Service, North Carolina Natural Heritage Program, and North Carolina State University. The committee identified habitats that are most threatened by development in North Carolina and created a list of priority species from the NC Wildlife Action Plan that were dependent upon those habitats. The committee also identified groups of species that are affected by development but that are not exclusively dependent upon any one habitat type.

These lists of species, or species groups, formed the basis of the literature review. Experts on each habitat type were contacted for feedback on species lists and for literature recommendations. For each species group, species names, habitat types, and keywords were entered into the Web of Science literature database. Upon retrieving and reviewing all relevant publications, findings were summarized and synthesized to form the scientific justification document (Appendix C).

Preliminary conservation recommendations were then developed based on review of the scientific justification, and these recommendations were presented to the advisory committee. After the advisory committee reached consensus on recommendations related to each habitat type, this document was compiled. Finally, this document was subjected to an extensive peer review process, and edits were made based on feedback from external experts. See page 25 for the list of reviewers.

1.4 Document Structure

This document is organized by habitat type. In each section, the habitat is defined, recommendations are presented, and selected references are listed. Appendix A defines terms used throughout the document. Appendix B presents a more detailed description of methodology. Appendix C presents the scientific justification used to develop these recommendations, and Appendix D contains the bibliography.

Although this document presents conservation recommendations for several habitat types in North Carolina, recommendations were not developed for all habitats in need of conservation action. Due to time constraints, we were unable to complete literature review and develop recommen-

dations for 1) beach and dune habitats and 2) heron rookeries. We hope to address these habitats in future versions of this document.

In addition, recommendations were not developed for certain imperiled habitats described in section 1.5.

1.5 Imperiled Habitats

Much of this document focuses on ways to minimize the impacts of development on habitats that are still found in significant quantities throughout the state. Our goal is to present ways to develop adjacent to or within these habitat types without eliminating their suitability for local wildlife populations. However, several other habitat types have been reduced in quantity to the point that any impacts to them should be avoided altogether. These habitat types include Spruce-Fir Forests, Maritime Forests, Coastal Peatlands, Estuarine Islands, and Inlet Spits. Because these habitat types are so rare and threatened, we did not develop land use recommendations for these habitats. *Our recommendation is to avoid impacting them altogether.* Therefore, these habitats are not treated like the other habitats in this document. Brief descriptions and a few key recommendations are provided below.

SPRUCE-FIR FORESTS ● Spruce-fir forests occur at elevations above 4,000 feet and are often comprised of Red Spruce, Fraser Fir, or components of northern hardwood and Northern Red Oak forests. Threats to Spruce-Fir forests include residential and recreational development, air pollution, non-native insects (especially the Balsam Wooly Adelgid), and climate change. This habitat is one of the most endangered ecosystems in the United States.

These forests are used by a variety of breeding birds of conservation concern such as Magnolia Warbler and Red Crossbill. In addition, the Carolina Northern Flying Squirrel, Northern Saw-Whet Owl, Black-Capped Chickadee, and Long-Tailed Shrew use these forests, as do state-listed Pygmy Salamander and Weller's Salamander.

When development must occur in this habitat, contact the US Fish and Wildlife Service (see http://www.fws.gov/asheville/htmls/generalinfo/aboutasheville.html) to identify potential impacts to the Carolina Northern Flying Squirrel.

MARITIME FORESTS ● Maritime Forests are found along barrier islands and the mainland coast on stabilized upper dunes and flats that are protected from salt water flooding and spray. Maritime forests are dominated by Live Oak, Sand Laurel Oak, Loblolly Pine, Yaupon Holly, Groundsel Tree, and Coastal Red Cedar. These habitats are important breeding and migration stopover points for many migratory birds, and are key breeding areas for declining populations of the Eastern Painted Bunting.

The condition of maritime forests in North Carolina is extremely poor, and these habitats are among the most endangered in the state. Maritime Forest habitat is considered "high ground," and is some of the only suitable land for building close to beaches. Due to population growth and the explosion of second homes on North Carolina's coast, residential and commercial coastal development has eliminated most of the state's Maritime Forest habitat. Species of conservation concern that use this habitat type include Eastern Painted Bunting, Northern Yellow Bat, Oak Toad, Southern Dusky Salamander, Eastern Spadefoot, Northern Scarlet Snake, Outer Banks Kingsnake, and Eastern Coachwhip.

COASTAL PEATLANDS ● Coastal Peatlands include Pocosins, Pond Pine Woodlands, Atlantic White Cedar Forests, Bay Forests, and Coastal Depressions. Most of these coastal wetlands in private ownership have been drained and converted to pine plantations, agriculture, or development. In addition to drainage, reduced fire regimes have led to reductions in the quality of coastal peatland habitat. Species of conservation concern that use coastal peatland habitats and adjacent uplands include Pine Barrens Treefrog, Many-Lined Salamander, Worm-eating Warbler, and Wayne's Black-throated Green Warbler.

ESTUARINE ISLANDS & INLET SPITS ● Estuarine islands and inlet spits are found along the mainland coast and barrier islands of North Carolina. Estuarine islands can be either natural or created by dredged material. Inlet spits are accumulations of sand and sediment that develop within oceanic inlets. Spits can form at the ocean and bay sides of inlets. Estuarine Islands & Inlet Spits are particularly important nesting habitats for several priority species of colonial waterbirds, including terns, skimmers, pelicans, wading birds, and American Oystercatchers. These habitats are threatened by beach stabilization projects and other development activities along the North Carolina coast.

EPHEMERAL POOL HABITAT

SPOTTED SALAMANDER

SECTION 2. WETLAND HABITAT RECOMMENDATIONS

In this section, we present general recommendations for wetlands as well as recommendations for ephemeral pools and mountain bogs. We have given special attention to these two types of wetlands because 1) they are especially threatened by development, and 2) much research on species associated with such wetlands exists.

2.1 Wetland Habitat Definition

In this document, we use the term "wetlands" to refer to most wetlands in North Carolina, including seeps, ephemeral pools, depression ponds, floodplain pools, swamp forests, beaver swamps, and mountain bogs. Most wetlands have some value for wildlife in North Carolina. A variety of species identified as priorities in the North Carolina Wildlife Action Plan use wetlands, such as the Four-toed Salamander, Little Blue Heron, Yellow-Crowned Night Heron, Spotted Turtle, Barking Treefrog, and Willow Flycatcher. Many of these species require both the wetlands and suitable adjacent uplands in order to carry out all life functions. Some wetlands that are valuable for wildlife will be classified as jurisdictional wetlands. Others, particularly small, ephemeral wetlands, will not qualify as jurisdictional wetlands. These small, ephemeral wetlands are in particular need of protection.

2.1.1 Planning and Development Recommendations for All Wetland Habitats

This section outlines recommendations for conserving all types of wetland habitats. These recommendations describe ways to conserve wetland habitat alongside development at two different scales: 1) the core terrestrial habitat scale and 2) the adjacent landscape scale.

2.1.2 Core Terrestrial Habitat

"Core terrestrial habitat" consists of the wetland itself and 750 feet of protected upland habitat beyond a wetland's boundary. Its extent is based on reptile and amphibian use of wetlands in North Carolina. Reptiles and amphibians associated with wetlands in North Carolina can routinely travel further than 750 feet from wetlands. However, scientific research has indicated that a 750 foot core area will provide enough habitat for most priority species to complete an average migration into surrounding uplands.

1. Protect wetlands from fill or alteration of their hydrology.
   - If some wetlands must be filled or altered, protect those with the highest habitat value. Habitat value can be determined by conducting a basic ecological assessment of wetlands prior to development projects.
   - Use conservation easements, covenants, or deed restrictions to keep core terrestrial wetland habitat properly protected and managed.
   - Where possible, restore natural wetland hydrology and vegetation at altered or degraded sites.

CORE TERRESTRIAL HABITAT ZONES

2. Protect a minimum 150 foot undisturbed "critical habitat zone" around wetlands (see Figure 1). This initial 150 foot buffer is the most important habitat to protect.

3. Ideally, protect an additional 600 foot naturally vegetated "secondary upland habitat zone" for a total core terrestrial habitat of 750 feet from the wetland boundary (see Figure 1).
   - An even larger upland buffer is necessary to protect some wetland-associated species, such as Tiger Salamander and Gopher Frog.

- In general, wetlands surrounded by higher intensity development will need wider buffers than those surrounded by lower intensity development, and wetlands with greater habitat value will need wider buffers than those with less habitat value.

4. If development must occur within the core terrestrial habitat:
   - Keep development out of the 150 foot critical habitat zone.
   - Conduct an ecological assessment to identify which parts of the upland buffer are the most valuable for wildlife. Protect these areas from development and maintain undeveloped corridors between them.
   - Cluster development within a concentrated 25% area of the "secondary upland habitat zone", and orient this disturbed area so that it is not between adjacent wetlands or within a known animal movement corridor.
   - Maintain forest cover within the developed area to the maximum extent possible.

MINIMIZING CONSTRUCTION IMPACTS

- Mark the edges of protected core terrestrial habitat with permanent markers such as signs or tree paint.
- Keep site clearing, grading, lawn establishment, and other soil disturbing activities out of the recommended core terrestrial habitat.
- Use silt fencing to keep amphibians out of active construction areas.
- Avoid placing exterior and road lighting within the core terrestrial habitat. If lights must be placed within this habitat, use low spillage lights, and avoid using fluorescent and mercury vapor lighting.

2.1.3 Wetland Management Recommendations

1. Minimize the use of chemical herbicides within the core terrestrial habitat.
   - If herbicide use is necessary, obtain a surfactant-free 53.8% glyphosate product such as Accord Concentrate (Dow), Rodeo (Dow), AquaNeat (Nufarm), Foresters (Nufarm), or Aquamaster (Monsanto) and mix it with the surfactant Agri-Dex (Helena). Surfactants have been shown to cause harm to amphibians using wetland areas.

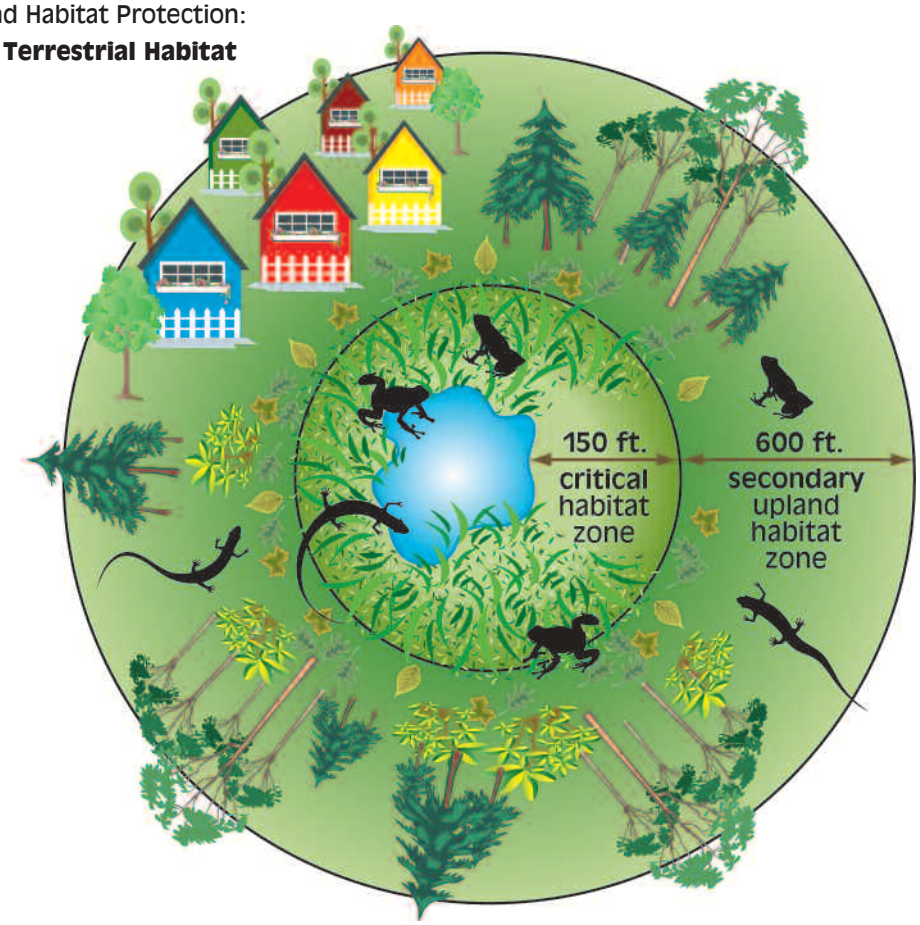
2. Cluster any trails or infrastructure associated with recreation activities within a 25% developed area.

3. Avoid planting exotic species and actively remove exotic, invasive species where practical.

2.1.4 Adjacent Landscape

In most places, the "adjacent landscape" consists of an area outside of core terrestrial habitat but within 1 mile of

Figure 1. Wetland Habitat Protection:
Core Terrestrial Habitat



any wetland. In habitats where Gopher Frogs occur, such as Longleaf Pine habitats in the Sandhills and southern Coastal Plain, the "adjacent landscape" extends out to ~2 miles from the wetland (see section 4).

1. Preserve naturally vegetated wildlife corridors between wetlands that are up to 1 mile apart.

2. Maintain a naturally vegetated cover of at least 50% within the "adjacent landscape".

ROAD CONSTRUCTION

3. Avoid the placement of roads or any other form of development between adjacent wetlands.

4. Where roads must cross between wetlands, minimize road width and construct wildlife passages to allow migration and dispersal movements by priority species.

5. Prioritize the placement of wildlife passages between wetlands with the highest habitat value.

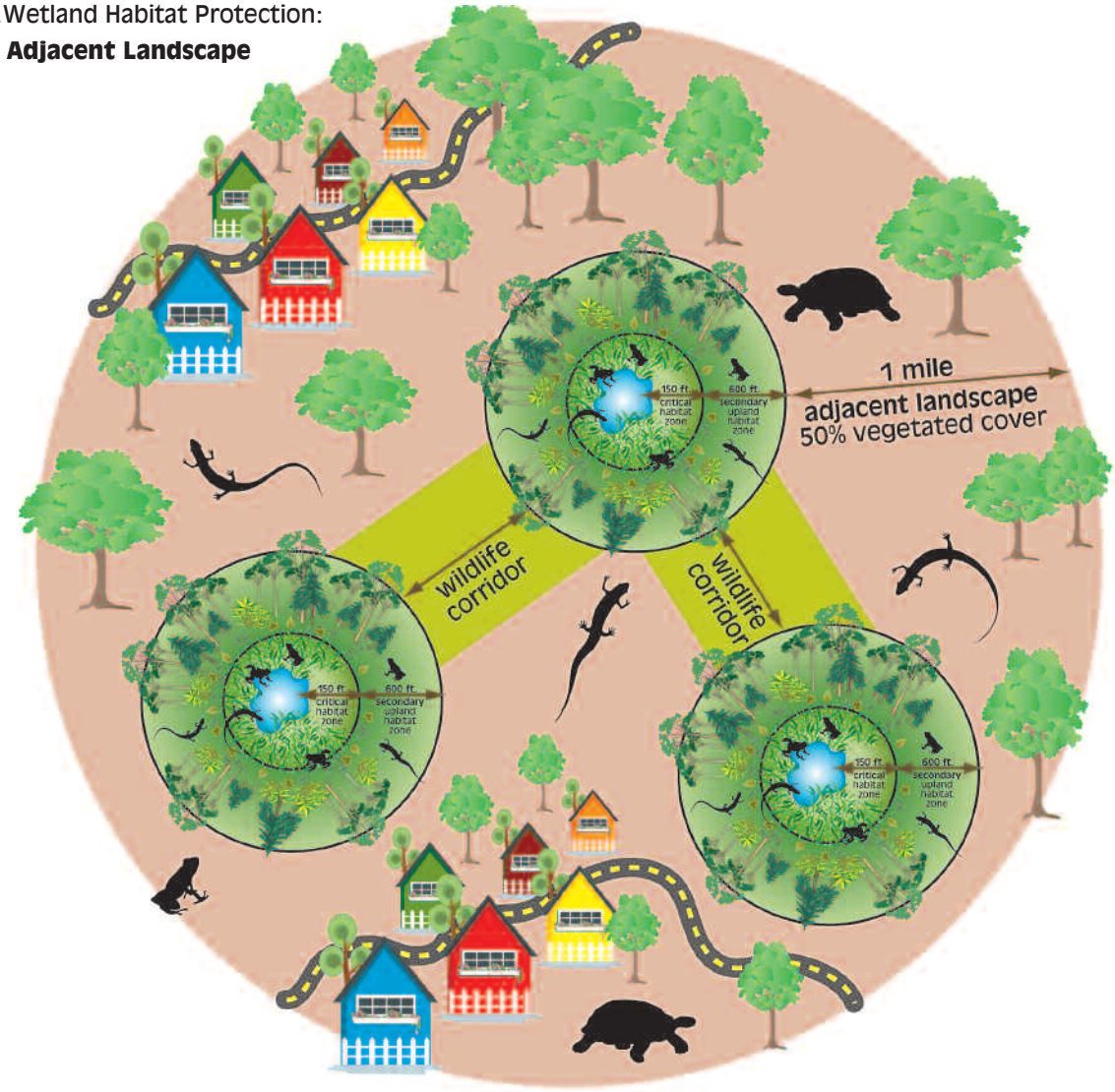
6. In key areas between wetlands, avoid constructing roads that will support traffic volumes of 2,000 or more vehicles/day. Traffic levels above 2,000 vehicles/day have been shown to inhibit amphibian and reptile movements, cause high levels of mortality, and deplete local populations.

STORMWATER MANAGEMENT

7. Minimize impacts to water quality in wetland habitats.
   - Minimize impervious surfaces in local watersheds to reduce stormwater runoff.
   - Maintain hydrological regimes on site and within the adjacent landscape at pre-construction levels.
   - Do not divert surface water from existing development into wetlands, or otherwise use wetlands as stormwater detention ponds.
   - Locate stormwater management structures outside of the recommended core terrestrial habitat and outside of any corridors that connect wetlands.

8. Avoid using traditional curb and gutter structures since they can disrupt reptile and amphibian movement.
   - Instead, use curbing with a 1:4 slope that small animals can cross, or use no-curb alternatives.

Figure 2. Wetland Habitat Protection: **Adjacent Landscape**



- Treat stormwater runoff using grassy swales with less than 1:4 sloping edges.

2.2 Ephemeral Pool Recommendations

Section 2.3 presents conservation recommendations that only apply to ephemeral pools. To conserve wildlife using ephemeral pools, apply the general recommendations in section 2.1, as well as the recommendations below, to the site.

2.2.1 Habitat Definition

Ephemeral pools are small wetland communities that dry out seasonally (typically in the summer and fall). Small wetland communities are a type of priority habitat in the NC Wildlife Action Plan (WAP) as many of these wetlands provide habitat for multiple priority species in the WAP. Ephemeral pools can be classified as either jurisdictional or non-jurisdictional wetlands.

Ephemeral pools include Floodplain Pools, Upland Pools, Upland Depression Swamp Forests, and small depression ponds. Ephemeral pools are located in all regions of North Carolina. Some priority species that will benefit from the protection of ephemeral pools include Spotted Salamander, Eastern Tiger Salamander, Mole Salamander, Ornate Chorus Frog, and Carolina Gopher Frog.

2.2.2 Planning & Development Recommendations

1. Preserve clusters of ephemeral pools where they exist.

2. When creating wetlands for mitigation, create clusters of ephemeral pools rather than isolated ones.

2.2.3 Management Recommendations

To enhance the upland habitat surrounding ephemeral pools:

1. Avoid an abrupt transition in vegetative structure from core terrestrial habitat to adjacent land. Maintain some natural vegetation in transition zone.

2. Reforest post-agricultural lands within 750 feet of ephemeral pools.

3. Allow piles of coarse woody debris and standing dead trees to decompose naturally on the ground in the adjacent uplands, and import or create cover objects (logs or stumps) for wildlife.

4. Remove invasive exotic plants.

5. Restore the natural hydroperiod of ephemeral pools. This could include filling old ditches if necessary.

6. Where opportunities exist, create ephemeral pools in the surrounding landscape.

2.3 Bog Habitats

Section 2.3 presents conservation recommendations that only apply to bog habitats. To conserve wildlife using bog habitats, apply the general recommendations in section 2.1, as well as the recommendations below, to the site.

2.3.1 Bog Habitat Definition

This habitat is a general classification for wetlands found in the mountains and western piedmont that are suitable habitat for Bog Turtles. Bog habitats are typically defined as wetlands that are sunny, soggy, and fed by groundwater and springs.

Bog habitats include the following natural community types[3]: Southern Appalachian Bog, Southern Appalachian Fen, Hillside Seepage Bog, and Swamp Forest-Bog Complex. However, the recommendations below are primarily focused on protection and management strategies for meadow bogs, wet meadows, and wet pastures. Species that will benefit from these recommendations include the Bog Turtle, Alder Flycatcher, Meadow Jumping Mouse, Southern Bog Lemming, and Four-toed Salamander.

2.3.2 Planning & Development Recommendations

1. Conduct site assessments of bog habitats.
   - Where bogs are present, contact a bog expert prior to development to identify whether the site could be Bog Turtle habitat. For bog expertise, contact Project Bog Turtle at www.projectbogturtle.org, Dennis Hermann at southernbogturtles@nc.rr.com, or NCWRC at 919-707-0050.
   - Ensure that any bog habitat assessment accurately defines the size of the bog, and maps any ditches, drains, buried tiles or pipes, stream channels, trees and shrubs, and rare plant and animal occurrences.

2. Prioritize protection of bog habitats in any conservation-based land acquisition program.
   - Prioritize the protection of large bogs, and of clusters of Bog Turtle habitats and streams that connect them.
   - Protect all satellite wetlands (seeps, wet ditches, springs, and any wetland patches) within 1–2 miles from a known Bog Turtle site.
   - Bog habitats should not be used for active recreational areas or site amenities, including stormwater ponds or other impoundments.

2.3.3 Management Recommendations

Some degraded bog habitats, specifically meadow bogs or wet pastures, need active management. To ensure proper management in these types of bogs, develop a management plan for all bogs that includes plans to manage woody vegetation and hydrology.

3 Schafale, M.P. & Weakley A.S. (1990). *Classification of the Natural Communities of North Carolina, Third Approximation*. North Carolina Natural Heritage Program. Available online: http://www.ncnhp.org/Images/Other%20Publications/class.pdf

MANAGEMENT OF WOODY VEGETATION

In some cases, bogs will provide better habitat with active management. Bog habitat management should be approached on a case-by-case basis, but often bogs that become overgrown with woody vegetation will provide less favorable habitat for wildlife. Best practices for managing excessive vegetation include:

1. Mechanical and chemical treatments
   - Kill trees by cutting, limited girdling, and/or with a wetland-approved herbicide.
   - Targeted removal of unwanted plants is preferred to broadcast foliar applications.
   - Mowing can be used to control shrubs, but should be done in the winter (if the soils are firm and no ruts will be created). Where haying is an objective, mow at high blade settings no more than once per year.
   - Create a mosaic of 25% forested habitat and 75% open habitat within the bog to preserve hibernacula (places where Bog Turtles hibernate during winter months).

2. Controlled grazing
   - Follow a prescribed grazing plan that has been recommended by a bog turtle expert.
   - To use controlled grazing as a management tool, periodically bring in cattle, goats, sheep, or horses to keep waterways open and minimize encroachment of woody and non-native vegetation.
   - Controlled grazing should not be used in bogs that contain rare plants. Contact the NC Natural Heritage Program (http://www.ncnhp.org/Pages/contactpage.htm) to determine if a bog contains rare plants.

3. Prescribed fire
   - Prescribed fire, when employed as part of a long-term fire management plan, can be used to control woody vegetation.
   - Do not plow firebreaks in bogs and wet meadows.

4. Exotic and invasive species control
   - Do not plant invasive species and promote the planting of native species near bogs.
   - When possible, remove invasive plants by employing digging, pulling, pruning, and USDA approved insects as part of an integrated pest management effort.

BOG HYDROLOGY

5. Address bog hydrology in the management plan.
   - Avoid habitat alteration through filling, draining, damming/inundating, and excessive groundwater withdrawal (except to restore natural hydrology).
   - Use dead/seasoned woody debris to construct small dams along water channels within the site to allow water to be diverted and retained, but contact a trained hydrologist for help with any flow alteration strategies.
   - Avoid flooding hummocks and other areas where hatchlings or eggs could be disturbed.

6. Restore bog turtle habitat where appropriate conditions exist by plugging or filling old ditches and draining larger man-made ponds.

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CERULEAN WARBLER

RIPARIAN HABITAT

SECTION 3. RIPARIAN AND FLOODPLAIN HABITATS

3.1 Habitat Definition

Riparian and floodplain habitats are terrestrial (upland) habitats that abut streams and rivers of all sizes. Multiple terrestrial species that have been identified as priorities in the North Carolina Wildlife Action Plan, such as the Three-Lined Salamander, Cerulean Warbler, Common Ribbonsnake, and Rafinesque's Big-eared Bat, depend upon riparian and floodplain forests.

This section presents recommendations on how much habitat is needed to benefit terrestrial species (birds, reptiles, amphibians, and mammals) that use the upland areas around streams and rivers. For recommendations related to conservation of aquatic species (fish and mussels) that do not use upland habitats, please see the NCWRC's "Guidance Memorandum to Minimize Secondary and Cumulative Impacts" (http://www.ncwildlife.org/Wildlife_Species_Con/documents/pg7c3_impacts.pdf).

3.2 Planning & Development Recommendations

Section 3.2 outlines recommendations for conserving riparian and floodplain habitats at two different scales: 1) the core terrestrial habitat scale and 2) the watershed scale.

3.2.1 Core Terrestrial Habitat

The core terrestrial habitat consists of the stream or river itself as well as a protected upland riparian zone on each side of the waterway.

RIPARIAN (STREAM) BUFFERS ●

1. To benefit priority species of terrestrial wildlife, a buffer width of 300–600+ feet is needed on each side of perennial streams. Buffer widths should be tailored to local conditions where sufficient information exists.
   - ▶ To benefit most priority terrestrial species, a 600+ foot buffer with native vegetation is needed on each side of all perennial streams.
   - ▶ If conserving 600 foot buffers is not possible, conserve a minimum 300 foot native vegetated buffer on each side of streams to provide habitat for amphibians and some bird species.
   - ▶ Where steep slopes exist within riparian buffer zones, increase buffer widths 2 feet for every 1% increase in slope, and do not count areas with slopes over 25% toward the buffer width.
2. Measure riparian buffer widths from the top of the stream bank.
3. Identify riparian habitats that have the highest value for wildlife, and focus the most stringent protections on those areas.
   - ▶ Areas with higher value can be identified by referencing GIS data (see http://www.ncwildlife.org/greengrowth/) or through field delineations.
4. To benefit neotropical migratory birds, prioritize protection of riparian areas with the widest bottomland hardwood forests.

5. Buffer intermittent and ephemeral streams according to the recommendations found in the NCWRC's Guidance Memorandum, located at the following web address: http://www.ncwildlife.org/Wildlife_Species_Con/documents/pg7c3_impacts.pdf

6. Where floodplains are wider than the recommended buffer, extend the protected buffer to the edge of the 100 year floodplain.

7. Restore degraded portions of riparian buffers by planting native species or facilitating natural regeneration of native plants.

8. Where roads must cross streams, consult a biologist for assistance in determining appropriate location and design specifications to accommodate wildlife.

RIPARIAN HABITAT MANAGEMENT ●

9. Keep the following land disturbing activities out of the riparian buffer:
   - Impervious surfaces
   - Timber harvesting and logging roads
   - Mining
   - Septic tank drain fields
   - Waste disposal sites
   - Application of pesticides and fertilizer (except as necessary for buffer restoration)
   - Sewer lines, utility lines
   - Lawn establishment

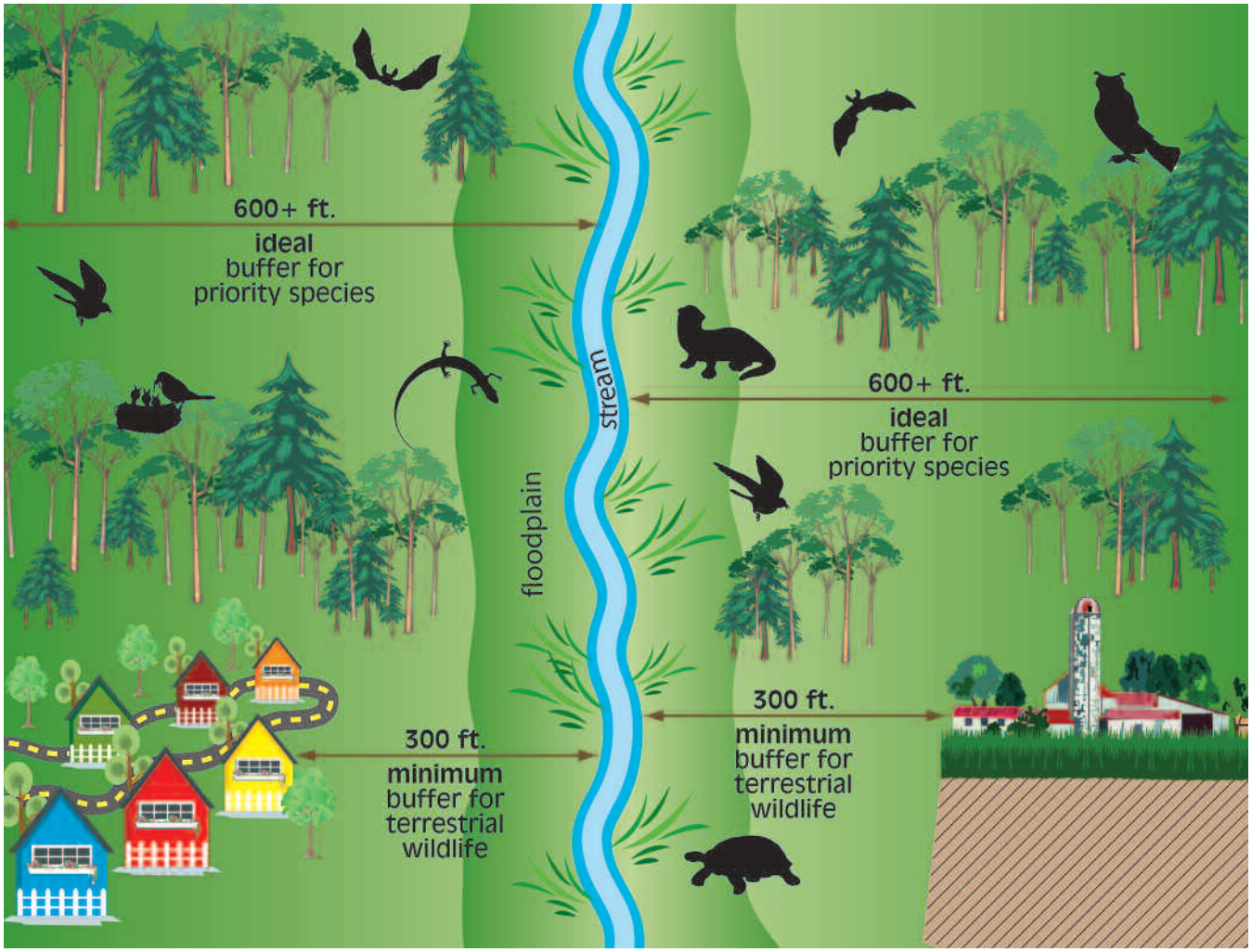
10. Minimize negative impacts of recreation trails within the riparian buffer.
    - If greenways or trails will be placed within the buffer, keep the tree canopy intact by minimizing trail width and building trails on the upland edge of the buffer.
    - Minimize run-off and erosion from trail construction and trail use.

11. Remove exotic, invasive plants in buffer areas, where practical.

3.2.2 Watershed Recommendations

1. Limit impervious surfaces to less than 10% of the watershed, or incorporate stormwater management practices into development projects to maintain pre-development hydrological conditions in the watershed.

Figure 3. Riparian & Floodplain **Habitat Protection**



2. Minimize stream crossings with roads.

3. Use bridges instead of culverts for stream crossings.
   - Where bridges cross streams, maximize the span of the bridge to allow passage of terrestrial animals on either side of the river.
   - Multi-cell culverts, bottomless culverts, or other culverts designed for wildlife movement, should be used when bridges are not possible.

4. Incorporate measures listed in the NCWRC's Guidance Memorandum to Address and Mitigate Secondary and Cumulative Impacts (http://www.ncwildlife.org/Wildlife_Species_Con/documents/pg7c3_impacts.pdf) into all development projects within your community.

3.3 Selected References

Bailey, M. A., J. N. Holmes, K. A. Buhlmann, and J. C. Mitchell. 2006. Habitat management guidelines for amphibians and reptiles of the southeastern United States. Partners in Amphibian and Reptile Conservation, Montgomery, AL.

Crawford, J. A., and R. D. Semlitsch. 2007. Estimation of core terrestrial habitat for stream-breeding salamanders and delineation of riparian buffers for protection of biodiversity. Conservation Biology 21:152-158.

Semlitsch, R. D., and J. R. Bodie. 2003. Biological criteria for buffer zones around wetlands and riparian habitats for amphibians and reptiles. Conservation Biology 17:1219-1228.

GOPHER FROG

LONGLEAF PINE HABITAT

SECTION 4: LONGLEAF PINE HABITAT

4.1 Habitat definition

These recommendations apply to Dry Longleaf Pine Forest, Wet Longleaf Pine Forest, Mesic Pine Flatwoods, Pine/Scrub Oak Sandhill, Xeric Sandhill Scrub, and Coastal Fringe Sandhill habitats described in Schafale & Weakley[4].

NC Wildlife Action Plan species that will benefit from these recommendations include Carolina Gopher Frog, Eastern Tiger Salamander, Mimic Glass Lizard, Bachman's Sparrow, Red-cockaded Woodpecker, Eastern Fox Squirrel, and Barking Treefrog.

4.2 Planning and Development Recommendations

1. Protect large tracts of Longleaf Pine forest.
   - Longleaf forest patches that are at least 2,000 acres are needed to maintain viable populations of many species associated with Longleaf Pine habitats.
   - Protecting high quality habitat patches that are smaller can benefit some priority species, especially if patches are located in close proximity to each other.

2. Position development, including roads, in ways that minimize negative impacts on the connectivity between ephemeral pools in Longleaf Pine forests. Local populations of species such as the gopher frog depend upon clusters of ephemeral pools in Longleaf Pine habitats.
   - In key areas between pools, avoid constructing roads that will support traffic volumes of 2,000 or more vehicles/day. Roads that approach or exceed 2,000 cars/day are barriers to amphibian and reptile movements and can deplete local amphibian populations, especially if they are within ~2 miles of wetlands.
   - Follow our recommendations about developing the "adjacent landscape" around wetlands (see section 2.1.4 in this document).

3. Incorporate information on the locations of and distances to Red-cockaded Woodpecker territories when selecting areas of Longleaf Pine forest to set aside for protection or restoration.
   - Consult the U.S. Fish and Wildlife Service Red-cockaded Woodpecker recovery plan for regulations and recommendations regarding woodpecker habitat, or contact the USFWS or NCWRC for assistance.

4. Prescribed fire is a tool natural resource managers use to properly manage Longleaf Pine forests. During the development process, acknowledge the potential for conflicts with smoke from prescribed fire.
   - Consider the potential for smoke when planning developments and high-traffic roads near Longleaf Pine forests.

4 Schafale, M.P. & Weakley A.S. (1990). *Classification of the Natural Communities of North Carolina, Third Approximation*. North Carolina Natural Heritage Program. Available online: http://www.ncnhp.org/Images/Other%20Publications/class.pdf

- Maintain at least ½ mi of undeveloped land between developments or high-traffic roads and Longleaf Pine habitats to minimize potential smoke nuisance for homeowners and drivers.
- Encourage developers to place smoke easements on properties, or to use disclosure statements to notify potential homebuyers of the potential for smoke in housing developments adjacent to Longleaf Pine habitats.

4.3 Management Recommendations

1. Actively manage longleaf pine forests
   - Promote large diameter longleaf pine trees, canopy openings, sparse mid stories, and a diverse, herbaceous ground cover composed of native plants.
   - Manage for longleaf pine forest regeneration through restoration of the natural fire regime, which includes managing the prescribed fire frequency, the seasonality or time of year prescribed fire is applied, and the intensity of prescribed fires.
   - If application of prescribed fire is not possible, remove hardwoods and promote understory plant diversity with habitat management techniques that minimize soil disturbance.
   - Harvest timber or mow during dry periods rather than during wet ones to protect soil structure.
2. Leave stumps, logs, dead standing snags, and other coarse woody debris following timber harvests and do not fill stump holes.
3. Avoid activities such as pine straw raking that negatively impact the herbaceous layer.
4. Avoid clear-cutting longleaf pine stands.

4.3 Selected References

Sutherland, R. W. 2009. The effects of urbanization on reptiles and amphibians in the sandhills region of North Carolina. Dissertation. Duke University, Durham, NC.

U.S. Fish and Wildlife Service. 2003. Recovery plan for the red-cockaded woodpecker (Picoides borealis): second revision. U.S. Fish and Wildlife Service, Atlanta, GA.

Woodward, D. K., and P. D. Doerr. 2007. Status and ecology of the Northern Pine Snake and Southern Hognose Snake in the sandhills region of North Carolina. US Fish and Wildlife Service.

YELLOW-BILLED CUCKOO

UPLAND FOREST HABITAT

SECTION 5. UPLAND FOREST HABITAT

5.1 Habitat Definition

A variety of upland forest types occur in North Carolina. These recommendations address upland hardwood and mixed pine–hardwood forest types, including all mesic, dry, and dry-mesic forest types described in Schafale & Weakley[5].

The recommendations below will benefit forest interior species, including those that are "area sensitive." Many priority species in the NC Wildlife Action Plan that are associated with forests are "area sensitive" species. Area sensitive species are animals that are highly sensitive to the conversion of large areas of habitat into smaller patches.

Priority species that will benefit from these recommendations include: Cerulean Warbler, Worm-eating Warbler, Black-throated Green Warbler, Yellow-billed Cuckoo, Eastern Fox Squirrel, and Indiana Bat.

5.2 Planning and Development Recommendations

1. Conserve 50% of your community's land as high-quality, undeveloped natural forest. High quality forests are characterized by high native plant diversity and large trees interspersed with standing snags and other woody debris.

2. If conserving 50% of your community's land as natural, undeveloped forest is unrealistic, conserve forest patches large enough to benefit area sensitive species.
   - ▶ In communities where less than 30% of the jurisdiction will be protected as forested land, targeting larger patch sizes for permanent protection is particularly important.
   - ▶ To maximize chances of protecting the full range of priority species that use upland forests in your community, target protection of contiguous forested blocks that are more than 7,500 acres in size.
   - ▶ If such a target is impractical, setting protection goals based on the following size recommendations will protect some of the area sensitive species in your community:
     - In the Mountains, target conservation of 1,750 acre forest blocks where Cerulean Warblers are known to occur and 500 acre blocks elsewhere.
     - In the Piedmont and Coastal Plain, conserve 75 acre upland forest blocks. However, we encourage the protection of 500 acre upland forest blocks if they are connected to bottomland forests or where Black-throated Green Warblers are present in the Uwharrie Mountains.
   - ▶ In all regions of the state, conserve and maintain 50% of forested land within 1.5 miles of protected forest blocks to increase the desirability of patches to area sensitive species.

3. Protect the highest quality forest tracts in your community.
   - ▶ Forest tracts that are known to support species with high or moderate area-sensitivity (such as those identified in section 5.1) should receive the greatest protection.
   - ▶ To determine which tracts are currently known to have the highest quality, either contract with a qualified biologist to conduct field surveys or use existing GIS data (www.ncwildlife.org/greengrowth/Conservation_Data.htm) to identify potential tracts.

4. Protect small woodlots and canopy cover in residential areas.
   - ▶ Although many forest bird species are restricted to large woodlots for nesting, even small (3–5 acre) woodlots may be tremendously important as migratory stopover sites for forest interior birds, especially in regions where

5 Schafale, M.P. & Weakley A.S. (1990). *Classification of the Natural Communities of North Carolina, Third Approximation.* North Carolina Natural Heritage Program. Available online: http://www.ncnhp.org/Images/Other%20Publications/class.pdf

forest habitat is particularly scarce. Maintaining a native tree canopy in developed areas will benefit some forest birds.

5. Minimize "edge effects" to protected forest lands.
   - Priority species will be impacted by "edge effects". Edge effects extend ~350 feet from a forest's edge into the interior. Protect forest blocks that are large enough to minimize this edge habitat.
   - Establish "soft edges," or edges with curvilinear boundaries and a gradual thinning of vegetation (e.g. smaller shrubs grading into larger bushes and taller trees) at the edge of a forest.
   - Attempt to concentrate buildings, roads, campgrounds, and other development along the edges of protected forestlands and not within the interior of forest blocks.

6. Protect known roosting sites for bats.
   - Avoid disturbances that could alter the temperature or moisture at known roosts.
   - Place trails and other sources of human recreation as far away as possible from known roosting sites.

7. Connect protected areas with wildlife corridors.
   - The optimal width of a wildlife corridor depends on the types of habitat the corridor will connect and the species that will use the corridor. Consult with a NCWRC biologist for specific information on wildlife corridor design.
   - If retention of a contiguous corridor is not possible, attempt to protect small patches between larger protected forests.

8. Design and manage greenways to benefit forest area sensitive species.
   - To benefit the full range of forest interior species, create greenways that are at least 1000 feet wide.
   - If protecting greenways this wide is not possible, creating greenways that are a minimum of 330 feet wide will provide breeding habitat for some area sensitive species.
   - Greenways that are less than 150 feet wide can provide dispersal habitat for many wildlife species and stopover habitat for migrating birds, but are unlikely to be used as breeding habitat by most priority species.

5.3 Management Recommendations

When managing community land as forested habitat, we recommend adopting the following practices:

1. Maintain a well developed understory of native plants. Many species of forest birds require the food, nest sites, and cover provided by the forest understory.

2. Retain snags and brush piles. If there is a safety concern with a snag, do not cut the tree to its base, but cut to a height consistent with safety.

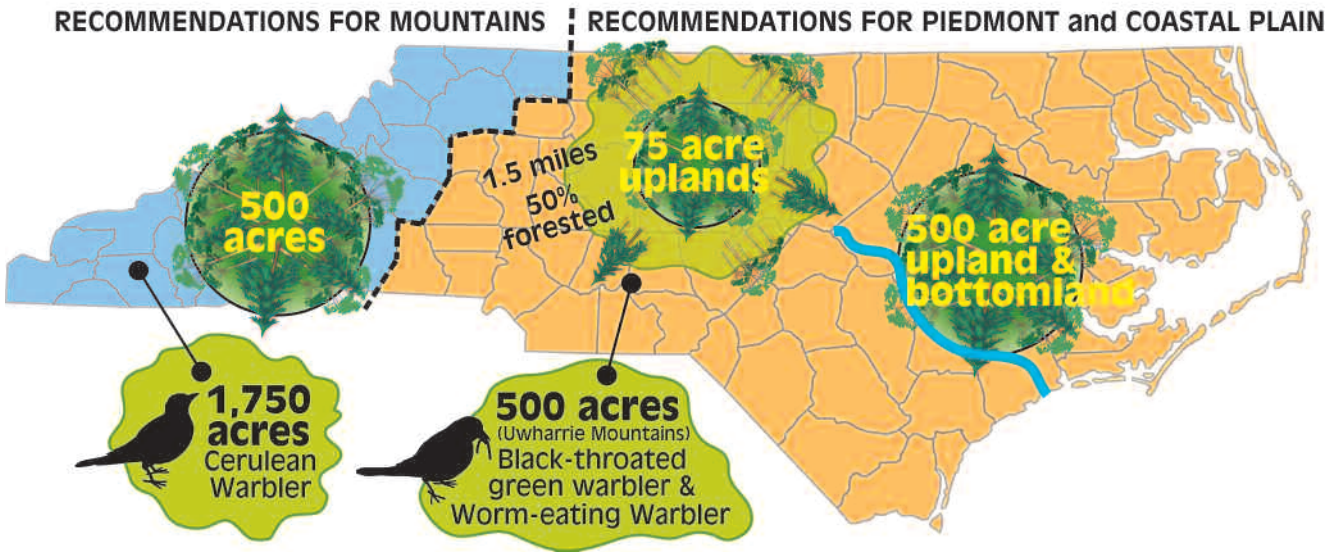
3. Maintain large trees and provide a continuous supply of potential roost trees for bats.
   - Manage forests so that groups of 6 or more large, dead trees that are within ½ mile of each other are always available, and maintain a forested buffer around these trees.

4. Promote a varied and diverse vegetative structure that is consistent with the native forest type, including small-scale tree cutting to create small canopy gaps. Remove invasive, exotic vegetation when practical.

5. If timber is to be harvested from a forest tract, selective thinning and small patch cuts are recommended. Avoid harvesting hardwoods unless hardwood removal will benefit wildlife.

6. Promote reforestation of gaps between disconnected forest tracts, either through natural succession or through planting of native trees.

Figure 4. Conserving Upland Forest Habitat for **Priority Species**



7. Where forested habitats will be used for nature-based recreation activities, encourage public use within the forest edges rather than extending activities into the forest core.

8. If deer populations are over-browsing the forest understory, consider implementing a management strategy such as exclosures or a managed deer harvest.

9. In appropriate situations, managers should consider incorporating prescribed fire into upland hardwood forest management. Controlled burning efforts should aim to restore the natural frequency, seasonality, and intensity of historical fire regimes.

5.4 Selected References

Barclay, R. M. R., and A. Kurta. 2007. Ecology and behavior of bats roosting in tree cavities and under bark. Pages 17-60 in M. J. Lacki, J. P. Hayes, and A. Kurta, editors. Bats in forests: conservation and management. The Johns Hopkins University Press, Baltimore, MD.

Betts, M. G., G. J. Forbes, and A. W. Diamond. 2007. Thresholds in songbird occurrence in relation to landscape structure. Conservation Biology 21:1046-1058.

Herkert, J. R., R. E. Szafoni, V. M. Kleen, and J. E. Schwegman. 1993. Habitat establishment, enhancement and management for forest and grassland birds in Illinois. Division of Natural Heritage, Department of Conservation. Natural Heritage Technical Publication #1.

Kalcounis-Ruppell, M. C., J. M. Psyllakis, and M. R. Brigham. 2005. Tree roost selection by bats: an empirical synthesis using meta-analysis. Wildlife Society Bulletin 33:1123-1132.

Mason, J., C. Moorman, G. Hess, and K. Sinclair. 2007. Designing suburban greenways to provide habitat for forest-breeding birds. Landscape and Urban Planning (80) 153-164.

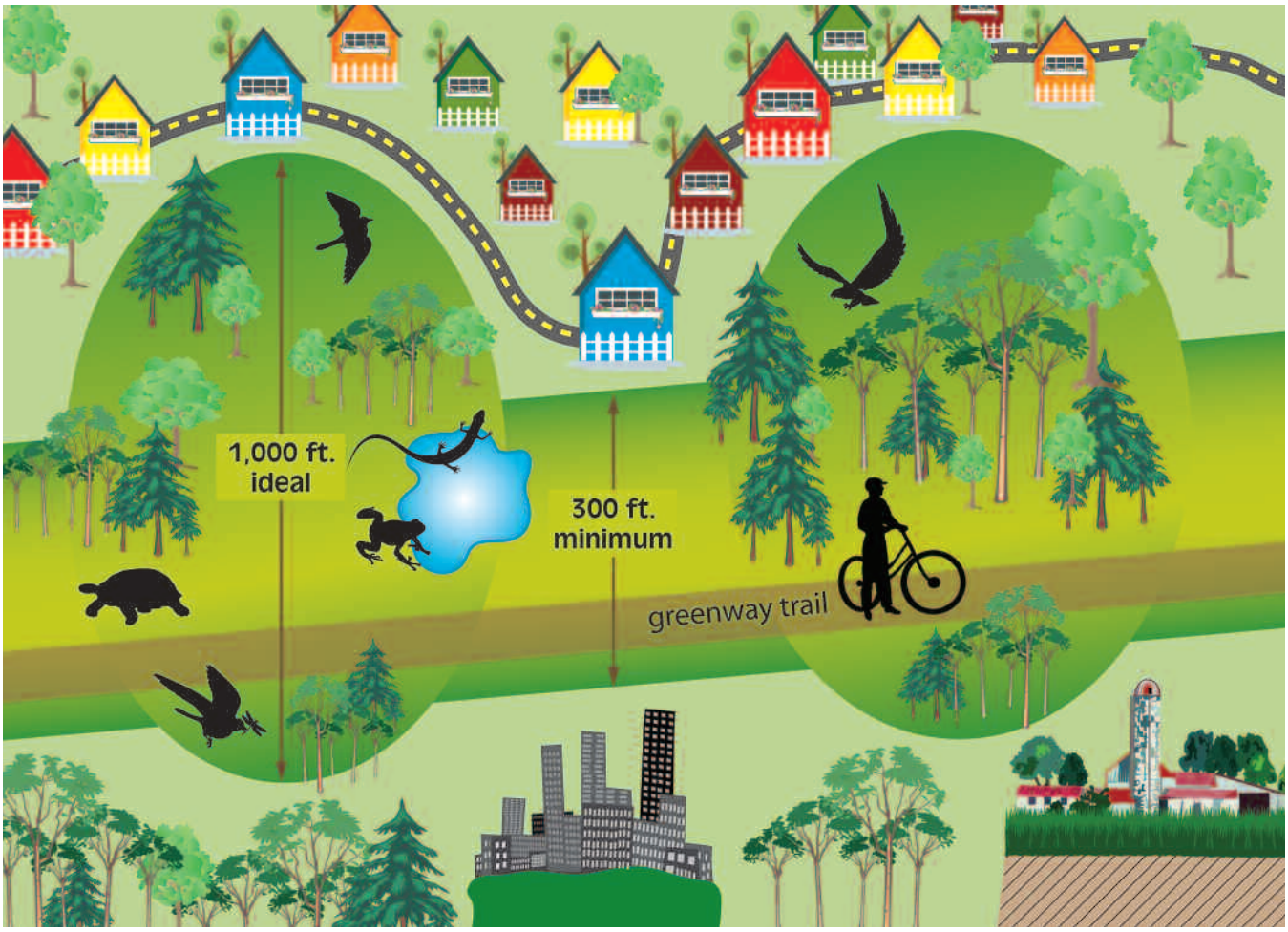
Robbins, C. S., D. K. Dawson, and B. A. Dowell. 1989. Habitat area requirements of breeding forest birds of the middle Atlantic states. Wildlife Monographs 103:3-34.

Rosenberg, K. V., R.W. Rohrbaugh, Jr., S.E. Barke, J. D. Lowe, R. S. Hames, and A.A. Dhondt. 1999. A land manager's guide to improving habitat for scarlet tanagers and other forest-interior birds. The Cornell Lab of Ornithology.

Taylor, D. A. R. 2006. Forest management and bats. Bat Conservation International Inc.

Vance, M. D., L. Fahrig, and C. H. Flather. 2003. Effect of reproductive rate on minimum habitat requirements of forest-breeding birds. Ecology 84:2643-2653.

Figure 5. Designing Greenways for **Priority Species**



BOBWHITE QUAIL

EARLY SUCCESSIONAL HABITAT

SECTION 6. EARLY SUCCESSIONAL HABITAT

6.1 Habitat Definition

Early successional habitat is habitat where most trees have been removed either through natural means or by human activity. This habitat type requires frequent disturbance that suppresses tree growth to prevent the land from returning to forest. Common types of early successional habitat include hayfields, clear-cuts and regenerating forests, shrublands, grasslands, field borders, pastures, and large canopy gaps. Early successional habitats can be composed of mixed grasses, wildflowers, vines, shrubs, and saplings. Scattered mature trees may be present but not to the point that they shade out the beneficial understory vegetation. Several priority species, such as the Northern Bobwhite Quail, Prairie Warbler, and Golden-Winged Warbler, depend on early successional habitat for nesting, foraging, and other life functions.

All early successional habitats require some form of periodic disturbance to maintain and enhance habitat quality. Without proper management, trees will become established and shade out grasses and forbs, making the habitat unsuitable for many priority species. Management techniques to control woody vegetation are typically applied on a 2–3 year rotation and include mechanical control (e.g., disking, mowing, or hand-cutting of trees), herbicides, grazing, and prescribed fire.

The recommendations below refer primarily to actions planners and developers can take to maintain suitable areas of potential early successional habitat. To realize the wildlife benefits of this habitat, additional recommendations on proper management of early successional habitats would need to be followed. The recommendations in section 6.2 apply to all types of early successional habitat. Recommendations that only apply to grassland habitat can be found in section 6.4.

6.2 Planning and Development Recommendations

These recommendations apply to all types of early successional habitat (grassland, shrubland, and other early successional habitat types).

1. Develop farmland protection plans for your community and integrate recommendations for managing early successional habitat for the benefit of wildlife into farmland protection plans.

2. Adopt policies that maintain viable working lands (agriculture and forestry) in contiguous areas within your community.

3. Manage utility corridors and other areas that require frequent vegetation control to benefit early successional species of wildlife.
   - ▶ Re-vegetate utility rights-of-way into grassland or shrubland habitat using native species.

- Establish rotational maintenance and vegetation control schedules. Manage only portions of corridors each year, and manage each portion on a 2–3 year rotational basis. Prescribed fire can produce better habitat than mowing or selective application of herbicides.
- Prohibit mowing between April 1 and October 1 to minimize impacts to ground nesting birds.

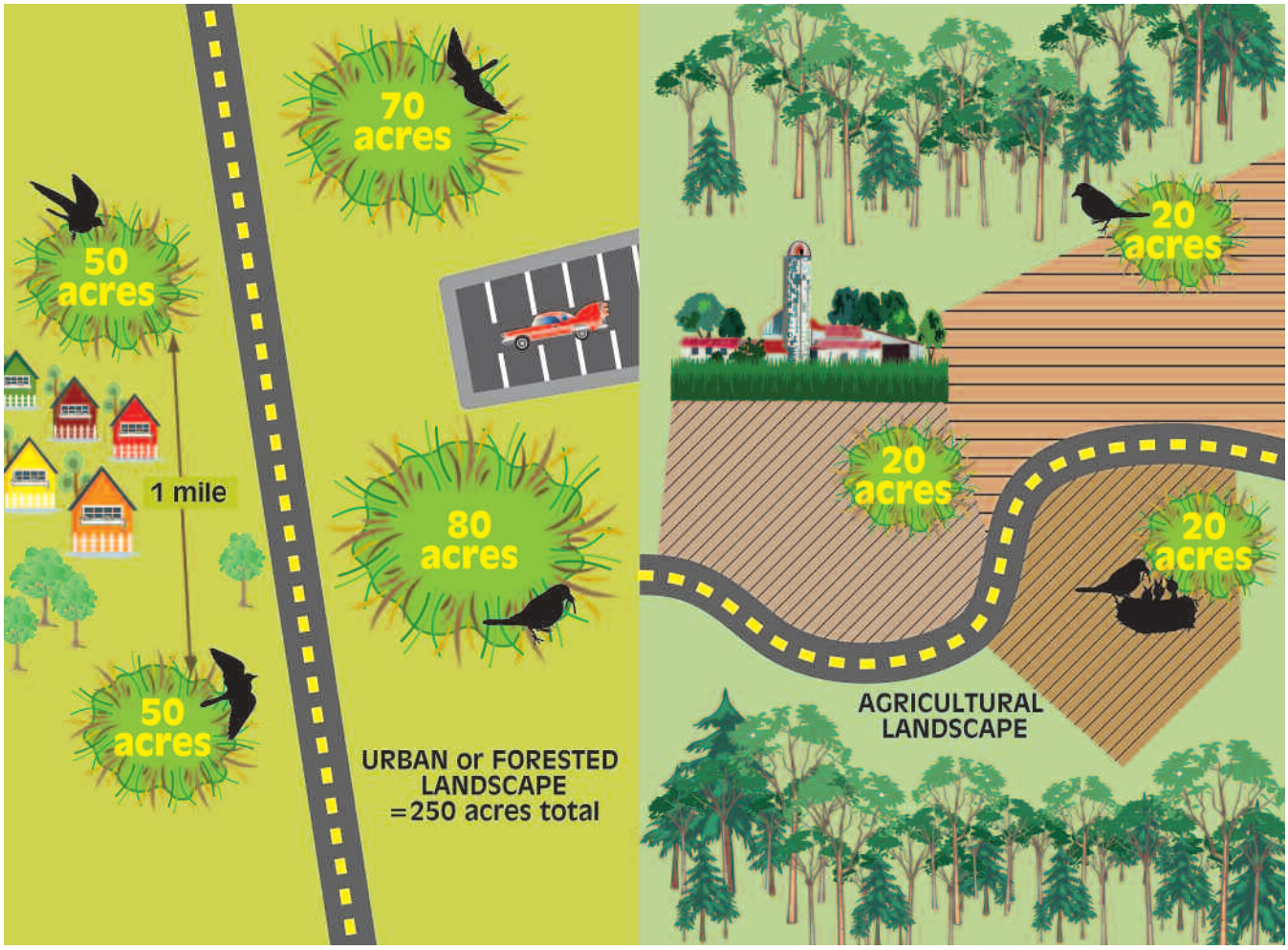
4. Utilize and promote the many state and federal programs which provide monetary and technical assistance for landowners to create and maintain early successional habitats.
   - More information is available by contacting a NC Wildlife Resources Commission Private Lands biologist (obtain contact info for your local biologist at 919-707-0050) or at your local Natural Resources Conservation Service office.
5. Discourage high-density development and other incompatible land uses within 1/2 mile of natural areas that are managed with prescribed fire.
6. If your community has the resources to conduct active resource management over the long term, prioritize the protection of some early successional habitat when purchasing land for parks or open space.
7. When early successional habitat is protected within community parks, consult with a qualified biologist to develop a management plan for long term management of this habitat.
8. When early successional habitat is to be protected as open space in a development project, require applicants to submit 1) a long term management plan, and 2) plans to fund long term management.

6.3 Management Recommendations

When managing land as early successional habitat:

- Manage through prescribed fire, selective herbicide application, or mowing whenever possible. Disking provides a beneficial vegetation response but can be harmful to priority species of reptiles and amphibians.
- Consult with a qualified biologist to develop a management plan for early successional habitat. An NC Wildlife Resources Commission private lands biologist may be able to provide assistance in writing a management plan.
- Consult the following publications for guidance:
  - Mecklenburg County Natural Resources Department (2005). Management of Early Successional Habitats.

Figure 6. Protecting Grassland Habitat for **Priority Species**



Contact Mecklenburg County Conservation Science Office at (704) 432-1391 for a copy of this report.

- Guide to Management of Habitats for Grassland Birds, located at: http://www.npwrc.usgs.gov/resource/birds/wiscbird/index.htm
- Golden-Winged Warbler Conservation Initiative Breeding Habitat Guidelines, located at: http://www.gwwa.org/resources/GWWA%20Habitat%20Brochure_Final.pdf

6.4 Grassland Habitat

6.4.1 Habitat Definition

Grasslands are one type of early successional habitat with a predominance of native grasses and forbs[6]. Examples of this habitat type include recently abandoned farm fields, pastures with native grasses, savannas, prairies, meadows, and mountain balds. While areas such as ball fields, golf courses, intensively managed horse farms, and mowed lawns are dominated by grasses, they do not provide quality grassland habitat for priority species.

6.4.2 Planning and Development Recommendations for Grassland Habitats

The recommendations below will benefit grassland "area sensitive" species. Area sensitive species are animals that are highly sensitive to the conversion of large areas of habitat into collections of smaller patches of habitat. These animals need larger patches of grassland to persist or breed successfully.

North Carolina Wildlife Action Plan species that will benefit from these recommendations include the Henslow's Sparrow, Eastern Meadowlark, Grasshopper Sparrow, Loggerhead Shrike, Mimic Glass Lizard, Star-nosed Mole, and Oak Toad.

1. Protect and actively manage existing patches of grasslands.

2. In urbanizing areas, protect grassland complexes that total 125–250 acres.

   ▶ While grassland complexes that total 125 acres in size will benefit many species, those that are more than 250 acres should benefit all area-sensitive grassland species of concern.

   ▶ If protecting grassland complexes this large is not possible, establish several smaller scattered grasslands. In this design, individual patches should be at least 15–20 acres in size and located within a mile of each other.

3. In rural areas with extensive farmland, protect 20-acre grassland patches across the landscape.

4. Where possible, protect grassland patches that are more circular in shape (i.e. not long and thin). Avoid establishing grasslands with very irregular borders and lots of edge.

5. Restrict recreational activities to the edges of grasslands.

6. Where possible, mowing entire grasslands should be limited to once every 2–3 years. Mowing 1/3 of a protected grassland each year will provide consistent wildlife cover, enhanced habitat diversity, and food production.

   ▶ Mowing should occur between mid-March and mid-April to ensure winter cover and to avoid disturbing wildlife during the critical stages of nesting and rearing young.

6.5 Selected references

Herkert, J. R., R. E. Szafoni, V. M. Kleen, and J. E. Schwegman. 1993. Habitat establishment, enhancement and management for forest and grassland birds in Illinois. Division of Natural Heritage, Department of Conservation. Natural Heritage Technical Publication #1.

Herkert, J. R. 1994. The effects of habitat fragmentation on midwestern grassland bird communities. Ecological Applications 4:461-471.

Johnson, D. H., and L. D. Igl. 2001. Area requirements of grassland birds: A regional perspective. Auk 118:24-34.

Renfrew, R.B. and C. A. Ribic. 2008. Multi-scale models of grassland passerine abundance in a fragmented system in Wisconsin. Landscape Ecology 23:181-193.

Ribic, C. A., R. R. Koford, J. R. Herkert, D. H. Johnson, N. D. Niemuth, D. E. Naugle, K. K. Bakker, D. W. Sample, and R. B. Renfrew. 2009. Area sensitivity in North American grassland birds: Patterns and processes. Auk 126:233-244.

Swanson, D. A. 1996. Nesting ecology and nesting habitat requirements of Ohio's grassland-nesting birds: A literature review. Ohio Division of Wildlife.

6 Forbs are herbaceous, non-woody flowering plants that are not grasses.
7 Grassland complexes are collections of smaller parcels of grassland located in close proximity to one another.

GREEN SALAMANDER

ROCKY OUTCROP HABITAT

Section 7: Rock Outcrops, Caves, and Mines

7.1 Habitat definition

This habitat group includes many rock outcrop community types described in Schafale & Weakley[8], including Boulderfields, Rocky Summits, Granitic Domes, Acidic Cliffs, Mafic Cliffs, Granitic Flatrocks, and Talus Slopes. This habitat group also includes caves and abandoned mines.

Rock outcrops occur in the Mountain and Piedmont regions of North Carolina. These recommendations primarily apply to rock outcrops in the mountains, but may also be relevant to selected sites in the Piedmont such as Pilot Mountain and Hanging Rock.

Many wildlife species, such as Peregrine Falcon, Green Salamander, and Allegheny Woodrat utilize rock outcrop habitat without regard to elevation, whereas others, such as Rock Vole and Long-tailed Shrew, will utilize only high elevation rock outcrop habitat. Caves and mines are often used by the same species that use rock outcrops, but can also be important hibernation sites for Long-tailed and Crevice Salamanders and several bat species including Virginia Big-eared Bat, Gray Bat, Small-footed Bat, Northern Long-eared Bat, and Indiana Bat.

These recommendations outline ways to conserve rock outcrop, cave, and mine habitats alongside development at three different scales: 1) the core habitat scale, 2) the adjacent landscape scale, and 3) the greater landscape scale.

7.2 Core habitat

The core habitat consists of the rock formation, cave, or mine, and the surrounding habitat within 650 feet of the rock formation.

7.2.1 Planning and Development Recommendations

1. Survey rocky habitats for Green Salamander, Allegheny Woodrat, bats, and Timber Rattlesnake, and assign high priority to protecting outcrops where these species occur.

   ▶ If a cave or mine is on the property, contact a biologist with the NCWRC or USFWS.

8 Schafale, M.P. & Weakley A.S. (1990). *Classification of the Natural Communities of North Carolina, Third Approximation.* North Carolina Natural Heritage Program. Available online: http://www.ncnhp.org/Images/Other%20Publications/class.pdf

- NC Wildlife Resources Commission, (919) 707-0050.
- U.S. Fish and Wildlife Service, Asheville Field Office, 160 Zillicoa St., Asheville, NC 28801-1038, 704-258-3939, http://www.fws.gov/asheville/htmls/generalinfo/aboutasheville.html.

▶ Due to the threat that white nose syndrome poses to bats, do not enter or survey caves and mines without a wildlife biologist.

2. Do not alter entrances of caves and mines without consultation of an expert. Blocking entrances of caves and mines will alter the conditions inside caves and mines and may make them unsuitable habitat for bats.

3. Avoid placing new development, clearing, or otherwise modifying land, in the core habitat. Maintain core habitat in a natural state.

4. Minimize erosion and soil disturbances uphill from rock outcrops so that eroded soil does not fill crevices that are important for wildlife.

7.2.2 Management Recommendations

1. Protect vegetative communities associated with cliffs and outcrops from soil compaction and erosion.

2. Promote a diversity of native trees, shrubs, vines, forbs, and fungi.

3. Leave woody debris in place, including felled trees.

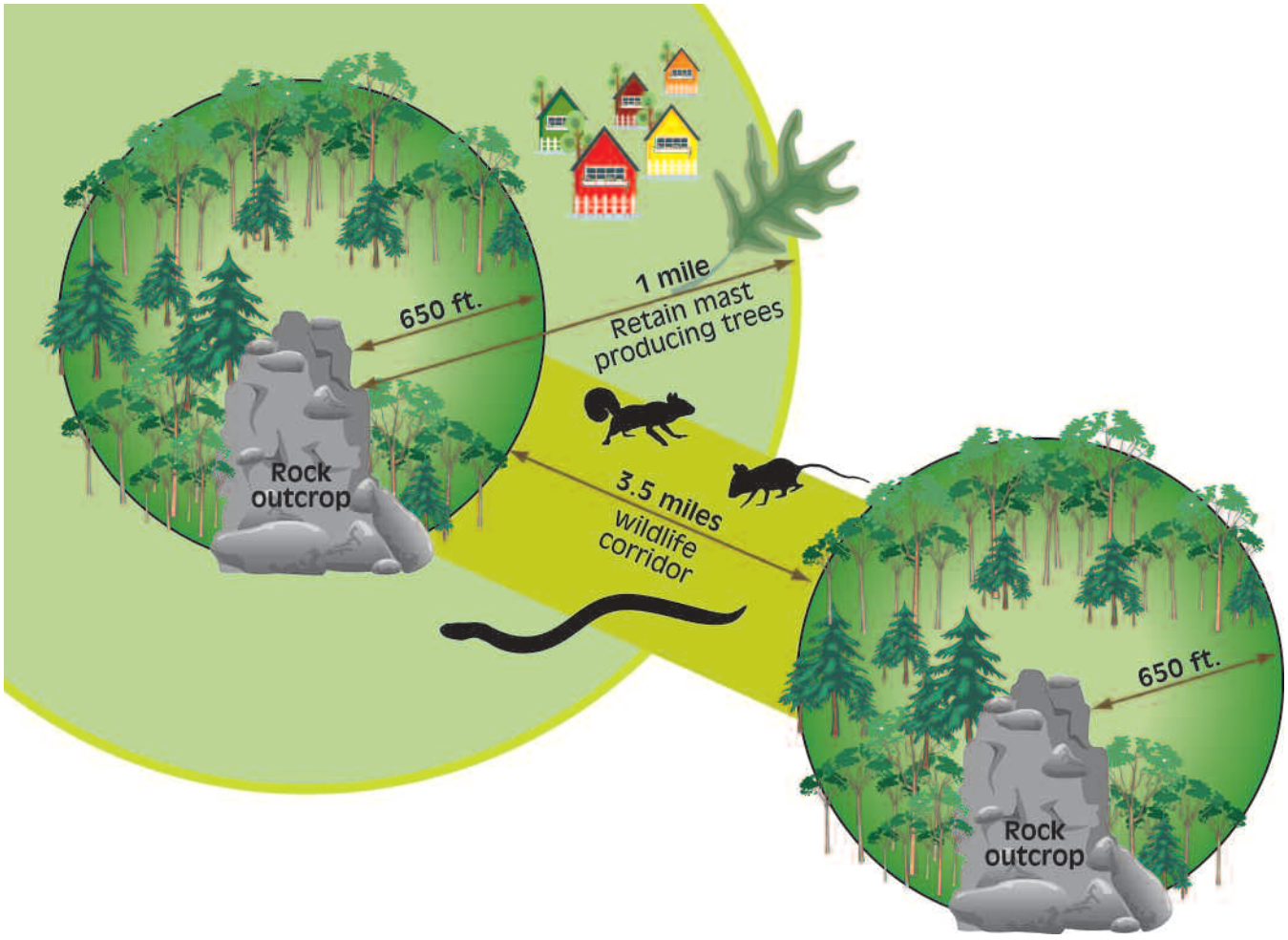
4. If logging must occur within the core habitat:
   - ▶ Avoid removing trees from the tops of cliff ridges.
   - ▶ Protect all major potential perches (dead trees and taller live trees) around Peregrine Falcon nests.

5. Manage recreational activities, such as rock climbing, in a way that minimizes impacts on rock outcrop plant communities and nesting Peregrine Falcons.

6. Given white nose syndrome concerns, restrict all human access into caves or abandoned mines that are used by bats.

7. Install gates with openings that permit the passage of bats inside the mouths of caves and abandoned mines.

Figure 7. Protecting **Rock Outcrop, Cave, and Mine Habitat**



Contact NCWRC at 919-707-0050 for assistance in figuring out if a gate is necessary and for bat-friendly gate designs.

7.3 Adjacent Landscape

The "adjacent landscape" consists of areas within 1 mile of rock outcrop, cave, or mine habitats. Its extent is based on estimates of common dispersal distances of Allegheny Woodrat and Timber Rattlesnake.

7.3.1 Planning and Development Recommendations

1. Attempt to retain mature hardwood forest with mast producing trees in at least two-thirds of the adjacent landscape.

2. If development must occur within the "adjacent landscape":
   - Avoid placing new roads and other barriers to wildlife dispersal in this zone.
   - Cluster developments to minimize the total amount of this area that is developed.
   - Place developments as far as possible from rock outcrops and caves.
   - Utilize existing roads rather than building new ones.
   - Route powerlines as far away as possible from rock outcrops and caves.

3. Avoid establishing new trails, picnic areas, or other facilities within 1/2 mi of Peregrine Falcon nesting sites.

7.3.2 Management Recommendations

1. Maximize the production of hard mast by using long forestry rotations and variable-age tree retention harvesting techniques.

2. Establish a buffer between human activity and Peregrine Falcon nesting sites during their breeding season (February-August).
   - Restrict human activity on cliff rims within 1/2 mile of Peregrine Falcon nests.
   - Restrict human access on or immediately below cliff faces within 1/4 -1/2 mile from nests.
   - Avoid forestry activity within 1/2 mile of Peregrine Falcon nests during the breeding season.

7.4 Greater Landscape

The "greater landscape" consists of areas within ~3.5 miles of rock outcrop, cave, or mine habitats. Its extent is based on estimates of maximal dispersal distances of Allegheny Woodrats and Timber Rattlesnakes.

7.4.1 Planning and Development Recommendations

1. Maintain continuous mature forest between habitats that are within ~3.5 miles of each other

2. Avoid placing major roads between habitats that are within ~3.5 miles of each other.

7.4.2 Management Recommendations

1. Reforest old timber roads to mature forest, creating as much of a closed tree canopy as possible.

2. Avoid clear-cutting and use selective cutting when possible.

7.5 Selected References

Cade, T. J., J. H. Enderson, and J. Linthicum. 1996. Guide to management of Peregrine Falcons at the eyrie. The Peregrine Fund Inc., Boise, ID.

Natural Resource Conservation Service and Bat Conservation International Inc. Bats and Mines: Evaluating abandoned mines for bats: recommendations for survey and closure. Bat Conservation International, Austin TX.

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Sherwin, R. E., J. S. Altenbach, and D. L. Waldien. 2009. Managing abandoned mines for bats. Bat Conservation International, Austin, TX.

Waldron, J. L., and J. Humphries. 2005. Arboreal habitat use by the green salamander, Aneides aeneus, in South Carolina. Journal of Herpetology 39:486-492.

Tuttle, M. D., and D. A. R. Taylor. 1998. Bats and Mines. Bat Conservation International, Inc, Austin TX.

BARN OWL

SECTION 8: WILDLIFE USING ARTIFICIAL STRUCTURES

8.1 Habitat Definition

A few species of terrestrial wildlife identified as priorities in the NC Wildlife Action Plan use artificial (or man-made) structures as habitat, including Barn Owl, Chimney Swift, and several priority bat species. These species are found increasingly within the built environment as their natural habitats decline due to urbanization, conversion of forestland to development, and changes in farming practices.

Barn owls typically use old buildings, particularly farm outbuildings close to grasslands, for roosting and nesting. Chimney swifts often nest in a variety of older buildings, monuments, and large, open chimneys near towns and cities. Bats are becoming more dependent on buildings and bridges in addition to their natural roosting places in tree holes and caves. Walls, eaves, and roofs are all potential roost sites for bats.

Barn owls, chimney swifts, and many bat species are of conservation concern primarily because their original habitat is declining. Suitable caves, cliff cavities, and hollow trees are becoming rare as natural areas are converted to development across North Carolina. In addition, nest sites continue to be lost during the renovation and demolition of old buildings. To minimize further impacts to priority species using artificial structures, we recommend considering adopting the following planning and building practices.

8.2 Planning and Development Recommendations

1. If Barn Owls, Chimney Swifts, or bats are found in a built structure, attempt to retain the structure.

2. If retaining the structure is not possible, contact a wildlife damage control agent to discuss removal options.
   - Locate contact information for agents in your county on the following website: http://www.ncwildlife.org/Coexisting_Wildlife/Coexist_Contact_WDCA.htm
   - If bats are present, consider erecting bat boxes or other structures to replace lost habitat.

3. Avoid capping chimneys in abandoned homes since chimney capping is a major factor in the decline of Chimney Swifts in the U.S.

4. When work is planned on a barn or other farm outbuilding, consider surveying the structure to determine whether or not Barn Owls or bats are present.
   - If animals are found, attempt to maintain the structure.
   - If it is not feasible to maintain the structure, then conduct structure removal or alteration activities prior to or after the breeding season.

5. If Chimney Swifts are found using a building, avoid maintenance and improvement work during the nesting season (May-August). If disturbed, the birds may abandon nestlings and eggs.

6. Where it is desirable to enhance or provide artificial structures for wildlife, reference the following websites:
   - For general recommendations, reference: http://www.nationaltrust.org.uk/main/w-wabman.pdf
   - For bats, reference:http://www.batcon.org/index.php/get-involved/install-a-bat-house/subcategory/intro.html
   - or Chimney Swifts, reference: http://www.wildlifemanagement.info/files/swallows_3.pdf
   - For Barn Owls, reference: http://www.barnowltrust.org

8.3 Selected References

The National Trust. 2003. Wildlife and Buildings Technical Guidance for Architects, Builders, Regional Building Managers, and Others. http://www.nationaltrust.org.uk/main/w-wabman.pdf

Appendix A.
DEFINITION OF TERMS

Area-sensitive species – a species whose patterns in habitat use, abundance, reproduction, or fitness are negatively impacted in small habitat patches. Definitions of small habitat patches typically vary by species.

Connectivity – the degree to which patches of habitat are connected to each other. This term is used in relation to individual patches as well as to landscapes in general.

Conservation threshold – the minimum level of any characteristic of a species' habitat that is needed in order for local populations to persist over time.

Corridor – a patch of habitat (usually linear) that connects two or more other habitat patches, providing habitat for animals as they disperse or migrate.

Disking – an agricultural practice used in management of early successional habitat that involves using a disk implement to disturb topsoil layers and existing vegetation to promote growth of early successional vegetation.

Dispersal – movement by an individual from its natal site in search of a new territory, habitat patch, breeding site, or other habitat requirement.

Disturbances – events or developments that significantly change an ecosystem or habitat either temporarily or permanently.

Edge effects – any influences on wildlife that are caused by conditions or species associated with the edges of habitats. An example of an edge effect is a decrease in avian reproductive success due to brood parasitism by the Brown-headed Cowbirds that are associated with forest edges.

Ephemeral pool – a pool of water that dries up periodically; a temporary pool.

Exotic species – a plant or animal species that is non-native.

Forest cover – land that is forested and undeveloped.

Forest interior species – an area-sensitive species that relies upon forest habitat and is sensitive to edge effects.

Fragmentation – the process of breaking up large, contiguous patches of habitat into smaller, spatially separated ones.

Hibernaculum – a habitat where an animal seeks refuge, particularly during times of hibernation. For example, bats use caves and mines as hibernacula in the winter.

Hydrology – the patterns of water movement, quality, volume, and distribution at a wetland.

Hydroperiod – the period of time during which a wetland is covered in water.

Impervious surface – surfaces such as roads, parking lots, and buildings that water flows over rather than through.

Indicator species – a species that is closely associated with a particular habitat type, and whose presence indicates quality habitat.

Invasive species – a species of plant or animal, typically non-native, that spreads and establishes itself in new areas rapidly.

Jurisdictional wetland – a wetland that is subject to regulatory requirements of Section 404 of the Clean Water Act, and that is subject to the U.S. Army Corps of Engineers jurisdiction.

Mid story – a level of forest vegetation that is composed of trees that are taller than shrubs but not as tall as the trees that make up the tree canopy.

Migration – a movement between habitats or locations that is repeated periodically.

Mitigation – habitat restorations or improvements that are performed at one site in order to offset habitat destruction or degradation at another site.

Natural Community -- a distinct assemblage of plants and animals, often referred to by the dominant vegetation type (ex: Longleaf Pine savanna)

Prescribed burning – the controlled application of fire to forests or grasslands in order to reduce fuels and restore or maintain ecosystem function

Priority species – a species that has been identified as a priority for conservation efforts in North Carolina by the North Carolina Wildlife Action Plan.

Semi-aquatic species – a species that relies on both aquatic and terrestrial habitats at some point in its life cycle.

Soft edge - a gradual transition between adjacent ecological communities or habitat types.

Stopover habitat – a habitat type or patch that individuals use for resting and refueling during migrations.

Terrestrial wildlife – species that carry out their entire life cycles in non-aquatic habitats.

Understory – ground level vegetation in a forest.

Undisturbed – an area that has not been exposed to human-induced disturbance events.

Urban greenway – a linear corridor of undeveloped land that is designated for recreation or environmental protection.

Wetland – an area of land with soil that is either permanently or temporarily saturated with water.

APPENDIX B.

METHODOLOGY

Development of the recommendations document began with a collaboration between the authors of this document and an advisory committee of wildlife professionals from the North Carolina Wildlife Resources Commission, U.S. Fish and Wildlife Service, and N.C. Natural Heritage Program.

The advisory group identified which habitats and groups of species, such as area-sensitive forest birds, upon which the literature review and development of recommendations would focus. Choices about what habitats and species groups to include were based on 1) whether they were identified as a conservation priority in the North Carolina Wildlife Action Plan, 2) the committee members' experience and knowledge of where and how development is affecting wildlife in the state, and 3) whether or not useful recommendations could be developed on how to better protect the habitat or species group.

For each focal habitat, a list of focal species upon which to base our literature review and recommendations was created. Each search began with NCWAP species associated with each habitat. A species list was created by identifying which animals were dependent upon each habitat, threatened by development, and for which appropriate recommendations could be crafted.

For each of these species groups, conservation issues and concerns were identified that could be addressed with information from the scientific literature. These issues and concerns were used to focus our primary research questions during the literature review. A list of experts on each of the species or habitat groups was also compiled.

Once the committee had agreed upon focal habitats and species, primary questions to research, and experts to contact, feedback on our search criteria was solicited from scientific experts. Experts were queried to determine 1) whether to add or remove any species, 2) whether any additional research questions should be addressed, and 3) bodies of literature to review, especially literature that would not show up in a search of scientific journal articles.

Species lists were refined based on expert feedback, and search keywords were generated that encompassed conservation issues, species' names, and sub-habitat types from Schafale & Weakley (1990). Our literature search in Web of Science consisted of the following steps:

1. All papers on the species or sub-habitat type published after 1990 in research journals were searched.
2. Papers from the resulting list that also contained one of the research question keywords were also searched.

3. Titles and abstracts of all papers in the list were reviewed, copies of articles that appeared useful were acquired.
4. Electronic copies of papers were obtained whenever possible, were saved in alphabetized folders, and bibliographic information plus abstracts and keywords were entered into an Endnote library.
5. Each paper was read, and relevant findings were entered into an Access database created specifically for our project. If papers were reviews of extensive recommendations, then recommendations were summarized in a separate Microsoft Word document.

When possible, research findings from North Carolina or the southeastern United States were used to develop recommendations. Where studies from North Carolina (or the southeastern United States) did not exist, findings from across the United States were used.

After reviewing all relevant literature that emerged from the search, scientific findings were summarized in Appendix C. Scientific findings were then translated into draft conservation recommendations. Scientific justification and conservation recommendations were then presented to the project advisory committee for review. The recommendations were revised according to the advisory committee's feedback.

Once literature review was completed for most habitats, the justification and recommendations for each habitat were compiled into this document. The document was then circulated through an extensive peer review process, and suggested revisions were incorporated into the final document.

APPENDIX C. SCIENTIFIC JUSTIFICATION

TABLE OF CONTENTS

FIGURES.

TABLES.

SECTION 1. INTRODUCTION

This appendix presents a summary of the literature reviewed to produce the document titled "Conservation Recommendations for Terrestrial Wildlife Habitats and Species in North Carolina." Note that expert knowledge was used to produce the final recommendations in the primary document. Statements that synthesize groups of papers are presented in italics. For the most part, these italicized statements summarize scientific papers reviewed below each statement. Bibliographic information for each citation used below can be found in Appendix D.

SECTION 2. WETLAND HABITATS

2.1 Core Terrestrial Habitat

2.1.1. Buffer Recommendations

Recommendations for conserving wetland associated species from the primary scientific literature include preserving critical terrestrial habitat buffers around small wetlands.

Semlitsch and Bodie (2003) Conservation Biology
- Maintain habitat out to 339 m from the edge of wetlands and streams.
- Maintain three protected zones around wetlands and streams
    - Aquatic buffer: 30 – 60 m from water's edge
    - Core habitat: 142 – 289 m from water's edge
    - Terrestrial buffer: 50 m from edge of core habitat buffer

Calhoun et al. (2005) Wetlands Conservation and Management
- Protect the pool.
- Protect a 30 m pool envelope, and protect 100% of this area from development.
- Protect 75% of the critical terrestrial habitat out to 230 m from pool.
    - The 230 m buffer is expected to protect >95% of population.
    - This does not address connectivity between pools.
    - Based on Semlitsch (2003) and Faccio (2003) who looked at migration and dispersal distances of pool-breeding salamanders.

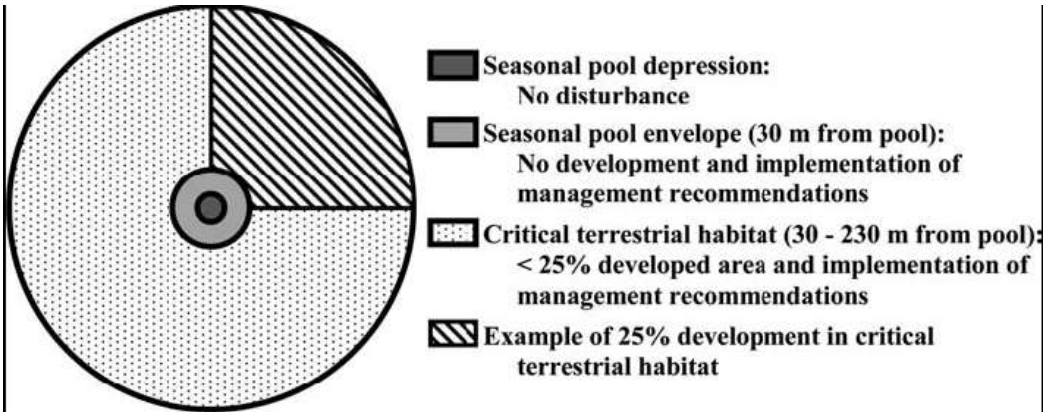


Figure 1. Conceptual diagram of Calhoun et al.'s (2005) recommendations

Hermann et al. (2005) Biological Conservation

- The authors recommend conservation strategies that focus on preserving large amounts of forest cover at distances up to 1 km from wetlands, rather than protective buffers because their study did not find strong correlations between amphibians and forest cover < 100 m from wetlands.

Montieth and Paton (2006) Journal of Herpetology

- Maintain a buffer of 185 m from the pool's edge to protect the habitat used by 95% of Spotted Salamanders.

McDonough and Paton (2007) Journal of Wildlife Management

- Maintain a buffer out to 370 m from the water's edge to preserve the habitat used by 95% of female Spotted Salamanders.
- This buffer width would encompass the habitat used by 100% of male Spotted Salamanders.

Baldwin et al. (2006) Journal of Herpetology

- The authors suggest an alternative to general buffer recommendations for cases where protecting large areas of habitat is infeasible and information is available on species presence and habitat use.
- "Conservation planners need to identify, link, buffer, and protect discrete habitat elements (such as isolated breeding pools, upland overwintering forest, and forested wetlands for Wood Frogs) within known maximum migratory distances from breeding pools." This approach would reduce the amount of overall protected area necessary for the persistence of populations (Baldwin et al. 2006).

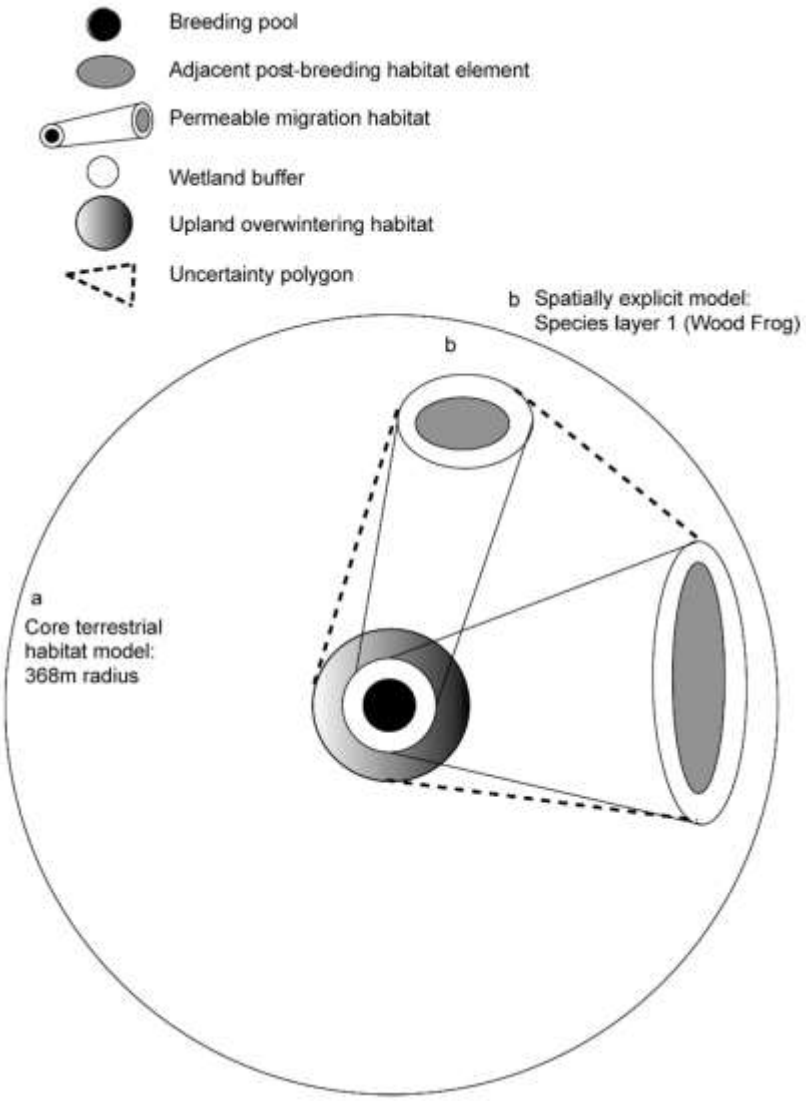


Figure 2. Conceptual diagram of the conservation strategy suggested by Baldwin et al. (2006).

2.1.2 Migration Distances

Reported distances between the aquatic breeding and terrestrial non-breeding habitats of semi-aquatic amphibian and reptiles suggest that semi-aquatic species need terrestrial habitat at distances of up to 500 m from the water's edge.

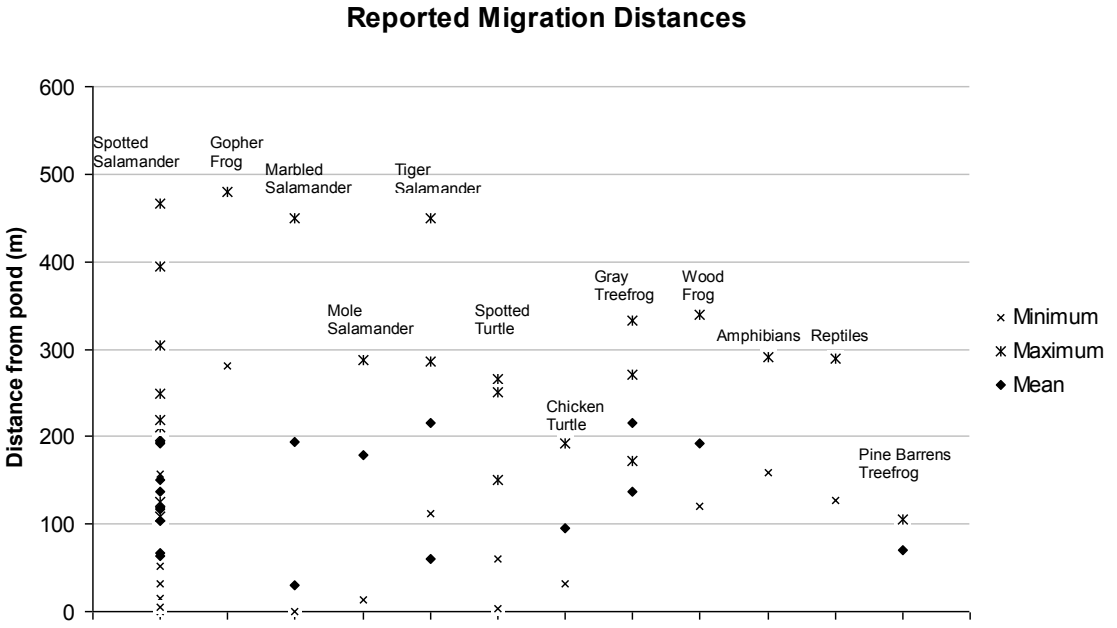


Figure 3. Migration distances for priority species from the primary scientific literature. (Each point represents a value reported in a scientific paper)

- During the breeding season, amphibian distributions are typically skewed toward the pond with peak densities at 30 m and most individuals migrating to distances between 30 and 200 m from the pond. Semlitsch and Rittenhouse (2007) estimated that 99% of pool breeding semi-aquatic amphibians stay within 1 km of breeding pools during the nonbreeding season. The also estimated that 95% of amphibians occur within 664 m of their breeding pools and 50% occur within 93m during the nonbreeding season. Their estimate of the 50% isopleth for frogs was 183 m from the pond's edge and the 95% isopleth estimate was 703 m. Their estimate of the 50% isopleth for salamanders was 41 m from the pond's edge and the 95% isopleth estimate was 245 m (Semlitsch and Rittenhouse 2007).
- Ninety five percent of Salamander populations use habitats at least 175 m from the edge of aquatic habitats (Faccio 2003).
- The majority of adult Marbled Salamanders breeding in seasonal ponds arrived from terrestrial habitats that were more than 30 m away (Gamble et al. 2006).
- Over 60% of Spotted Salamanders wintered in terrestrial habitats that were more than 60 m from their breeding pond (Regosin et al. 2005).
- McDonough and Paton's (2007) results, suggested that preserving an upland buffer of 185 m would protect habitat for approximately 95% of Spotted Salamanders.
- Between 16 and 21% of Spotted Salamanders wintered more than 164 m from their breeding ponds (Regosin et al. 2005).
- Over 13% of Red-spotted Newts wintered over 100 m from their breeding ponds while at least 43 - 45% wintered less than 60 m from their breeding ponds (Regosin et al. 2005).
- At least 40% of Wood Frogs wintered over 100 m from their breeding ponds (Regosin et al. 2005).

- Adult and juvenile Wood Frogs both frequently migrated more than 300 m from the edge of breeding ponds and moved to locations in excess of 410 m from the nearest breeding pool (Vasconcelos and Calhoun 2004).
- Blihovde (2006) documented a Gopher Frog traveling from a burrow to a breeding pond 90 m away.

2.1.3 Species-Forest Associations

Population models and landscape scale studies indicate that local amphibian populations are dependent upon forested areas surrounding breeding ponds.

- Simulations using population models indicated that terrestrial habitat is needed up to a minimum distance between 100 and 165 m from water's edge to maintain populations of Spotted Salamanders with a 95% probability of persistence over 20 years (Harper et al. 2008).
- Red-spotted Newts presence was most strongly associated with forest within 500 m, but also associated with forest up to 1000 m (Hermann et al. 2005).
- Spotted Salamanders were most strongly associated with forest within 250 m, but also associated with forest up to 1000 m) of the wetland (Hermann et al. 2005).
- Spotted Salamander breeding activity at wetlands was correlated with the total area of forest within 1 km of the wetland (Skidds et al. 2007).
- Wood Frog breeding activity at wetlands was positively correlated with the total area of forest within 1 km of wetlands and negatively correlated with the amount of residential habitat within 1 km (Skidds et al. 2007).
- Spotted Salamander breeding activity at wetlands was correlated with the total area of forest within 1 km of the wetland (Skidds et al. 2007).
- Herpetofaunal diversity was positively correlated with the proportion of forest cover in the landscape (Jochimsen et al. 2004).
- Spotted Salamanders were absent at wetlands with less than 40 % forest cover within 250 m of the water's edge and occurred at lower densities in wetlands with less than 80% cover (Hermann et al. 2005).
- Red-spotted Newts and Spotted Salamanders were associated with the presence of forest within 1,000 m of breeding pools (Hermann et al. 2005).

Studies that estimated threshold percentages of forest cover close to ephemeral wetlands have produced results that conflict within and among species, but some species appear to need large amounts of forested area in the surrounding landscape.

- “Landscapes with high forest cover within 100 m of breeding ponds are crucial for Wood Frog population maintenance” (Eigenbrod et al. 2008).
- The average percent forest cover within 200 m of Wood Frog breeding ponds was 58% (SE = 5.7) (Porej et al. 2004).
- Wood Frogs only bred in wetlands with at least 11% forest cover within 200 m of the water's edge (Porej et al. 2004).
- Wood Frog breeding effort peaked in wetlands with moderate (30-70%) canopy cover, decreasing as canopy cover approached 100% (Skidds et al. 2007).

- For Wood Frogs, forest cover thresholds decreased with the scale of the analysis (distance from breeding pond). Thresholds declined from 88% at the 30 m scale to 44% at the 1000 m (Homan et al. 2004).
- The average percent of forest cover within 200 m of ponds where Red-spotted Newts bred was 56% (SE = 7.2) (Porej et al. 2004).
- Red-spotted Newts bred in pools with between 36 and 83% forest cover within 200 m of the water's edge (Porej et al. 2004).
- Red-spotted Newts were present in low numbers in wetlands with surrounding forest cover less than 80% (within 500 m) (Hermann et al. 2005).
- Red-spotted Newts only occupied areas with forest cover greater than 50% (Gibbs 1998).
- Spotted Salamander breeding was not found to be correlated with canopy cover at wetlands (Skidds et al. 2007).
- Forest cover thresholds increased with scale (distance from pond) for Spotted Salamanders. Thresholds were around 30% at 100 m scales, 41% at 500 m, and 51% at 1000 m (Homan et al. 2004).
- Spotted Salamanders only occurred at pools with a minimum of 35% forest cover within 200m (Porej et al. 2004).
- The average percent forest cover within 200 m of wetlands with Spotted Salamanders in them was 62% (SE = 4.1) (Porej et al. 2004).
- Spotted Salamanders only occupied areas with forest cover greater than 30% (Gibbs 1998).

2.1.4 Differential Migration

Studies of amphibian habitat use suggest that females tend to migrate farther than males causing terrestrial habitat buffers that are too small to impact females more heavily than males.

- Female Red-spotted Newts, Spotted Salamanders, Blue-spotted Salamanders, and Wood Frogs ranged farther from breeding ponds than did males (Regosin et al. 2005).
- Female Gray Treefrogs were distributed farther away from breeding ponds than males (Johnson et al. 2007a).
- Adult male Spotted Salamanders migrated to areas between 5 and 304 m from the edge of wetlands while adult female Spotted Salamanders migrated to areas between 31 and 395 m from the edge of wetlands (McDonough and Paton 2007).

2.1.5 Habitat Boundaries

Hard forest edges appear to have a negative effect on amphibian abundance.

- Mole Salamander, Redback Salamander, and Wood Frog numbers were lower within 35 m of forest-clear-cut edges than they were between 35 and 70 m from the edge (DeMaynadier and Hunter Jr. 1998).

- Terrestrial Salamander abundance was low within 35 m of forest-road edges, indicating the existence of a road-effect zone (Semlitsch et al. 2007).
- The authors found a negative edge effect on Redback Salamanders up to 80 m from the edge of unpaved forest roads (Marsh and Beckman 2004).
- There was evidence of greater edge effects at high contrast forest edges than at soft edges (DeMaynadier and Hunter Jr. 1998).

2.2. Patch Configuration

2.2.1 Population Isolation

Some populations of semi-aquatic herpetofauna need access to multiple breeding sites for long-term persistence.

- American Toad, Spotted Salamander, and Wood Frog breeding activity at wetland ponds fluctuated over the course of 10 years in response to changes in predator abundance and hydrology, with periods where ponds were unsuitable for breeding.
- Simulations indicated that isolated populations of Wood Frogs with the required upland habitat still had a > 5% probability of going extinct within 20 years (Harper et al. 2008).
- Red-spotted Newts were only found breeding in ponds that were within 205 m of neighboring ponds (Porej et al. 2004).

2.3 Corridors

2.3.1 Dispersal distances

Small wetland communities that are up to 1.0 mi (~1.5 km) apart may be ecologically connected due to long-distance dispersal movements by priority amphibians. In the Sandhills region, ephemeral pools that are up to 2.2 mi (~3.5 km) can be ecologically connected due to the long dispersal distances of juvenile Carolina Gopher Frogs.

- Species richness at ponds was negatively correlated with the pond being more than 1 km from neighboring ponds (Burne and Griffin 2005).
- The maximum recorded dispersal distance within one year is 2500 m for Wood Frogs (Marsh and Trenham 2001).
- Juvenile Marbled Salamanders were found during their hatching year in basins up to 1,230 m from their natal pools (Gamble et al. 2006).
- Juvenile Wood Frogs dispersed an average of 1208 m from their natal pools (Vasconcelos and Calhoun 2004).
- First time breeding Marbled Salamanders dispersed between 142 and 1359 m from their natal pools, with 68% of individuals concentrated between 200 and 400 m (Gamble et al. 2007).
- Marbled Salamanders have been found up to 1 km from their natal ponds (Gibbons 2003).

- 95 % of successful first time breeding Marbled Salamander dispersers occurred within 862 m of the water's edge (Gamble et al. 2007).
- Red-spotted Newts were only found breeding in ponds that were within 205 m from neighboring ponds (Porej et al. 2004).
- Large proportions of juvenile Marbled Salamanders dispersed more than 100 m from their natal ponds (Gamble et al. 2006).
- Spotted Turtles had homeranges between 5 and 16 ha with gravid females using larger areas than males and both sexes using a variety of habitats (Litzgus and Mousseau 2004).
- Amphibian species richness was lower with greater wetland isolation, road density, and the overall proportion of urban land-use in the landscape (Jochimsen et al. 2004).
- Radio telemetry of four juvenile Gopher Frogs in the sandhills region of North Carolina documented their use of upland habitat at distances of 738, 698, 1,238, and 3,470 m from their breeding pond (Humphries and Sisson 2009).
- Juvenile Gopher Frogs in a Florida longleaf pine forest dispersed to sites that were up to 691 m from the natal ponds. The average distance the juvenile Gopher Frogs moved from their natal ponds was 173 m (SE = 30.7, N = 31)(Roznik and Johnson 2009).
- Franz et al. (1988) reported a maximum migration distance of 2 km for Gopher Frogs.

2.3.2 Habitat preferences

Amphibians have been found to migrate through a variety of habitats, but several studies show that forested habitats are preferred by dispersing amphibians.

- Migrating Spotted Salamanders avoided forest edge and grassland habitats, indicating that the permeability of forest-grassland edges is low (Rittenhouse and Semlitsch 2006).
- Adult Spotted Salamanders' movements away from breeding sites were random with respect to habitat (forested vs. clearcut), but juvenile Spotted Salamanders avoided dispersing through clear cuts, although a few individuals did move through cut areas (Patrick et al. 2008).
- Juvenile Spotted Salamanders avoided open-canopy habitats after leaving pools (Rothermel and Semlitsch 2002).
- Juvenile Spotted Salamanders exhibited nonrandom dispersal orientation at only 8 of 18 experimental ponds and did not show a strong orientation toward forest edges (Rothermel 2004).
- Marbled Salamanders did not show a preference for forested habitats over clear-cuts (Graeter et al. 2008).
- Red-spotted Newts were very rarely captured adjacent to fields and roads (Regosin et al. 2005).
- Wood Frogs avoid crossing fields, pastures, clear-cuts, lawns, and roads (Cushman 2006).

- Juvenile American Toads almost exclusively selected forested habitat for dispersal (Rothermel and Semlitsch 2002).
- Tiger Salamanders that were followed as they left breeding ponds moved through forest in all directions but avoided open habitats including roads, commercial areas, and grassy fields (Jochimsen et al. 2004).
- Long distance movements by adult Wood Frogs were directed toward moist, forested habitats.

2.3.3 Barriers to movement

Non-forested habitats are not preferred by dispersing and migrating amphibians, but some individuals can successfully move through them. The survival rates of individuals attempting to traverse these habitats are low.

- Some juvenile Gopher Frogs in a Florida longleaf pine community successfully crossed dirt roads (Roznik and Johnson 2009).
- Wood Frogs avoid crossing fields, pastures, clear-cuts, lawns, and roads (Cushman 2006).
- Marbled Salamanders did not show an inability to move through clear-cuts and forest-clear-cut edges (Graeter et al. 2008).
- Some adult Spotted Salamanders successfully traversed golf course fairways during migrations (Montieth and Paton 2006).
- Adult Spotted Salamanders traversed fairways at a golf course that were as wide as 195 m (McDonough and Paton 2007).
- Long distance movements by adult Wood Frogs were directed toward moist, forested habitats (Baldwin et al. 2006).
- Wood Frogs traversed non-forested areas that were 30 - 70 m wide (Baldwin et al. 2006).

Roads can act as barriers to migrating and dispersing amphibians.

- Red-spotted Newt and Redback Salamander movement was inhibited by a 12 m wide forest road with traffic levels of 300 vehicles per day (Jochimsen et al. 2004).
- Forest roads acted as barriers to Red-backed Salamanders with movement being reduced by around 51% (Marsh et al. 2005).
- Amphibians are better able to move through forest edges associated with open habitats than forest edges associated with roads during breeding migrations (Jochimsen et al. 2004).
- Wood Frogs and Spotted Salamanders avoid crossing fields, pastures, clear-cuts, lawns, and roads (Cushman 2006).
- If road mortality rates for migrating Spotted Salamanders exceeds a value somewhere between 10 and 20 percent across a regional population, then the population will be extirpated within 25 years (Gibbs and Shriver 2005).
- "Combinations of road densities greater than 2.5 km per km2 of landscape and traffic volumes greater than 250 vehicles per lane per day within the dispersal and

migration range of a particular breeding population of spotted salamanders could generate demographically significant mortality levels" (Gibbs and Shriver 2005).
- A greater proportion of dispersing amphibians cross roads than do individuals migrating or moving throughout home ranges (Jochimsen et al. 2004).

2.4. Adjacent Landscape

2.4.1 Species-Forest Associations

Amphibian presence and breeding activity at breeding ponds is positively correlated with forest cover.

- The authors recommend conservation strategies that focus on preserving large amounts of forest cover at distances up to 1 km from wetlands, rather than protective buffers because their study didn't find strong correlations between amphibians and forest cover < 100 m from wetlands (Hermann et al. 2005).
- Herpetofaunal diversity was positively correlated with the proportion of forest cover in the landscape (Jochimsen et al. 2004).
- Wood Frog breeding activity at wetlands was positively correlated with the total area of forest within 1 km of wetlands (Skidds et al. 2007).
- Red-spotted Newts and Spotted Salamanders were associated with the amount of forest within 1 km of breeding sites (Hermann et al. 2005).
- Spotted Salamander breeding activity at wetlands was correlated with the total area of forest within 1 km of the wetland (Skidds et al. 2007).

2.4.2 Forest Cover

Few studies have estimated threshold forest cover percentages between 200 and 1,000 m from ephemeral pools, but so far, studies suggest that the threshold is somewhere around 40%.

- The authors found evidence that ponds surrounded by at least 40-60% forest within a 1 km radius may be necessary to maintain amphibian diversity (Hermann et al. 2005).
- Wood Frogs bred in wetlands with between 6 and 40% forest cover between 200 and 1000 m of wetland edges (Porej et al. 2004).
- Wood frogs only occupied areas with forest cover greater than 30% (Gibbs 1998).
- For Wood Frogs, forest cover thresholds decreased with the scale of the analysis (distance from breeding pond). The threshold was 44% within 1000 m (Homan et al. 2004). However, forest cover thresholds increased with scale (distance from pond) for Spotted Salamanders. Thresholds were around 30 % at 100 m scales, 41% at 500 m, and 51% at 1000 m (Homan et al. 2004).

2.4.3 Road Density

Amphibian presence and breeding activity at breeding ponds is negatively correlated with road density.

- "The conservation value of landscapes with low forest cover will be greatly reduced if traffic densities are high within 2,000 m of breeding ponds, as the species particularly associated with open habitats - American Toads and Leopard Frogs - are also the most vulnerable to road traffic" (Eigenbrod et al. 2008).
- If road mortality rates for migrating Spotted Salamanders exceeds a value somewhere between 10 and 20 percent across a regional population, then the population will be extirpated within 25 years (Gibbs and Shriver 2005).
- "Combinations of road densities greater than 2.5 km per km^2 of landscape and traffic volumes greater than 250 vehicles per lane per day within the dispersal and migration range of a particular breeding population of Spotted Salamanders could generate demographically significant mortality levels" (Gibbs and Shriver 2005).
- Anuran species richness was negatively correlated with road density and this correlation was three times as strong as positive correlations between forest cover and anurans (Eigenbrod et al. 2008).
- Amphibian species richness was lower with greater wetland isolation, road density, and the overall proportion of urban land-use in the landscape (Jochimsen et al. 2004).
- Road density across the landscape has been found by numerous studies to be negatively correlated with species richness of herpetofauna (Jochimsen et al. 2004).
- Wood Frog breeding activity at wetlands was negatively correlated with the total area of residential development within 1 km of wetlands (Skidds et al. 2007).
- Tiger Salamander presence at isolated wetlands was negatively correlated with the length of paved roads within 1km (Porej et al. 2004).
- The ecological effects of roads extend to areas 100 - 800 m from the road's edge (Andrews et al. 2008).

2.5 Ephemeral Pools

The presence of fish in small wetlands precludes their use by some priority amphibian species.

- American Toads did not breed in pools during years when predators of their larvae were present (Petranka and Holbrook 2007).
- Spotted Salamanders were less likely to breed in pools during years when they contained fish that eat their larvae (Petranka et al. 2007).
- Wood Frogs did not breed in any wetlands containing fish (Porej et al. 2004).
- Wood Frogs did not breed in pools during years when predators of their larvae were present (Petranka and Holbrook 2007).

Preserve clusters of small wetlands rather than solitary, isolated wetlands.

- Preserve or create clusters of pools that vary in size and depth in order to facilitate adaptive habitat shifting to avoid predators of larvae (Petranka and Holbrook 2007).

- Petranka et al. (2007) recommended creating or preserving groups of 5 - 10 pools in order to promote amphibian populations' ability to persist.
- Where ephemeral pools have been lost, constructing chains of artificial wetlands that are 100 – 200 m apart can facilitate dispersal and recolonization by amphibians (Bailey et al. 2006).

2.6 Bog Habitats

2.6.1 Bog Turtle Habitat Management Needs

Bog Turtles need sunny, spring-fed wetlands that have both wet and dry pockets.

- Chase et al. (1989) found that Bog Turtle densities were greatest at sites within circular basins with spring-fed puddles of shallow water, a soft mud and rock substrate, low grass and sedge vegetation, and an interspersion of wet and dry pockets.
- Morrow et al. (2001) found that Bog Turtles appeared to prefer habitats with sedges and rushes that were thick and low to the ground, bulrushes, arrowhead, and rice cut grass, which are all found in wet areas.
- The 44 Bog Turtles that Ernst et al. (1989) tracked hibernated in Muskrat and Meadow Vole burrows, as well as in clumps of carex, at the base of cedar stumps, and at the bottom of waterways (43%).

Grazing is one effective means of controlling succession and invasive vegetation.

- Tesauro and Ehrenfeld (2007) found that Bog Turtle numbers, density, and frequency of juvenile occurrence were greater at grazed sites than where grazing had been abandoned.
- One bog restoration effort found that light cattle grazing moderated the inhospitability of invasive Reed Canary Grass for Bog Turtles (Tesauro 2001).
- Phragmites cover decreased by 85% in a wet meadow following the introduction of sheep and goats. Sheep ate *Microstegium vimineum* and kept it from reproducing by keeping it low to the ground (Lee et al. 2001).
- Allowing cattle access to a limestone fen reduced shrub cover by 33 percent and purple loosestrife cover by 40 percent (Lee et al. 2001).
- Phragmites cover decreased by 50 or 60 percent in a wet meadow following the introduction of 80 pound goats. The cover of two native species (*Pilea pumila* and *Equisetum fluvitale*) increased by 75% (Tesauro 2001).

Conduct site assessments of mountain bogs.

- Identify wetlands with patches of shallow water, deep mud, and tall, dense vegetation, and avoid threats to this habitat structure such as plant succession and wetland draining (Carter et al. 1999).
- If the site is sunny, soggy, and spring-fed, then survey the sight for bog turtles. If it is not known bog turtle wetland but has an emergent and/or shrub wetland

component, then it should be surveyed to determine if it is potential bog turtle habitat.
- Contact NCWRC and Project Bog Turtle to see if site is Bog Turtle habitat (Somers et al. 2000). Contact Project Bog Turtle: N. C. Herpetological Society, 11 West Jones Street, Raleigh, NC 27601. www.projectbogturtle.org

Control exotic and invasive species.

- When possible, remove invasive plants by digging, pulling, constant pruning or grazing (Herman 2003).
- USDA approved insects can be used to control invasive plants, such as purple loosestrife (EDF 2009).

Captive breeding programs can be used to sustain Bog Turtle populations.

- To maintain the long term persistence of Bog Turtles, use captive breeding programs to restock populations and preserve genetic variability (Morrow et al. 2001).

Protect mountain bogs through land acquisition or cost-share programs.

- Consider the following land protection mechanisms (Herman 2003):
    - Wetlands reserve program: NRCS or USFWS
    - Wildlife habitat incentives program: NRCS
    - Partners for Wildlife: USFWS
    - Registry and dedication: NC Natural Heritage Program
    - Conservation lease agreement: Project Bog Turtle and NC Herpetological Society

Plant succession should be inhibited in Bog Turtle habitats through light grazing, burning, manual removal of woody plants, or careful herbicide use.

- Management of Bog Turtle habitat should include 1) retarding woody vegetation development by browsing, selective cutting, or burning to prevent canopy closure: 2) maintain potential and usable dispersal corridors that connect groups of habitat units and potential habitat 3) create new meadow bogs by artificial flow modifications (tapping into the aquifer where possible) 4) encourage and protect beaver populations; 5) control invasive and exotic plant species such as multiflora rose; and 6) manage predator and competitor populations (mainly Raccoons) (Lee et al. 2001).
- Controlled grazing: periodically bring in cattle, goats, sheep, and horses following an approved prescribed grazing plan (EDF 2009).
- Chemical and mechanical treatments: Targeted removal of unwanted plants is preferred to broadcast foliar applications. Kill trees by cutting, girdling, or with a wetland-approved herbicide. Mowing can be used to control shrubs but should be done in the winter. Create a mosaic of 25% forested habitat and 75% open habitat to preserve hibernacula and aestivation sites (EDF 2009).

- Various vegetation control techniques need to be tested, results shared between partners and then applied effectively. Maintaining cattle on sites is not without problems, including the crushing of adult Bog Turtles, young, and nests. New grazing techniques, including seasonal or permanent exclusion of livestock need to be part of site conservation (Lee et al. 2001).
- Kiviat (1978) outlined the following management tactics, on an as needed basis, that should be considered as reserves are set aside for the protection of bog turtle populations: 1) maintain regional beaver populations or create new meadows by artificial flow modifications; 2) maintain usable dispersal-ways connecting groups of habitat units and potential habitats; 3) retard woody vegetation development by cutting, browsing, or burning to prevent canopy closure; 4) control introduced thicket-forming plants such as multiflora rose, honeysuckles, etc.; and 5) manage predator and competition populations (Herman 2003).
- Maintain early successional habitat through selective cutting, herbicides (use with care so as not to harm desirable species), cutting shrubs and small trees after the leaves emerge, cutting vegetation during early to mid summer, girdling large diameter trees, and grazing by herbivores. Use spring and fall grazing by small herds of cattle, horses, or goats to keep waterways open and prevent them from becoming weed-choked (Herman 2003).
- Where haying is an objective, mow at high blade settings no more than once a year (Bailey et al. 2006).
- Control woody encroachment and succession (Bailey et al. 2006).
- Avoid plowing firebreaks in bogs and wet meadows (Bailey et al. 2006).

Preserve or restore the hydrological integrity of wetlands

- Restore bog turtle habitats by plugging or filling old ditches and draining ponds. Remove fill dirt or debris after the hydric soil boundaries have been mapped, re-establish creek channels, and dam exit streams to restore sheet flow (Herman 2003).
- Avoid habitat alteration through filling, draining, damming/inundating, and excessive groundwater withdrawal (Bailey et al. 2006).
- Protect against run-off from roads or adjacent agricultural fields by planting vegetated buffers, using no-till practices in adjacent fields, or constructing diversions or sediment catch basins.
- Accurately define the size of the wetland. Include a primary boundary around the core of the wetland and secondary boundaries around areas that buffer the core. Include this information in the form of a map of the local area and the watershed where the wetland occurs. Also map any ditches, drains, buried tiles or pipes, stream channels, trees and shrubs, and rare plant and animal occurrences (Somers et al. 2000).
- Develop a management plan for the bog (Somers et al. 2000).
    - Address hydrology in the plan
        - Delineate current and proposed hydric soil areas.
        - Include plans for maintaining and protecting water quantity and quality.
        - Analyze the water budget.

- Manage bog hydrology by:
  - Formulate flow alteration strategy with the help of a professional.
  - Determine whether permits are needed.
  - As one option, consider installing a ditch plug to grade.
  - Determine the best time of year to begin the manipulation.
  - Avoid flooding hummocks and other areas where hatchlings or eggs could be disturbed.
  - Use generous native vegetation buffers around the wetland to filter nutrient and chemical runoff and benefit wildlife.
  - Use debris resulting from woody plant removal to construct small dams along water channels within the site to allow water to be diverted and retained.

2.6.2 Bog Turtle Movement

Bog Turtles spend most of their time in close proximity to wetlands, but some populations move to areas that are far away from their breeding sites.

- Chase et al. (1989) captured one hundred and thirty turtles and the greatest distance at which a turtle was found from the water was 7 m. A little over half (58.7%) were found within 20 cm of the water. Their sampling methods, however, were not designed to find long distance dispersers.
- Carter et al. (1999) radio-tracked Bog Turtles and found that the maximum distance from water that a Bog Turtle traveled between May and December was 7 m. The average distance was 1 m.
- The median migration distance (between hibernacula and restored wetlands, ditches, and other small seepage slope habitats) of a Tennessee population of Bog Turtles was at least 800 m (0.5 mi) (Herman 2003).
- The maximum distance that an Eastern Ribbonsnake was observed from the shoreline was 173 m, but all individuals were within 5 m of the shoreline during summer (Bell et al. 2007). The authors, however, did not perform extensive searches in areas far away from the shoreline.
- Mole salamanders migrated between 13 and 287 m from the edge of aquatic habitats, and the average migration distance was 178 m (Semlitsch and Bodie 2003).
- Three of 31 Bog Turtles that were tracked visited neighboring ponds that were between 0.4 - 0.6 km away and then returned to their original capture site (Carter et al. 2000).
- Reports exist of Bog Turtles moving upstream during the spring to distances of 185 - 215 m away, and then returning downstream in the fall (Chase et al. 1989).

2.6.3 Habitat Buffers

Establishment or maintenance of buffers around Bog Turtle wetlands is critically important.

- Bog Turtles require a “behavioral” buffer to protect habitat used for movements adjacent to the wetland. Sites need a “hydrologic” buffer to ensure retention of suitable water budgets. This latter buffer may be large and determination may require expensive hydrologic studies. Use of the watershed boundary might be sufficient. As many of the sites are on active farms, there is a great need to work cooperatively with these farmers to promote practices beneficial to the turtles (Lee et al. 2001).
- Restore native vegetation in between wet habitats and drier uplands.

2.6.4 Patch Size and Configuration

Large wetlands are likely to host a greater number of small mammal species.

- Small mammal species richness increased with wetland size (Francl and Castleberry 2004).
- Meadow Vole abundance was not related to patch size but meadow voles were not detected in wetlands smaller than 1.3 ha (Francl and Castleberry 2004).

Species abundance and habitat diversity is likely to be greater in large bogs than in smaller ones.

- Conservation efforts should focus on large wet meadows because, in this study, the abundance of and occupancy by several species was greater in large meadows. Also, the suite of habitat features required by species are more likely to be present over time in large patches (Riffell et al. 2001).

Protecting networks of Bog Turtle habitats, and streams that connect them, will allow for gene flow within and among populations.

- Chase et al. (1989) recommended protecting networks of wetlands to allow gene flow and movement.
- "Secure five important sites and any number of secondary sites in a metapopulation. Establish one to two metapopulations in each county or sub-watershed unit. This would provide tangible results on which future efforts could build” (Lee et al. 2001).

2.6.5 Movement Corridors

While Bog Turtles spend most of their time close to one breeding site, long distance movements of over 4000 m (2.5 mi) have been reported.

- Bog Turtle metapopulations usually include sites that are less than 1.6 km (1.0 mi) from each other with stream corridors that turtles can freely move through connecting them (Herman 2003).
- One female Bog Turtle was observed moving at least 4000 m (2.5 mi) or 4800 m (3.0 mi), depending on its route (Herman 2003).

- A male Bog Turtle in Tennessee moved from 3600 m to 4000 m (2.25 - 2.50 mi) between two wetlands, depending on which route he took (Herman 2003).
- Bog Turtles have been observed moving distances greater than 400 m (0.25 mi) from their initial capture site (a bog turtle habitat) (Herman 2003).
- An adult Bog Turtle was found 2,700 m from where it had been captured during the previous year (Carter et al. 2000).
- Somers et al. (2007) opportunistically tracked a Bog Turtle that moved more than 800 m along a stream.
- Bog Turtles have been documented moving 750 m from their natal bogs (Herman 2003).
- A Bog Turtle was found at least 1600 m (1.0 mi) from the nearest know turtle habitat (Herman 2003).
- One Bog Turtle was recorded moving either 2400 m (1.5 mi) or 2640 m (1.65 mi) between wetlands, depending on whether or not she followed streams between the sites or moved across dry land (Herman 2003).

Bog Turtles use streams to move between wetlands but can also move through forested habitats.

- Chase et al. (1989) observed Bog Turtles using streams while moving from one wetland to another.
- Bog Turtles have been observed moving through small rocky streams, spring-heads, and hemlock, rosebay forests (Herman 2003).

Recommendations from the literature

- Since Bog Turtles are capable of moving long distances, drainage systems and dispersal corridors should be maintained between populations (Morrow et al. 2001).
- When planning roads, include culverts or bridges that allow turtles to safely cross them (Bailey et al. 2006).

2.6.6 Adjacent Landscape

High proportions of deciduous forest in the landscape surrounding wetlands benefit Southern Bog Lemmings, but avian species richness is higher at wetlands with a greater variety of habitats in the surrounding landscape.

- More Southern Bog Lemmings were captured at wetlands with more deciduous forest within 1000 m of them, but small mammal species richness decreased with the proportion of mixed coniferous and deciduous forest cover within 1000 m (Francl and Castleberry 2004).
- In an analysis of one of two years of data, species richness of wetland-nesters was positively associated with a landscape context composed of lake, streams, and wet meadows versus forested wetlands (Riffell et al. 2003).

- Riffell et al. (2003) found that bird species richness and abundance in wet meadows along the Lake Huron shoreline were positively associated with more complex landscape contexts as opposed to simple, forested ones.

Small mammal species richness is negatively correlated with the density of trails in the surrounding landscape.

- Small mammal species richness decreased with increased trail density within 1000 m of wetlands (Francl and Castleberry 2004).

Recommendations from the literature

- Wet meadows located in complex landscape contexts, especially those connected to other types of wetlands, should be given priority over wet meadows in simple contexts (Riffell et al. 2003).

SECTION 3. RIPARIAN HABITATS

3.1 Core Terrestrial Habitat

3.1.1 Amphibians and Reptiles

Studies of terrestrial habitat use by stream breeding salamanders suggest that they sometimes rely on areas as far as 43 m (141 ft) from a stream.

- Samples of stream salamanders adjacent to headwater streams in western North Carolina indicated that 95% of the individuals of the farthest-ranging species. (*Eurycea wilderae*) were within 42.6 m of the stream (Crawford and Semlitsch 2007)
- Larval stream salamander abundance (Southern Two-lined and Black Bellied Salamanders) was low when buffer widths were less than 30 m. Abundance was similar in streams with 30 m buffers and ones with extensive undisturbed forest surrounding them (Peterman and Semlitsch 2009).
- Salamanders in southern Appalachian streams use adjacent terrestrial habitats within 36 m (possibly farther) of the stream (Petranka and Smith 2005).
- Perkins and Hunter (2006) sampled stream salamander habitat use to define a riparian zone around first order streams in Maine. The riparian zone extended 7-9 m from the stream.
- Stream salamanders were found at distances of 33 m from streams (Perkins and Hunter Jr. 2006).
- Longtail Salamanders migrate to upland sites as far as 31 m from streams (Semlitsch and Bodie 2003).
- Northern Two-lined Salamanders use upland areas out to 31 m from streams (Semlitsch and Bodie 2003).

Core terrestrial habitat for reptile species associated with North Carolina's streams and rivers extends as far as 192 m from the water's edge.

- The average distance from water that Chicken Turtles migrated was 95 m (311 ft), and the maximum was 192 m (629 ft) (Semlitsch and Bodie 2003).
- Eastern Ribbon snakes have been documented in areas 173 m from a shoreline (Bell et al. 2007).
- A study of 23 Striped Mud Turtles in Florida measured an average migration distance of 15.6 m and a maximum migration distance of 49 m from the water's edge (Semlitsch and Bodie 2003).
- A study of Spiny Softshells in Indiana found that they usually migrated 2 m from the water's edge while a study in Arkansas documented migration distances up to 3 m from water (Semlitsch and Bodie 2003).

Recommendations from the literature

- Crawford and Semlitsch (2007) recommended preserving a 92.6 m forested buffer on each side of southern Appalachian streams (42.6 m of core terrestrial habitat plus 50 m buffer).
- Maintain 30-35 m of forested, core terrestrial habitat adjacent to southern Appalachian streams, as well as a forested buffer for the core terrestrial habitat. A buffer width of 10-25 m may be necessary depending on the adjacent land use, with a larger buffer being necessary for highly disturbed or developed edges (Petranka and Smith 2005).
- 230 m buffers should be used to preserve terrestrial habitat for reptiles (Calhoun et al. 2005).
- Maintain three protected zones around wetlands and streams (Semlitsch and Bodie 2003):
    - Aquatic buffer: out to 30 – 60 m from water's edge
    - Core habitat: 142 – 289 m from water's edge
    - Terrestrial buffer: 50 m from edge of core habitat buffer

3.1.2 Birds

Riparian buffer widths between 100 and 175 m are likely to preserve suitable patches of habitat for a large proportion of bird species. Smaller buffer widths, especially in developed landscape, would be insufficient for forest-associated species.

- In a study of bird diversity in six riparian habitats, 90 to 95% of bird species were found within 100 to 175 m (328 to 574 ft) of the stream, depending on the site (Spackman and Hughes 1995). However, the authors did not recommend a single buffer width for conservation of bird diversity because of variability in the spatial distribution of birds between streams.
- Leaving a riparian buffer of 15 - 23 m in a clearcut landscape maintained habitat for some mature forest-associated bird species, but other species disappeared (Wenger 1999).
- Acadian Flycatchers, American Redstarts, Kentucky Warblers, Northern Parulas, Red-eyed Vireos, Ovenbirds, Wood Thrushes, and Yellow-throated Warblers were

only found in forested-riparian areas that were greater than 95 m wide (no study sites were between 95 and 400 m wide) (Peak and Thompson 2006).
- Forested riparian areas that were 60 m wide did not provide suitable habitat for forest song birds, and partial cuts, clearcuts, and clearcuts of adjacent upland habitats without cutting in riparian forests all negatively impacted Ovenbirds, Black-throated Green Warblers, and Wood Thrushes, which are all associated with mature forests (Hanowski et al. 2005).

Overall bird diversity and the probability of occurrence for some species both increase with riparian buffer width.

- Wider bottomland hardwood forests had greater bird diversity regardless of whether or not upland habitats were scrub-shrub or pine (Wenger 1999).
- Neotropical migrant bird diversity increases with riparian buffer width (Hodges and Krementz 1996, Wenger 1999).
- Peak and Thompson (2006) found more bird species in wide than in narrow forested-riparian areas.
- The probabilities of occurrence for Acadian Flycatchers, Prothonotary Warblers, White-eyed Vireos, and Red-eyed Vireos are positively correlated with riparian buffer width (Hodges and Krementz 1996).

Bird densities do not always increase with buffer width.

- Hodges and Kremetz (1996) found that the densities of Acadian Flycatcher, Blue-gray Gnatcatcher, Northern Parula, Prothonotary Warbler, Red-eyed Vireo, and White-eyed Vireo did not increase with riparian corridor width.
- One study of riparian buffers up to 70 m wide found that densities of all bird species increased with buffer width (Wenger 1999).

Even wide riparian corridors can have elevated rates of bird nest failure because of land use practices in adjacent areas.

- Nest success in forested corridors can be low due to predation by species associated with agriculture, even in riparian corridors 530 m wide (Peak et al. 2004).

Recommendations from the literature

- Wenger (1996) reported recommendations for buffer widths needed for preserving bird populations that ranged from 15 to 100 m.
- Riparian buffers of 100 m (330 ft) along rivers in the southeastern coastal plains should be sufficient to support populations of neotropical migrant forest birds (Hodges and Krementz 1996).
- “To conserve forest area-sensitive species in agricultural landscapes located throughout the Midwest, retain forested-riparian areas greater than or equal to 400 m in width, and when possible, increase the width of all forested-riparian areas (Peak and Thompson 2006).”

3.2 Adjacent Landscape

For stream salamanders, features of the adjacent landscape and surrounding watershed can be just as limiting as features of the streams and core terrestrial habitat.

- Stream salamander diversity was negatively affected by canopy loss associated with roads and this effect was greater than any barrier effects of culverts (Ward et al. 2008).
- Stream salamander abundance and percent disturbed habitat within 61 m of the stream were only loosely correlated. Much stronger negative correlations existed between stream salamander abundance (*Desmognathus fuscus and Eurycea cirrigera*) and the percentage of the entire watershed composed of disturbed habitat (Willson and Dorcas 2003).

Some studies have found linear relationships between salamander abundance and development in the watershed but one study found a threshold response at 20% disturbed habitat in the landscape.

- Southern Two-lined Salamander (*Eurycea cirrigera*) abundance decreased linearly as the impervious surface levels in stream catchments increased (Miller et al. 2007).
- Willson and Dorcas (2003) examined two species of stream salamanders' relationships with the percentage of disturbed habitat in the landscape and found that one, Southern Two-lined Salamander (*Eurycea cirrigera*), exhibited a threshold effect at 20% while the other, Northern Dusky Salamander (*Desmognathus fuscus*), showed a negative and linear relationship with abundance.

SECTION 4. LONGLEAF PINE HABITAT

4.1 Patch Size

Red-cockaded Woodpecker home range sizes vary by region and are generally smaller in higher quality pine woodland habitat. The largest reported territory was 225 ha, the smallest was 14 ha, and the range wide mean (from 16 studies) is 75 ha.

- Red-cockaded Woodpecker home range size is inversely related with habitat quality so that smaller territories are needed in areas with high quality habitat (USFWS 2003).
- Red-cockaded Woodpeckers expand their home ranges during the nonbreeding season so that annual and nonbreeding home ranges are larger than breeding season home ranges (Wood et al. 2008).
- Habitat fragmentation is expected to considerably decrease Red-cockaded Woodpecker population growth when there are fewer than 50 territories in the landscape (Bruggeman and Jones 2008).

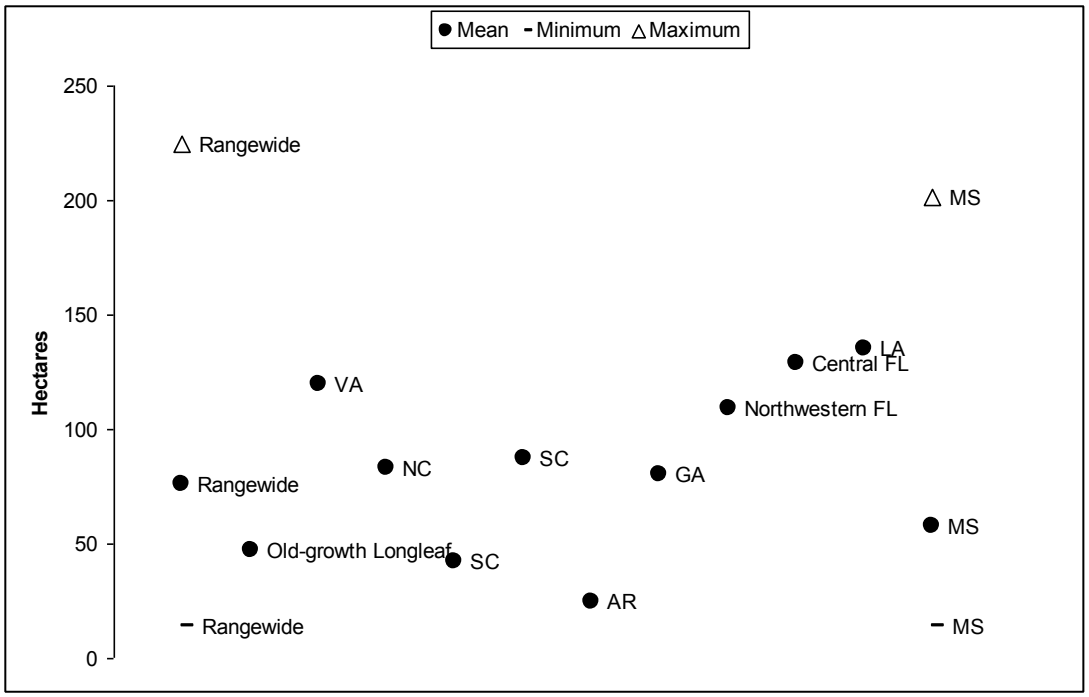


Figure 4. Mean, minimum, and maximum home range sizes of Red-cockaded Woodpeckers reported by Wood et al. (2008) and the US Fish and Wildlife Service (2003) for different regions.

- The range wide mean of Red-cockaded Woodpecker territories reported in the literature is 76.1 ha, and home range sizes from 14 to 225 ha have been reported in the literature (Wood et al. 2008).
- Wood et al. (2008) estimated the mean annual home range of Red-cockaded Woodpeckers in Mississippi loblolly pine forests to be 58.4 ha (SE = 4.5). Annual home ranges were between 14.4 and 201.5 ha.
- The US Fish and Wildlife Service's Red-cockaded Woodpecker recovery plan (2003) states that woodpecker clusters require between 40.5 and 161.9 ha of habitat and also reports the following mean home range sizes.
    - South Carolina: 87 ha
    - Central Florida: 129 ha
    - Northwest Florida: 109 ha
    - Georgia: 80 ha
    - Virginia: 120 ha
    - North Carolina: 83 ha
    - Longleaf pine forest: 47 ha
- Skorupa and McFarlane (1976) reported a mean annual home range of 41.9 ha for Red-cockaded Woodpeckers in mixed pine forests of South Carolina.
- Doster and James (1998) reported a mean annual home range of 24.8 ha for Red-cockaded Woodpeckers in Arkansas.
- Jackson and Parris (1995) reported a mean annual home range of 135 ha for Red-cockaded Woodpeckers in mixed pine forests in Louisiana.

Northern Pine Snake territories can be as large as 272 ha, but they can utilize a variety of woodland habitats. Coachwhip territories can be as large as 268 ha. Southern Hognose Snakes have much smaller home ranges (mean = 4.5 ha).

- Coachwhip territories (minimum convex polygon) in a Texas oak savanna were as large as 142.1 to 268.4 ha and the average home range size was 70.4 ha (SE = 83.8) (Johnson et al. 2007b).
- Northern Pine Snake home ranges are larger for males (mean = 100 ha) than for females (mean = 50 ha), and they utilized xeric longleaf pine forest, turkey oak forests, and early successional habitats (Woodward and Doerr 2007). The smallest home range reported was 11.5 ha and the largest was 272.1 ha.
- The average home range size for Southern Hognose Snakes in the Sandhills of North Carolina is 4.5 ha (range = 3 to 10.5 ha) (Woodward and Doerr 2007).

Fox Squirrels do not appear to be negatively impacted by urbanization.

- Moore and Swihart (2005) found that Fox Squirrels were more likely to occur in isolated forest fragments.
- Salsbury (2008) found that Fox Squirrel nest densities were similar in small and large woodlots in a suburban landscape and concluded that squirrel density is not negatively affected by urbanization.

Red-cockaded Woodpecker territories are considered isolated when they are more than 4 km apart because although some individuals have been observed dispersing long distances, most dispersing individuals only travel much shorter distances.

- Red-cockaded Woodpeckers have been observed dispersing distances greater than 100 km in their first year of life, but most individuals travel much shorter distances (USFWS 2003).
- In their development of maps of the functional heterogeneity of a Texas landscape for Red-cockaded Woodpeckers, Azevedo et al. (2000) designated a separation distance of 4.1 km (at which territories become isolated) for patches of habitat based on flight distance measurements by Walters et al. (1988).
- Cox and Engstrom (2001) estimated that populations of Red-cockaded Woodpeckers have a good chance of persistence when they consist of more than 120 territories that are spatially aggregated, and they recommended maintaining groups of more than seven active clusters (family groups containing breeding adults) that are within 2 km of each other.

Prescribed fires and the smoke that it produces pose risks to nearby developments and their inhabitants (Mobley 1976, Andreu and Hermansen-Baez 2008)

Management recommendations from the scientific literature

- Use management and site preparation techniques, such as fire and chemical applications, that minimize soil disturbance and maintain herbaceous ground cover (Bailey et al. 2006).
- Harvest timber during dry periods rather than during wet ones (Bailey et al. 2006).
- Leave stumps, some logs, dead standing snags, and other coarse wood debris following timber harvests (Bailey et al. 2006).
- Restore natural fire frequency, seasonality, and (where feasible) intensity.
- Retain old stumps, especially longleaf pine "lighter stumps" (Bailey et al. 2006).

4.2 Landscape Issues

Studies of road effects on amphibians and reptiles suggest that a traffic level of 2,000 vehicles per day is a threshold level above which local populations of amphibians and snakes are reduced, the risk of mortality for individual amphibians approaches 100 percent, and the risk of mortality for individual snakes crossing roads approaches 80 percent. The traffic level below which local populations of amphibians and reptiles are unaffected, therefore, must be under 2,000 vehicles per day.

- In his road-cruising study in the Sandhills Region of North Carolina, Sutherland (2009) found that amphibian encounter rates were much lower at road segments with traffic densities over 303 cars per day per 30 m map pixel than at segments with traffic densities under 303. Total amphibian encounter rates decreased abruptly when traffic levels exceeded 2,000 vehicles per day, and the encounter rates for nocturnal snakes along roads in the North Carolina Sandhills dropped when traffic levels rose above 2,048 vehicles per day.
- Hels & Buchwald (2001) estimated the probability of mortality for amphibians at different traffic intensities in Denmark. Slow moving species had probabilities of mortality that were close to one at a traffic intensity level of 2,000 vehicles per day. There was a general trend of steep incline in the chances of dying up to around 2,000 vehicles, above which amphibians would almost certainly be killed (Hels and Buchwald 2001).
- Andrews & Gibbons (2005) used measurements of snake movement rates and behavioral responses to cars to estimate the probability of mortality for Timber Rattlesnakes crossing roads. They estimated that the probability of mortality was over 80% at a traffic level of 2,000 vehicles per day and near 100% at a level of 9,000 vehicles per day.
- It only takes between 500 and 2,000 cars per day to seriously reduce detection rates for snakes and amphibians (Sutherland 2009).

Once the proportion of suitable Red-cockaded Woodpecker habitat in the landscape drops below 70 percent, the selection of sites for protection should consider the spatial distribution of woodpecker clusters in order to maximize the positive effects of new habitats on woodpecker populations.

- Cox and Engstrom's (2001) demographic model for Red-cockaded Woodpeckers suggested that random selection of properties for conservation was nearly as

effective as strategic selection once the proportion of the landscape that was suitable habitat reached between 60 and 70%.

SECTION 5. UPLAND FOREST HABITAT

5.1 Area-Sensitivity

Many forest birds that breed in North Carolina are sensitive to habitat patch size.

- The following species are moderately area-sensitive: Yellow-billed Cuckoo, Black-billed Cuckoo, Hairy Woodpecker, Acadian Flycatcher, Scarlet Tanager, Summer Tanager, Red-eyed Vireo, Northern Parula, Yellow-throated Warbler, Louisiana Waterthrush, Kentucky Warbler, White-breasted Nuthatch, Tufted Titmouse, Blue-gray Gnatcatcher, Wood Thrush (Herkert et al. 1993).
- Highly sensitive forest bird species include: Broad-winged Hawk, Pileated Woodpecker, Least Flycatcher, Yellow-throated Vireo, Black-and-white Warbler, Worm-eating Warbler, Cerulean Warbler, Ovenbird, Mourning Warbler, Hooded Warbler, American Redstart, Brown Creeper, Veery (Herkert et al. 1993).
- Parker et al.'s (2005) meta anaylsis patch size effects on forest birds found significant negative patch size effects on the probability of Black-throated Green Warbler, Cerulean Warbler, Northern Parula, Northern Waterthrush, Ovenbird, Red-eyed Vireo, Rose-breasted Grosbeak, Scarlet Tanager, Veery, White-eyed Vireo, Worm-eating Warbler, and Yellow-billed Cuckoo occurrence.
- Ovenbird, Wood Thrush, and Red-eyed Vireo densities in Ottawa Canada all decrease with increasing patch size (Lee et al. 2002).

5.2 Landscape composition

Higher rates of area-sensitive forest bird occurrence, abundance, and reproductive success have been reported at sites surrounded by greater amounts of unfragmented forest cover.

- Rates of brood parasitism vary with the amount of agricultural lands in the landscape (Faaborg et al. 1995).
- Of the 15 variables Robbins et al. (1989) assessed, proportion of habitat within 2 km was generally the most common predictor of occurrence among 75 species of forest birds analyzed.
- The annual survival rates of Ovenbirds in boreal forest patches located within agricultural landscapes was lower than in patches within continuous forest or areas where timber was harvested (Bayne and Hobson 2002).
- Ovenbirds nesting in small forest fragments in a suburban, forested landscape had higher reproductive success than those nesting in small fragments in agricultural landscapes due to differences in rates of nest parasitism (Hersek et al. 2002).
- Ovenbird densities and reproductive success were lower in a fragmented Missouri landscape than in an unfragmented one (Porneluzi and Faaborg 1999). The pairing success of Ovenbirds did not differ between fragmented and unfragmented sites.

- Roberts and Norment (1999) found that surrounding forest cover within 1 km of study sites positively influenced Scarlet Tanager breeding success (Roberts and Norment 1999).

Estimates of the minimum percent forest cover in the landscape (within 2,000 km of patches) vary. Cerulean and Hooded Warblers need extensive forest cover (close to 100%) while minimums for other species are between 10 and 67%.

Forest birds
- Nine of 15 forest songbird species examined by Betts et al. (2007) exhibited thresholds in occurrence with increasing amounts of habitat in the landscape. Thresholds at the 2,000 m extent for species found in the southern Appalachians ranged from 22 to 48% (mean = 26.6, SE = 6.6) were lowest for Common Yellowthroats and Black-throated Blue Warblers, and were highest for Magnolia and Nashville Warblers (Betts et al. 2007).
- DeMeo (1999) did not find an effect of the proportion of habitat in the landscape on forest bird abundance, species richness, or nesting success in a landscape with more than 42% core habitat (habitat > 100 m from edges) except for Hooded Warblers.

Acadian Flycatcher
- Vance et al. (2003) estimated a 50% chance of Acadian Flycatchers occurring when 53% of the landscape is forested.

Cerulean Warbler
- Vance et al. (2003) estimated a 50% chance of Cerulean Warbler occurrence when 99 % of the landscape was forested.

Hooded Warbler
- Hooded Warbler abundance was affected by the amount of habitat in a landscape with more than 42% habitat > 100 m from edges (DeMeo 1999).
- (Vance et al. 2003) estimated a 50% chance of Hooded Warbler occurrence when 78.5 % of the landscape was forested.

Kentucky Warbler
- Vance et al. (2003) estimated a 50% chance of Kentucky Warbler occurrence when 66.5% of the landscape was forested.

Ovenbird
- Ovenbird pairing success was not influenced by the amount of forest cover in the surrounding landscape (Lee et al. 2002).
- Surrounding forest cover and patch size were both important predictors of Ovenbird abundance in Ottawa, Canada, but percent forest cover surrounding habitat patches had a stronger effect than patch size (Lee et al. 2002).

- Betts et al. (2007) estimated threshold values of percent habitat in the landscape for Ovenbird occurrence of 50.58 (SE = 7.83), 22.08 (SE = 4.06), and 30.65 (SE = 5.08) at the 150 m, 1000 m, and 2000 m extents.
- Vance et al. (2003) estimated a 50% chance of Ovenbird occurrence when 38 % of the landscape was forested.

Scarlet Tanager
- Vance et al. (2003) estimated a 50% chance of Scarlet Tanager occurrence when 26.5% of the landscape was forested.
- Habitat patches become less suitable when percent forest cover in the landscape drops below 30 - 40% and unsuitable when forest cover drops below 10%. If percent forest cover is below 10%, then even large patches will not be suitable (Rosenberg et al. 1999).

Wood Thrush
- Vance et al. (2003) estimated a 50% chance of Wood Thrush occurrence when 10% of the landscape is forested.

Table 1. Summary table of minimum amounts of forest required in the landscape for forest songbirds.

(Note: Most studies examined landscape within 2km of habitat)

Source	Minimum % of forest in the landscape	Response variable	Notes
Forest birds			
DeMeo 1999	>42	Occurrence & reproductive success	42% represents core area: the area > 100 m from edges.
Betts et al. 2007	48	Occurrence	Highest threshold of an Appalachian breeder
Acadian Flycatcher			
Vance et al. 2003	53	Occurrence	50% probability of occurrence
Cerulean Warbler			
Vance et al. 2003	99	Occurrence	50% prob. of occurrence
Hooded Warbler			
Vance et al. 2003	78.5	Occurrence	50% prob. of occurrence
Kentucky Warbler			

Source	Minimum % of forest in the landscape	Response variable	Notes
Vance et al. 2003	66.5	Occurrence	50% prob. of occurrence
Ovenbird			
Vance et al. 2003	38	Occurrence	50% prob. of occurrence
Betts et al. 2007	31	Occurrence	Threshold estimate at 2,000 m extent
Scarlet Tanager			
Vance et al. 2003	26.5	Occurrence	50% prob. of occurrence
Rosenberg et al. 1999	20	Occurrence	This is a minimum below which Tanager detections would be rare.
Wood Thrush			
Vance et al. 2003	10	Occurrence	50% probability of occurrence

The proportion of forest cover in a landscape influences the prominence of edge and patch area effects on area sensitive birds. When the proportion of forest in the landscape within 2km of a patch is below 30-40%, the size of the patch itself becomes more important.

- Ovenbird occurrence was positively influenced by patch size at sites with little habitat in the surrounding landscape (Betts et al. 2007).
- Keyser (2002) examined nest predation rates in relation to distance from edge and landscape context and found that edge effects (higher predation rates) interacted with habitat type surrounding study sites. Nest predation rates were higher close to edges in residential landscapes than in forested landscapes.
- Many species of forest birds are less area sensitive in landscapes with more than 30% forest in the landscape (Freemark et al. 1995).
- Patch size is important for most area sensitive species when the proportion of forest within 2 km of a habitat patch is less than 33%. Ovenbirds were only area sensitive in forest patches that had < 33% forest cover within 2 km. Wood Thrush were not area sensitive in patches with more than 67% forest within 2 km but Scarlet Tanagers were (Robbins et al. 1989).
- In the piedmont, patch size is important for Scarlet Tanagers at all percentages of forest cover. In the Appalachians, patch size only becomes important when percent forest cover is below 40%; if forest cover is over 40%, then any size forest patch will have at least low suitability (Rosenberg et al. 1999).

- In the Midwest, landscapes that remain at least 70% forested tend to minimize adverse effects of fragmentation (Rosenberg et al. 1999).

Table 2. Rosenberg et al.'s (1999) calculated minimum patch area requirements for Scarlet Tanagers

(Note: This was based on 136 study sites in various regions of the eastern US and for a range of percentages of forest cover in the landscape. They collected survey data and information on patch size and forest cover and compared probabilities of occurrence for unfragmented areas with that of different combinations of patch area and percentage of forest cover. They then estimated the patch size that would provide the same probability of occurrence as an unfragmented habitat (high suitability), a probability 25% less than that of unfragmented forest (moderate suitability), and a probability 50% less than that of unfragmented forest (low suitability).

	Minimum area (acres) required for Scarlet Tanagers		
Percentage of forest in 2,500-acre block	**High suitability**	**Moderate suitability**	**Low suitability**
Atlantic coast region (piedmont)			
70	21	4	1
60	62	11	2
50	172	31	5
40	476	86	14
30	NA	249	40
20	NA	NA	129
10	NA	NA	NA
Appalachians (mountains)			
70	Any size	Any size	Any size
60	Any size	Any size	Any size
50	Any size	Any size	Any size
40	25	4	Any size
30	148	26	4
20	NA	185	26
10	NA	NA	NA
NA means acreage values exceed those available at the percentage of forest category.			

5.3 Patch Size

Increased levels of nest parasitism and predation along fragment edges are a key component of relationships between birds and patch size. Edge effects are frequently considered to penetrate 100 m into forest patches but studies have also reported edge effects at distances of 300, 500, and 600 m from edges.

- DeMeo (1999) documented reduced nest survival for forest songbirds nesting within 25 m of open-canopy and partially open-canopy road edges in West Virginia. At open canopy roads, survival increased until at least 500 m from an edge. Similarly, birds placed a majority of nests within 50 m of edges but those within 50 m of edges suffered reduced nest survival rates (DeMeo 1999).
- Parker et al. (2005) found that distance to edge has a correlation with the occurrence of Great-crested Flycatcher, Summer Tanager, and Yellow-billed Cuckoo, a positive correlation with Acadian Flycatcher occurrence, and no effect on the occurrence of 13 other forest bird species included in the study, including American Redstart, Black-throated Blue Warbler, Black-throated Green Warbler, Black and White Warbler, Hooded Warbler, Indigo Bunting, Northern Parula, Ovenbird, Red-eyed Vireo, Rose-breasted Grosbeak, Scarlet Tanager, Veery, and Wood Thrush.
- At an Illinois site, areas within 600 m of edges were population sinks for Acadian Flycatchers because of low reproductive success, showing that edge effects can penetrate far into habitat patches (Hoover et al. 2006).
- Successful Acadian Flycatcher nests were farther from edges than unsuccessful nests (Bakermans and Rodewald 2006).
- Moorman et al. (2002) examined Hooded Warbler nest success in relation to forest edges in a heavily forested landscape and did not find a significant effect of distance to edge on nesting success. However, nearly all of the nest parasitism by Brown-headed Cowbirds that they documented occurred at nests within 100 m of an edge.
- Edge effects on Cerulean Warbler territory densities penetrated forest patches to distances of about 100 m (Weakland and Wood 2005).
- Mazerolle & Hobson (2003) mapped Ovenbird home ranges in a boreal forest patches in Saskatchewan and found that home ranges were distributed toward patch edges.
- Burke and Nol (2000) reported elevated levels of nest parasitism by Brown-headed Cowbirds at Ovenbird nests within 100 m of edges in mature, deciduous forest fragments in Ontario, Canada.
- Ovenbird pairing status in Missouri was positively influenced by patch size and was greater more than 300 m from patch edges than within 300 m of edges (Van Horn et al. 1995).
- Van Horn et al. (1995) recommended excluding edge areas (within 300 m) when calculating minimum-area requirements.

Table 3. Summary table of reported distances that various edge effects penetrate into patches of forest

Source	Distance to edge (m)	Response variable	Notes
Forest birds			
Rosenberg et al. 1999	100	-	
DeMeo 1999	25	Nest survival	Distance to roads

Source	Distance to edge (m)	Response variable	Notes
DeMeo 1999	50	Nest survival	Distance to forest edges
DeMeo 1999	500	Nest survival	Distance at which nest survival stopped increasing
Herkert et al. 1993	100	Enhanced nest predation	
Acadian Flycatcher			
Hoover et al. 2006	600	Reproductive success	
Hooded Warbler			
Moorman et al. 2002	100	Nest parasitism	
Cerulean Warbler			
Weakland & Wood 2005	100	Territory densities	
Ovenbird			
Burke & Nol 2000	100	Nest parasitism	
Van Horn et al. 1995	300	Pairing status	

Studies that have examined patch size requirements without considering the proportion of habitat in the landscape have used different criteria for identifying a minimum patch area and produced a variety of estimates of minimum patch sizes. Thresholds for species occurrence are probably lower (smaller patch sizes) than for successful reproduction. Forests that are more than 3,000 ha will have the best chance of hosting complete forest bird communities. Patches that are 700 ha or more in size will have a 50% chance of hosting Cerulean Warblers. Patches that are 200 ha or more will have a 50% chance of hosting Worm-eating and Black-throated Green Warblers. Nonlinear forests 30 ha or more in area will likely be sufficient in providing interior forest where several area sensitive species will occur and Ovenbirds can successfully nest.

Forest birds

- Threshold values of patch size for reproductive success in Black-and-White Warblers (between 15 and 23 ha) are larger than thresholds for occurrence, territory establishment, and pair formation (Butcher 2008).

- Robbins et al. (1989) found that 3,000 ha is the minimum patch size needed to retain all species of forest songbirds in Maryland.
- Herkert et al. (1993) estimated that the minimum area requirement for moderately area sensitive species was between 16 and 36 ha and was between 120 and 280 ha for highly sensitive species.
- The minimum patch size necessary for area-sensitive forest birds in Missouri is believed to be 340 ha (Van Horn et al. 1995).
- Burke & Nol (2000) recommended preserving forest tracts at least 500 ha in size to provide population source habitats for songbirds associated with forests. They also recommend patches have > 50 ha of core area (the area not subjected to edge effects).
- Midwestern forest fragments between 54 and 65 ha only hosted half of the neotropical forest bird species know to inhabit forests in the region (Freemark et al. 1995).
- Forest fragments under 10 ha are unsuitable for many forest-dwelling neotropical migratory species (Freemark et al. 1995).
- Forest patches should be at least 30 ha to provide interior areas for neotropical migrant forest birds (Freemark et al. 1995).

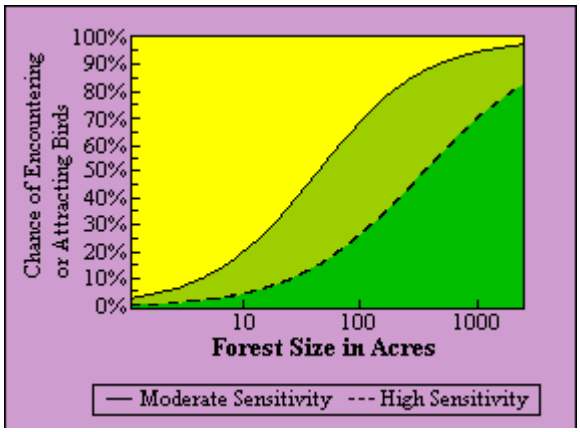


Figure 5. Graph of incidence function for moderately and highly area sensitive forest birds (Herkert et al. 1993).

Acadian Flycatcher

- Robbins et al. (1989) estimated that the minimum area requirement for a 50% probability of Acadian Flycatcher occurrence was 15 ha, and individuals will use forests as small as 0.2 ha. The probability of Acadian Flycatcher occurrence was at its maximum in forest patches over 3,000 ha.

Black-throated Green Warbler

- Askins et al. (1987) did not find Black-throated Green Warblers in patches of forest smaller than 187 ha.

Cerulean Warbler

- Cerulean Warblers inhabited forests as small as 138 ha, but the minimum area requirement for a 50% chance of Cerulean Warblers occurring at a site was 700 ha. The probability of Cerulean Warbler occurrence was greatest in forest patches over 3,000 ha (Robbins et al. 1989).
- Robbins et al. (2009) reported territories sizes of 0.9 +/- 0.1 ha for Cerulean Warblers in Missouri riparian forests (n = 20).
- Oliarnyk and Robertson (1996) reported territory sizes between 0.38 and 2.4 ha (mean = 1.04 ha, SE = 0.16, N = 18) for Cerulean Warblers.
- Askins et al. (1987) did not find Cerulean warblers in patches of forest smaller than 647 ha.
- Cerulean Warbler territories were 6.5 times greater in unfragmented forests than in forests fragmented by clearing created for coal mining (Weakland and Wood 2005).
- Mean territory sizes for Cerulean Warblers reported in the scientific literature include 0.21 ha and 0.98 ha (SE = 0.18, range = 0.23,2.21) (Perkins 2006).

Hooded Warbler

- Rush and Stutchbury (2008) compared the reproductive success of Hooded Warblers in large (155-231 ha) and small (5-29 ha) forest patches in Pennsylvania. The daily nest survival of Hooded Warblers did not differ but nest parasitism by Brown-headed Cowbirds was higher in small forest fragments. The number of young per nest that survived to independence was greater in large forest fragments than in small ones, making nests in large forest patches more productive.

Kentucky Warbler

- The minimum area requirement for Kentucky Warblers based on an incidence function at 50% probability of occurrence was 17 ha. Individuals were not detected in any forest patches less than 9.3 ha in area. Estimated probabilities of occurrence at patch sizes between 0.3 and 3,000 ha in Maryland showed a peak at approximately 320 ha (Robbins et al. 1989).

Ovenbirds

- Ovenbirds' reproductive success was only high enough to compensate for adult mortality in forest fragments with more than 23 ha of forest > 100 m from edges (Burke and Nol 2000).
- Estimated probabilities of Ovenbird occurrence at patch sizes between 0.3 and 3,000 ha in Maryland suggested a threshold at approximately 100 ha (Robbins et al. 1989). Ovenbirds inhabited forest patches as small as 0.8 ha. The minimum area requirement for Ovenbirds based on an incidence function at 50% probability of occurrence was 6 ha. The probability of Ovenbird occurrence was greatest in forest patches that were 450 ha (Robbins et al. 1989).
- Ovenbird pairing success was higher in continuous forest than in patches of forest (Lee et al. 2002).
- Ovenbird territory sizes were on average 2.58 ha (SE = 0.36) in a fragmented landscape and 2.89 ha (SE = 0.11) in an unfragmented forest landscape in Missouri (Porneluzi and Faaborg 1999).

- The average home range size of Ovenbirds in a boreal forest in Saskatchewan was 2 ha (SE = 0.85, n = 21) (Mazerolle and Hobson 2003).

Scarlet Tanager

- Roberts & Norment (1999) found that pairing success, fledging success, and density of Scarlet Tanagers in New York increased with forest patch size.
- The minimum area requirement for Scarlet Tanagers, based on an incidence function at 50% probability of occurrence, was 12 ha, but they inhabited forest patches as small as 2.1 ha. They were most likely to occur in forest patches over 3,000 ha (Robbins et al. 1989).
- No territorial male Scarlet Tanagers were present at study sites in patches less than 10 ha (Roberts and Norment 1999).
- In the Appalachians, forest patches must be at least 10.5 acres in size and percent forest cover surrounding the patch must not be below 10% for the patch to retain even a low level of suitability. In the piedmont, forest patches must be at least 52 acres and forest cover must be above 10% (Rosenberg et al. 1999).

Wood Thrush

- Wood Thrushes inhabited forests as small as 0.2 ha but the minimum area requirement for Wood Thrush based on an incidence function at 50% probability of occurrence was 1.0 ha. The probability of Wood Thrush occurrence was at a maximum in forest patches that were 500 ha. Overall, Their estimated probabilities of Wood Thrush occurrence at patch sizes between 0.3 and 3,000 ha in Maryland suggested a threshold at between 32 and 100 ha (Robbins et al. 1989).
- Patch size was a significant predictor of Wood Thrush abundance but percent of deciduous forest in the surrounding forest was not (Lee et al. 2002).

Worm-eating Warbler

- Askins et al. (1987) only found Worm-eating Warblers in forest fragments larger than 23 ha.
- The minimum area requirement for Worm-eating Warblers based on an incidence function at 50% probability of occurrence was 150 ha. They inhabited forest patches as small as 21 ha, and the probability of Worm-eating Warbler occurrence was greatest in forest patches over 3,000 ha.

Table 4. Summary table of reported minimum patch sizes for focal forest songbird species

Source	Recommended minimum patch size	Response variable	Notes
Forest birds			
Burke & Nol 2000	500	-	Including areas subject to edge effects
Van Horn	340	Occurrence	Citing others.

Source	Recommended minimum patch size	Response variable	Notes
1995			
Freemark et al. 1995	30	-	To provide interior areas
Herkert et al. 1993	16-36	Occurrence	For moderately sensitive species. Based on incidence function and 50% prob. occurrence
Herkert et al. 1993	120-280	Occurrence	For highly sensitive species. Based on incidence function and 50% prob. occurrence
Cornell Lab of Ornithology	3,000	General	Recommendation
Robbins et al. 1989	3,000	Occurrence	For max prob. of hosting all species
Acadian Flycatcher			
Robbins et al. 1989	0.2	Occurrence	Smallest patch size with detection.
Robbins et al. 1989	15	Occurrence	For 50% prob. of occurrence
Black-throated Green Warbler			
Askins et al. 1987	187	Occurrence	Smallest patch where they occurred
Cerulean Warbler			
Robbins et al. 1989	700	Occurrence	Used incidence function for 50% probability of occurrence
Askins et al. 1987	647	Occurrence	Smallest patch where they occurred
Robbins et al. 1989	138	Occurrence	Smallest patch where they occurred
Kentucky Warbler			
Robbins et al. 1989	17	Occurrence	Based on incidence function at 50% prob. of occurrence
Robbins et al. 1989	9.3	Occurrence	Smallest patch size with a detection
Robbins et al. 1989	320	Occurrence	Maximum prob. of occurrence
Ovenbird			
Galli et al.	4 ha	-	Central NJ

Source	Recommended minimum patch size	Response variable	Notes
1976			
Hayden et al. 1985	300 ha	-	Central Missouri
Robbins 1979	2,650 ha	-	Eastern Maryland
Burke & Nol 2000	23 +	Reproductive success	Not including areas within 100 m of edge
Robbins et al. 1989	6	Occurrence	Based on incidence function at 50% prob. occurrence
Robbins et al. 1989	100	Occurrence	Based on threshold in incidence curve
Robbins et al. 1989	0.8	Occurrence	Smallest patch size with a detection.
Robbins et al. 1989	450	Occurrence	Based on size w/ maximum prob. occurrence
Scarlet Tanager			
Robbins et al. 1989	12	Occurrence	Based on incidence function at 50% prob. of occurrence
Rosenberg et al. 1999	10.5	Occurrence	For low suitability in mountains
Rosenberg et al. 1999	52	Occurrence	For low suitability in piedmont
Robbins et al. 1989	2.1	Occurrence	Smallest patch size with a detection
Roberts & Norment 1999	10	Breeding activity	Smallest patch size with a territorial male.
Wood Thrush			
Robbins et al. 1989	1	Occurrence	Based on incidence function at 50% probability of occurrence.
Robbins et al. 1989	500	Occurrence	Patch size with maximum occurrence
Robbins et al. 1989	100	Occurrence	Based on threshold in incidence curve.
Worm-eating Warbler			
Askins et al. 1987	32	Occurrence	Smallest patch size with a detection
Robbins et al. 1987	21	Occurrence	Smallest patch size with a detection
Robbins et al. 1987	150	Occurrence	Based on incidence function at 50% probability of occurrence

In linear forest patches, patch width is an important factor for forest birds. Minimum forest widths reported in the literature are near 100 m, but widths over 400 m have also been recommended.

- Bakermans and Rodewald (2006) examined factors affecting Acadian Flycatcher abundance and productivity in bottomland hardwood forests at multiple scales and found that urbanization in the surrounding landscape was the most important factor. Patch size was also important, but minimum forest widths were different for urbanized (105 m) and rural (85 m) landscapes.
- Acadian Flycatchers did not breed successfully in urban forests less than 130 m wide and in rural forests less than 106 m wide (Bakermans and Rodewald 2006).
- Ovenbird numbers remained stable in riparian buffer strips that were > 100 m wide (each side of lakes) following the clearing of adjacent forest (Lambert and Hannon 2000).
- Peak and Thompson (2006) found more bird species in wide (400-530 m) than in narrow (55-95 m) forested-riparian areas. Acadian Flycatchers, American Redstarts, Kentucky Warblers, Northern Parulas, Red-eyed Vireos, Ovenbirds, Wood Thrushes, and Yellow-throated Warblers were only found in forested-riparian areas that were greater than 95 m wide.
- "To conserve forest area-sensitive species I agricultural landscapes located throughout the Midwest, land managers should retain forested-riparian areas greater than or equal to 400 m in width, and when possible, increase the width of all forested-riparian areas" (Peak and Thompson 2006).

SECTION 6. EARLY SUCCESSIONAL HABITAT

6.1 Grassland patch size

A variety of factors influence the density, occupancy, and breeding success of birds in grasslands. Some bird species respond to habitat patch size, but this response varies across regions, years, and landscapes.

- In an agricultural landscape, Grasshopper Sparrow densities were correlated with habitat type in patches but not land use in the surrounding landscape (2009a).
- Murray et al. (2008) did not find a relationship between Grasshopper Sparrow abundance in grassland patches and the proportion of grassland in the adjacent landscape (Murray et al. 2008).
- The type of land cover within 1.2 km of grassland patches influenced the abundance of Grasshopper Sparrows (Renfrew and Ribic 2008).
- Grasshopper Sparrow densities were positively correlated with the amount of grasslands within 200 m of Ribic and Sample's (2001) study sites.
- In an agricultural landscape, Henslow's Sparrow abundance was not correlated with land use outside of grassland patches (Ribic et al. 2009a).

- Murray et al. (2008) did not find a relationship between Henslow's Sparrow abundance in grassland patches and the proportion of grassland in the adjacent landscape.
- Patch size has a stronger influence on grassland bird abundance when there is less grassland in the surrounding landscape (Renfrew and Ribic 2008).
- The area-sensitivity of Grasshopper Sparrows varied across study sites in the northern Great Plains used by Johnson and Igl (2001).
- Grasshopper Sparrow occurrence was area-sensitive with greater occurrence rates in large patches, regardless of the landscape composition (Bakker et al. 2002).
- Densities of Grasshopper Sparrows were higher in large patches (Renfrew and Ribic 2002).
- Grasshopper Sparrow densities were not correlated with field (patch) size (Ribic and Sample 2001).
- Winter and Faaborg (1999) did not find a correlation between Grasshopper Sparrow densities and patch size, but their patches were too large to detect moderate area-sensitivity.
- Murray et al. (2008) did not find a relationship between Henslow's Sparrow abundance in grassland patches and the proportion of grassland in the adjacent landscape. They may have failed to detect relationships between species and specific grassland types.
- Henslow's Sparrow densities in Missouri prairies were positively correlated with patch size, but breeding success was not significantly correlated with patch size (Winter and Faaborg 1999).
- Grassland bird abundance increases with patch size (Renfrew and Ribic 2008).
- As patch size increased, so did bird diversity (Helzer and Jelinski 1999).

Estimates of the minimum patch size needed by grassland species vary among studies.

- Davis (2004) estimated that minimum patch size requirements for Grasshopper Sparrows in native prairies of Saskatchewan were 134 ha (95% CI = 23-544), but noted that patch size requirements are likely to vary among regions due to differences in habitat, landscape composition/fragmentation, and regional abundance. He suggested that edge:area ratio is a better predictor of abundance than patch size.
- 4.8 ha of breeding habitat should be preserved to sustain a breeding pair of Florida Grasshopper Sparrows (Delany and Moore 1995).
- At meadow patches greater than 8 ha, there was a 50% chance of Grasshopper Sparrows occurring. There was a chance of Grasshopper Sparrow occurrence greater than 80% in patches that were at least 25 ha (Helzer and Jelinski 1999).
- Patches of wet meadow that had a perimeter:area ratio less than 0.018 also had a 50% chance of hosting Grasshopper Sparrows. There was an 80 % chance of occurrence in patches with a ratio of approximately 0.010 (Helzer and Jelinski 1999).
- The minimum patch size needed for there to be a 50% chance of Grasshopper Sparrow occurrence was 100 ha (Vickery et al. 1994).
- Walk and Warner (1999) estimated that a patch size of at least 12 ha was needed for there to be a probability of Grasshopper Sparrow occurrence greater than 50%.

- Herkert (1994) reported a minimum patch area requirement of 30 ha for there to be a 50% chance of Grasshopper Sparrow occurrence.
- Swanson (1996) reported estimates of minimum patch size for Grasshopper Sparrows from the scientific literature that were between 1 and 100 ha, and found that their occurrence was highest in patches more than 10 ha in area.
- The average territory size of 30 Florida Grasshopper Sparrows was 1.8 ha (Delany and Moore 1995).
- Florida Grasshopper Sparrow territories were between 0.6 and 4.8 ha (Delany and Moore 1995).
- Bajema and Lima (2001) cited studies that reported minimum patch sizes needed by Henslow's Sparrows that were from 50 - 100 ha, but their own analysis of data from reclaimed strip mine grasslands showed no effect of patch size, patch shape, or landscape composition on Henslow's Sparrow abundance.
- The minimum area requirement for there to be a 50% chance of Henslow's Sparrow occurrence during the breeding season was 75 ha (Walk and Warner 1999).
- Herkert (1994) reported a minimum patch area requirement of 55 ha for there to be a 50% chance of Henslow's Sparrow occurrence.
- Henslow's Sparrow occurrence is greatest in grassland patches that are more than 50 ha (Renfrew and Ribic 2008).

Table 5. Estimates of minimum patch size for area-sensitive, grassland birds reported in scientific literature

(Note: Text in gray is from studies that used proportional sampling, which produces biased results that support area-sensitivity (Horn and Fletcher 2000, Ribic et al. 2009b)

Source	Minimum patch size (ha)	Response variable	Comments
Grasshopper Sparrow			
Davis 2004	23 – 244	Abundance & occurrence	Saskatchewan, Canada, used incidence function and 50% chance of occurrence.
Delany & Moore 1995	4.8	Territory size	For one breeding pair. Authors say estimate is conservative
Helzer & Jelinski 1999	8 or 25	Occurrence	Proportional sampling, Used incidence function and 50% chance of occurrence
Vickery et al. 1994	100	Occurrence	Used incidence function and 50% chance of occurrence.
Walk & Warner 1999	12	Breeding behavior & occurrence	Used incidence function and 50% chance of occurrence.
Herkert 1994	30	Occurrence	Used incidence function and 50% chance of occurrence
Birds of North	30-100	--------	--------

Source	Minimum patch size (ha)	Response variable	Comments
America Online			
Balent & Norment 2003	4	Not given	From Ryan Meyers' review
Kobal 1999	16	Not given	From Ryan Meyers' review
Swanson 1996	1-100	---------	Based on review
Henslow's Sparrow			
Bajema & Lima	50-100	---------	Reporting minimums from literature
Walk & Warner 1999	75	Breeding behavior & occurrence	Proportional sampling, used incidence functions and 50% chance of occurrence.
Herkert 1994	55	Occurrence	Used incidence function and 50% chance of occurrence.
Swanson 1996	> 50	Occurrence	Based on review
Grassland birds			
Vickery et al. 1994	200	Occurrence	For grassland bird communities in Maine
Herkert et al. 1993	50-100	---------	Based on review of published and unpublished research
Perkins et al. 2003	4,000	---------	From Ryan Meyers' review
Cornell Lab of Ornithology	50 – 100	---------	No justification for numbers given (from Herkert et al. 1993?).

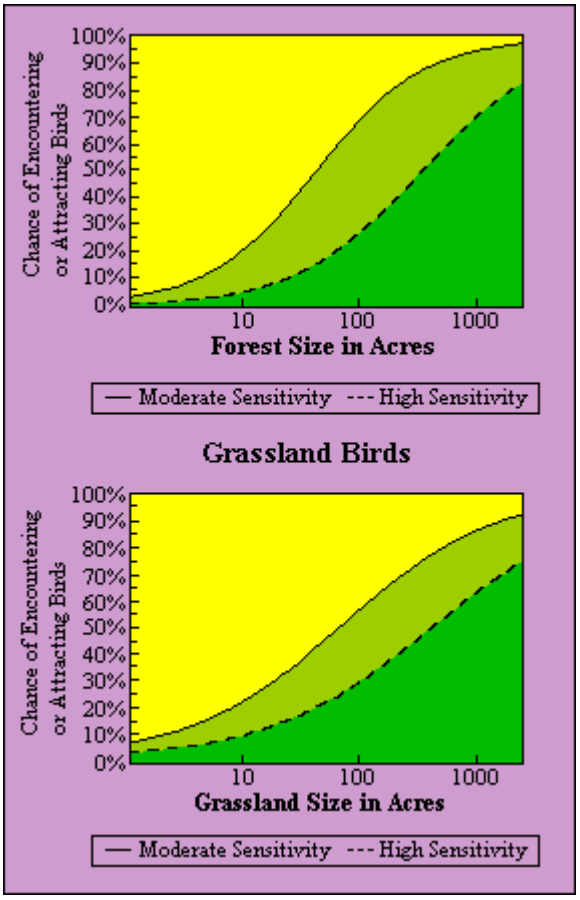
Recommendations from the literature

- Herkert et al. (1993) made the following recommendations regarding area-sensitivity in grasslands
  - Avoid fragmenting existing grassland patches.
  - Grassland restorations aimed at benefiting bird species that are most sensitive to grassland fragmentation should be at least 125 acres and preferably more than 250 acres in area. Smaller plantings less than 50 acres will benefit grassland bird species least sensitive to habitat fragmentation, but much larger tracts are necessary to benefit grassland bird species with high sensitivity to habitat fragmentation.
  - While circular plots are ideal, square plots are preferred to rectangular plots of similar acreage. Avoid establishing restorations with very irregular borders.
  - Where 50 acre or greater contiguous restorations are not possible, establish several smaller scattered restorations. In this design, individual patches should be at least 15-20 acres in size and preferably be located within one mile of each other. It is highly desirable that any adjacent, grassy habitats such as pastures, hayfields, and grassed waterways be incorporated into the

overall design by using them as connections between grassland patches or as non-woody, open edges.

- If hiking trails are to be developed, restrict activities to the edges of the area. Grassland birds are visible and audible from a long distance and supplemental plantings can provide adequate viewing of prairie vegetation.

Figure 6. Estimates of minimum patch sizes for moderately and highly area-sensitive bird species for forest and grassland habitats from Herkert et al. (1993)



6.2 Shrubland Patch Size

Many studies of shrubland birds have failed to find patch size effects on their reproduction, survival, and densities, but a meta analysis found that densities of several species are lower at the edges of patches than in interiors areas.

- Several studies have classified shrubland birds as edge-specialists but Schlossberg and King (2008) conducted a meta analysis of studies on edges and shrubland bird densities and found that several shrubland birds in the eastern US, including Prairie Warblers, Yellow-breasted Chat, Field Sparrow, Indigo Bunting, and American Goldfinch, occur at lower densities along edges (< 30 m from the edge) than interior

areas (> 60 m from the edge), and therefore should benefit from large shrubland patches.
- Rodewald and Vitz (2005) failed to find any difference in the age ratios of common shrubland birds from large (13-16 ha) and small patches (4-8 ha), but Yellow-breasted Chats were more abundant in large patches.
- Askins et al. (2007) examined bird densities in forest openings of a variety of sizes, though all were less than 21 ha, and failed to find any correlation between patch size or landscape variables and bird densities. However two area-sensitive species, Yellow-breasted Chat and Golden-winged Warbler, were absent from all patches.
- Neither species richness nor reproductive success of shrubland birds in South Carolina clearcuts were affected by patch size (Krementz and Christie 2000).
- Yellow-breasted Chat densities in Ohio shrublands increased with patch size, but annual survival and reproductive success were not different in large versus small patches (Lehnen and Rodewald 2009).
- Reproductive success for Yellow-breasted Chats did not differ between isolated and continuous patches of riparian habitat in British Columbia (Morgan et al. 2007).
- Morgan et al. (2007) reported an average Yellow-breasted Chat territory size of 0.25 ha, which was smaller than previously reported territory sizes (0.5-1.0 ha, Dennis 1958; 1.24 ha, Thompson and Nolan 1973).
- In light of their finding that shrubland bird abundance was greater farther away from edges, Rodewald and Vitz (2005) recommended that "managers should make efforts to create patches large enough to contain areas > 50 - 80 m from edges" and favor "square or circular patches rather than rectangular or irregular ones".

SECTION 7. ROCK OUTCROPS, CAVES, AND MINES

7.1 Core Habitat

Hibernating bats are sensitive to repeated disturbances by human activity. Disturbance has a relatively large effect on over-winter survival by causing bats to use energy that they need to make it through the hibernation period. Cave gates that are properly designed do not have significant effects on cave microclimates.

- Human disturbance can cause bats to avoid or abandon roosting sites inside mines and caves (Tuttle and Taylor 1998).
- When a bat is aroused from hibernation by human disturbance, it burns from 10 to 60 days worth of the fat that it needs to survive hibernation through the winter (Tuttle and Taylor 1998).
- Individual-based models of overwinter survival for Little Brown Bats (Myotis luicfugus) indicated that human disturbance had a bigger effect on hibernating bat survival than did winter length. The relationship between the number of disturbances and survival was not linear, so that a small number of (non-tactile) disturbances had little effect on survival but high disturbance levels had large effects (Boyles and Brack Jr. 2009).

- Indiana Bats that roosted in a cave without human activity lost less weight during the winter than those roosting in other caves with human activity during the winter (Johnson et al. 1998).
- Tactile disturbances have a greater effect on the energy expenditures of hibernating bats than non-tactile disturbances (Speakman et al. 1991).
- "Bat roosts in geologic features are easily disturbed or destroyed. The greatest threats are disturbance from human commercial and recreational activities" (Taylor 2006).
- Martin et al. (2006) tested for differences in the microclimates within Oklahoma caves before and after installing gates but found no biologically significant differences on cave microclimates.

Allegheny Woodrats utilize a core habitat composed of the surface rock community as well as foraging habitat that extends up to 500 m from the rock community although most records of foraging distances fall below 200 m.

- Allegheny Woodrat habitat sites are composed of a surface rock community surrounded by 200 m of foraging habitat (Hassinger et al. 2008).
- During the fall, Allegheny Woodrats at two rock outcrops traveled an average of 54.5 m (SE = 13.0, range = 5.2 - 210.0) and a maximum of 210.0 m from their dens during nocturnal foraging trips (Hornsby et al. 2005).
- The upper end of the range of foraging and non-dispersal movements of Allegheny Woodrats is 500 m from surface rock communities (Ford et al. 2006).
- Allegheny Woodrats will tolerate a variety of macrohabitats (primary, secondary, selective cut, etc.) but they forage in areas with high understory species diversity within these habitat types (Castleberry et al. 2006).
- Castleberry et al. (2001) reported home range estimates for Allegheny Woodrats during summer (mean = 6.5 ha for males, 2.2 ha for females) that were smaller than those reported for woodrats during the fall.
- Hornsby et al. (2005) recorded mean home range sizes of 0.65 ha (SE = 0.20) for Allegheny Woodrats during fall. Home range sizes did not differ by sex, age, or between sites that near harvested or intact forest. Mean home range sizes of 0.18 ha have been reported for female Allegheny Woodrats during the spring (Hornsby et al. 2005).

Most of the populations of Green Salamanders that have been studied winter inside rock outcrops but forage and nest in the surrounding forest. However, there is evidence that some populations do not depend upon rock outcrops.

- Green Salamander clutches have been observed in trees that were more than 750 m from any known rock outcrops and in other places that were not near any rock outcrops. This suggests that some populations of green salamanders are not exclusively dependent upon rock outcrops (Wilson 2003).
- Waldron and Humphries (2005) documented substantial use of forest habitat around rock outcrops by Green Salamanders. They over-wintered in rock outcrops and

moved into surrounding forest during the warm season, using large hardwood trees. Green Salamanders were found in trees up to 42 m from a rock outcrop.

Recommendations from the scientific literature

- Contact the following organizations for assistance with mine management plans or surveys (Tuttle and Taylor 1998).
    - American Cave Conservation Association, P.O. Box 409, Horse Cave, KY 42749, 502-786-1466.
    - Bat Conservation International, www.batcon.org
    - U.S. Fish and Wildlife Service, Asheville Field Office, 160 Zillicoa St., Asheville, NC 28801 – 1038, 704-258-3939.
- Visits into hibernation areas should be brief and never repeated more than once in the same winter (Tuttle and Taylor 1998).
- "Timber harvests near caves and mines should be conducted carefully to avoid impacting roost environments by changing airflow patterns, sun exposure, humidity, groundwater flow or by increasing public access" (Taylor 2006).
- Assess both absolute and relative value of mines as roost sites for bats (Sherwin et al. 2009).
    - Absolute value refers to whether or not a site matches designations of important habitat types (i.e., a roost of endangered bats) that would automatically receive protection.
    - Relative value includes assessing a site's use or quality against what is available in the region.
- Assess the importance of a mine for bats. Consider what species are being addressed, what types of roosts are being investigated (maternity, hibernation, bachelor, mating, night, migratory, hibernation.), and what the number of bats using the cave represents in light of each species biology, population status, and ecology (Sherwin et al. 2009).
- "Management decisions regarding the closure or protection of mines as hibernation roosts should be based on the mine's significance for the region and species – and not on general models that assume simplistic relationships" (Sherwin et al. 2009).
- Before surveying, closing, or gating mines, experts knowledgeable about bats and mine safety should be consulted (Tuttle and Taylor 1998).
- Before surveying, closing, or gating mines, experts knowledgeable about bats and mine safety should be consulted (Tuttle and Taylor 1998).
- Conduct a survey for bats or signs of bat activity within mines and caves before sealing them (Tuttle and Taylor 1998).
- Assess mines for bats by observing entrances rather than internal surveys when possible (Tuttle and Taylor 1998).
- Manage forests within 200 m of surface rock communities to increase mast production for Allegheny Woodrats. Plant native mast-producing trees within 200 m of known Allegheny Woodrat activity centers, promote a diversity of native trees, shrubs, vines, forbs, and fungi, and leave woody material, including felled trees intact (Hassinger et al. 2008).

- A 100 m forested buffer should be kept around rock outcrops with green salamander colonies to protect their habitat from drying out (Petranka 1998).
- For Green Salamander conservation, limit habitat disturbance, provide outreach and conservation incentives to private land owners, and strengthen and enforce restrictions on collecting throughout the Blue Ridge. Developers and land managers should survey for Green Salamander populations and potential habitats during the project planning stages and avoid disturbance to rock-outcrops in general (Wilson 2001).
- Minimize erosion and soil disturbance uphill from surface rock communities because eroded soil can fill crevices that are important for species associated with rocky habitats (Bailey et al. 2006).
- If a rock outcrop is used by Timber Rattlesnakes, remove vegetation that shades the outcrop. If it is used by Green Salamanders, maintain vegetation that shades the outcrop (Bailey et al. 2006).

7.2 Patch configuration

Allegheny Woodrats fit into the metapopulation model where colonies are clustered across the landscape and connectivity between colonies that are closer than the maximum dispersal distance of individuals is important for the long term persistence of colonies. Individual woodrats can move between colonies that are less than 10 km apart.

- Allegheny Woodrat conservation measures should be focused on metapopulations (groups of surface rock communities) rather than on individual rock outcrops (Peles and Wright 2008).
- Allegheny Woodrat habitat sites that are less than 10 km apart should be considered part of the same metapopulation and connectivity between these sites should be protected (Hassinger et al. 2008).

7.3 Corridors

Six km is the maximum recorded dispersal distance by an Allegheny Woodrat but experts on this species think that the true maximum dispersal distance is likely closer to 10 km. However, most successful dispersals involve movements of less than 2.5 km. Annual migration distances for Timber Rattlesnakes vary among studies and sample sizes are usually low. Males typically travel further from den sites than females and have also been found at distances up to 6 km from their hibernaculum. Roads can act as barriers to Timber Rattlesnake movements even at low traffic levels.

- The maximum reported dispersal distance for Allegheny Woodrats is 6 km, but 10 km is a better approximation of the distance at which woodrat habitat sites are isolated. Most successful interhabitat site dispersals involve movements that are less than 2.5 km (Hassinger et al. 2008).
- Timber Rattlesnakes have been documented moving to sites that were 6 km from their hibernacula (Ernst 1992).

- Average dispersal distances for male Timber Rattlesnakes in a Virginia study were 2.45 km for adult males and 2.16 km for adult females (Ernst 1992).
- The mean maximum distance from their hibernacula occupied by Timber Rattlesnakes was 4.07 km. Females' maximum dispersal distance was about half of this (Ernst 1992).
- Male Timber Rattlesnakes in New York dispersed an average of 1.4 km from hibernacula. Females moved an average of 280 m (Ernst 1992).
- Andrews & Gibbons (2005) used data that they collected in the field on snake movement rates and behavioral responses to cars to estimate the probability of mortality for Timber Rattlesnakes crossing roads. They estimated that the probability of mortality was over 80% at a traffic level of 2,000 vehicles per day and near 100% at a level of 9,000 vehicles per day.

Recommendations from the scientific literature

- Protect dispersal corridors between adjacent surface rock communities that are less than 2 km apart (Hassinger et al. 2008).
- Retire and reforest timber sale haul roads within 1 km of occupied Allegheny Woodrat habitat sites and main haul roads that intersect or parallel dispersal corridors less than or equal to 2 km from habitat sites. Maintain as much of a closed tree canopy as possible for the above all existing dirt roads within 2 km of occupied habitat sites to minimize habitat changes that benefit generalist species that compete with or prey upon Allegheny Woodrats (Hassinger et al. 2008)
- Prevent the permanent dissection of the intervening forest when active Allegheny Woodrat habitat sites are within 2 km of a large area (greater than or equal to 100 ha) of nonforest (Hassinger et al. 2008).

7.4 Landscape

Allegheny Woodrat colony persistence appears to be related to the amount of forest within 2 km of surface rock communities.

- Active Allegheny Woodrat colonies are in locations that are near other active colonies, within completely forested landscapes within 1 km, and less surrounded by agriculture and permanent water (Ford et al. 2006)
- Hassinger et al. (1996) found that in the Pennsylvania Ridge and Valley province, Allegheny Woodrat populations within 1 kilometer of the forest edge were 15 times more likely to have declined to zero than those more than 2 kilometers from the forest edge. They concluded that a large, intact forest buffer is important for population persistence.
- Allegheny Woodrat habitat sites are more likely to have inactive colonies if they are less than 1 km from any large (more than 100 ha) non-forested areas than if they are more than 2 km from large non-forested areas (Hassinger et al. 2008).

Responses to humans by nesting Peregrine Falcons are highly variable among individuals and the different stages of their breeding cycle. Nevertheless, human

disturbance has been identified as one factor that can influence the breeding success of Peregrine Falcons.

- Human activities including logging, mining, road construction, and blasting can disrupt Peregrine Falcon breeding activity, but there is great variation in individuals' responses to human activity (Cade et al. 1996).
- Human activity is usually more likely to elicit a response in nesting Peregrine Falcons when it is above or beside of the nest than when it is below it (Cade et al. 1996).
- The suitability and constancy of occupation of cliffs by nesting Peregrine Falcons is influenced by cliff height and the frequency of human disturbance (Ratcliffe 1993).
- Many Peregrines will not leave their eggs if people pass along the foot of the cliff, even when they are clearly visible, but loud noises usually flush the bird (Ratcliffe 1993).
- Peregrine Falcons are less likely to leave their nests in response to human activity as the age of their eggs increases (Ratcliffe 1993). Some individuals will never leave their nests when humans approach them while others will flee and wait until the intruder is more than 500 m away to return to the nest (Ratcliffe 1993).
- Peregrine Falcons that are incubating usually flush in response to humans when prompted to do so by their mate. Once an intruder reaches a critical distance from the nest, usually a few hundred meters, the non-incubating parent takes flight and gives alarm signals that prompt the incubating bird to leave (Ratcliffe 1993).

Recommendations from the scientific literature

- In areas that are managed for Timber Rattlesnakes, clear-cutting should be avoided and select cutting of ten percent or less is preferable (C.R.A.C.M. 2003).
- For Allegheny Woodrat conservation, "at least two-thirds of the foraging buffer's outer perimeter should abut a stand of mature mast-producing trees at any point in time" (Hassinger et al. 2008).
- In areas that are between 200 m and 2 km from surface rock communities, maximize the production of hard mast using long rotations and variable-age tree retention harvesting techniques (Hassinger et al. 2008).
- Establish 2 km wide "landscape protection zone" or a "nondissection buffer" around surface rock communities where commercial forest management is allowed (except within 200 m of the rock community) but roads, right-of-ways, and other forms of permanent fragmentation are discouraged (Hassinger et al. 2008).
- Protect a 2 km buffer of native forested habitat on one or more sides of surface rock communities for Allegheny Woodrat habitat conservation (Hassinger et al. 2008).
- Human activity should be kept one half mile away from breeding Peregrine Falcons (Cade et al. 1996).
- During the breeding season, restrict human activity on cliff rims to areas more than 0.5 mi (0.8 km) from Peregrine Falcon nests (Hays and Milner 1999).
- Restrict human access on or immediately below cliff faces to areas that are more than 0.25-0.5 mi (0.4 - 0.8 km) from nests during the breeding season (Hays and Milner 1999).

- Avoid forestry activity within 0.5 mi (0.8 km) of Peregrine Falcon eyrie cliffs during the breeding season, and do not remove trees on top of the cliff ridge if logging does occur (Hays and Milner 1999).
- Protect all major perches (living and dead trees) around Peregrine Falcon nests because they are used by adults (Hays and Milner 1999).
- Route powerlines away from Peregrine Falcon eyries (Hays and Milner 1999).
- "Where falcon nests are already established in proximity to humans there is no need to eliminate trails, picnic grounds, or other facilities except where the birds are evidently disturbed by the human activities. However, further facilities should not be established within 0.25-0.5 mi (0.4-0.8 km) of the eyries" (Hays and Milner 1999).

SECTION 8. BAT ROOSTS AND MATERNITY COLONIES

Forest bats use clusters of roost sites and usually switch to a new roost every two to five days. The number of roosts needed is unknown. The mean distance between roosts from studies that have reported mean distances from their study sites was 500 m, but the mean distance from one study was 1.1 km. One study documented a maximum distance of 5.8 km traveled between consecutive roosts.

- Most forest-associated bat species change roost sites frequently (Barclay and Kurta 2007).
- "The exact number of roost trees needed to maintain forest-bat populations is unclear and likely varies by forest type and region" (Taylor 2006).
- "Two of the most ubiquitous aspects of the lives of forest bats in North America are that individuals frequently change roosts and that they require multiple trees during a season." The mean time between changing roost sites from the 21 studies that have radio-tracked bats was 2.5 days (SE = 0.2) (Barclay and Kurta 2007).
- Of the 21 radio tracking studies of bat locations, the longest recorded length of time that an individual used the same roost-site was 5.3 days (a lactating Myotis septentrionalis) (Barclay and Kurta 2007).
- Tree-roosting bats usually use 1 - 6 different roosting trees, but some individuals use more than 6 trees (Barclay and Kurta 2007).
- Studies that recorded the number of roosts used by an entire Indiana Bat maternity colony found they used at least 8 - 25 trees per year (Barclay and Kurta 2007).
- Fourteen studies have measured the distances between consecutive roost sites (focusing on 9 species) and the mean distance was 497 m (SE = 97 m). The means of individual studies ranged from 74 to 1,100 m. Indiana Bats have been recorded moving 1 to 5,800 m between consecutive roost sites (Barclay and Kurta 2007).

Tree roosts used by bats are often associated with canopy gaps, usually in tall, large trees.

- Five of 9 studies that estimated canopy closure around roost trees found that female bats roosted in trees with less canopy closure (Barclay and Kurta 2007).

- A meta analysis of studies that examined bats' selection of trees for roosts determined that bats select trees that are taller, larger (DBH), and within more open canopies than random trees (Kalcounis-Ruppell et al. 2005).
- "Bats that roost under the bark or in crevices and cavities of dead trees frequently select the largest available snags, which often extend above the forest canopy" (Taylor 2006).

The distances between day roosts and foraging areas used by bats vary but they appear to be capable of moving several hundred if not thousands of meters to foraging areas. The availability and characteristics of roost sites are often likely to be more important than their proximity to resources in the landscape. However, some studies suggest that roosts are associated with riparian or wetland areas.

- Of 15 studies that documented a distance between capture locations and roosting sites for bats, the average distance was 1.5 km between the roosting site and capture site. Many individuals forage in areas more than 1.5 km from roosts. In light of this, it seems likely that the physical, structural, and thermal characteristics of roost sites are more important than their proximity to features in the immediate landscape. This is because of the relatively small differences in the time and energy required of bats to access resources within a few kilometers of roosts (Barclay and Kurta 2007).
- In a study conducted in Illinois forests, the mean distance between sites where Southeastern Bats were captured and where they roosted was 5.7 km (Barclay and Kurta 2007) .
- The mean distance between sites in South Dakota where Northern Long-eared Bats were captured and where they roosted was 2.2 km (Barclay and Kurta 2007).
- The mean distance between capture and roost sites in New Hampshire was 0.6 km (Barclay and Kurta 2007).
- Four of the 7 studies that examined whether or not bat roosts were located randomly with respect to distance to water have found associations between roost sites and distance to water. One study found that roost sites were farther away from water than random sites (Barclay and Kurta 2007).
- "Bat-foraging activity is often concentrated in riparian zones and in gaps in older, more-diverse forest stands" (Taylor 2006).

Recommendations from the literature

- "The most important action forest landowners can take to maintain bat populations is to provide a continuous supply of potential roost trees." Roost trees "include snags in various stages of deterioration (especially those in early stages of decay), hollow trees and the green and dying tress that can provide future snags" (Taylor 2006).
- "Emphasize larger-diameter snags because they generally remain standing and retain bark longer and support a greater variety of bats and other wildlife than smaller snags" (Taylor 2006).

APPENDIX D.

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APPENDIX E.

SPECIES NOMENCLATURE

Appendix E identifies the common and scientific names of species mentioned in the primary conservation recommendations document. Please note that this is not a comprehensive list of species that will benefit from implementation of the primary document's conservation recommendations. Species identified within the document are merely examples of NC Wildlife Action Plan priority species that will benefit from the suggested conservation actions.

BIRDS:

Scientific Name	Common Name
Aegolius acadius	Northern Saw Whet Owl
Chaetura pelagica	Chimney Swift
Coccyzus americanus	Yellow-billed Cuckoo
Colinus virginianus	Northern Bobwhite Quail
Dendroica cerulea	Cerulean Warbler
Dendroica discolor	Prairie Warbler
Dendroica magnolia	Magnolia Warbler
Dendroica virens waynei	Wayne's Black-throated Green Warbler
Egretta caerulea	Little Blue Heron
Ehaematopus palliatus	American Oystercatcher
Empidonax traillii	Willow Flycatcher
Falco peregrinus	Peregrine Falcon
Helmitheros vermivorus	Worm-eating Warbler
Loxia curvirostra	Red Crossbill
Nyctanassa violacea	Yellow-Crowned Night Heron
Passerina ciris	Eastern Painted Bunting
Picoides borealis	Red-cockaded Woodpecker
Poecile atricapilla	Black-capped Chickadee
Tyto alba	Barn Owl
Vermivora chrysoptera	Golden-Winged Warbler

MAMMALS:

Scientific Name	Common Name
Corynorhinus rafinessquii	Rafinesque's Big-eared Bat
Corynorhinus townsendii virginianus	Virginia Big-eared Bat
Glaucomys sabrinus	Carolina Northern Flying Squirrel
Lasiurus intermedius	Northern Yellow Bat
Myotis grisescens	Gray Bat
Myotis leibii	Small-footed Bat

Myotis septentrionalis	Northern Long-eared Bat
Myotis sodalis	Indiana Bat
Neotoma magister	Alleghany Woodrat
Sciurus niger	Eastern Fox Squirrel
Sorex dispar	Long Tailed Shrew

REPTILES AND AMPHIBIANS:

Scientific Name	Common Name
Ambystoma maculatum	Spotted Salamander
Ambystoma talpoideum	Mole Salamander
Ambystoma tigrinum	Eastern Tiger Salamander
Aneides aenus	Green salamander
Bufo quercicus	Oak Toad
Cemophora coccinea copei	Northern Scarletsnake
Clemmys guttata	Spotted Turtle
Clemmys muhlenbergii	Bog Turtle
Croatalus horridus	Timber Rattlesnake
Desmognathus auriculatus	Southern Dusky Salamander
Desmognathus wrighti	Pigmy Salamander
Deurycea longicauda	Longtail Salamander
Eurycea guttolineata	Three-lined Salamander
Hemidactylium scutatum	Four-toed Salamander
Hyla andersonii	Pine Barrens Treefrog
Hyla gratiosa	Barking Treefrog
Lampropeltis triangulum elapsoides	Outer Banks Kingsnake
Masticophis flagellum	Eastern Coachwhip
Ophisaurus mimicus	Mimic Glass Lizard
Plethodon longicrus	Crevice Salamander
Plethodon welleri	Weller's Salamander
Pseudacris ornata	Ornate Chorus Frog
Rana capito	Carolina Gopher Frog
Scaphiopus holbrokii	Eastern Spadefoot
Stereochilus marginatus	Many-lined Salamander
Thamnophis sauritus sauritus	Common Ribbonsnake

PHOTOGRAPHS BY

FRONT COVER, LARGE PHOTO: Joyce Kilmer Memorial Forest
N.C. Div. of Tourism, Film and Sports Development

FRONT COVER INSETS: Bog turtle, Cerulean warbler, Spotted salamander
N.C. Wildlife Resources Commission, Wikimedia Commons, N.C. Wildlife Resources Commission

PAGE 1, LARGE PHOTO: Bog habitat
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PAGE 1, INSET: Bog turtle
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PAGE 4, LARGE PHOTO: Ephemeral pool habitat
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PAGE 4, INSET: Spotted salamander
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PAGE 9, LARGE PHOTO: Mountain creek habitat
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PAGE 9, INSET: Cerulean warbler
Wikimedia Commons

PAGE 12, LARGE PHOTO: Longleaf pine habitat
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PAGE 12, INSET: Gopher frog
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PAGE 14, LARGE PHOTO: Upland forest habitat
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PAGE 14, INSET: Yellow-billed cuckoo
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PAGE 17, LARGE PHOTO: Early successional habitat
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PAGE 17, INSET: Bobwhite quail
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PAGE 20, LARGE PHOTO: Rocky outcrop habitat
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PAGE 20, INSET: Green salamander
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PAGE 23, LARGE PHOTO: Barn owl
U.S. Fish and Wildlife Service

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