PROCEEDINGS FROM THE

DoD Southeast Region Threatened, Endangered and At-Risk Species Workshop

27 February - 1 March 2007
Cocoa Beach, Florida

DoD EPA DOE SERDP
Strategic Environmental Research and Development Program

ESTCP

DEPARTMENT OF DEFENSE LEGACY PROGRAM

FOREWORD

These proceedings encompass outcomes from the Southeast Region Threatened, Endangered, and At-Risk Species (TER-S) Workshop, and reflect the opinions and views of workshop participants, and not necessarily those of the Department of Defense (DoD). This document is available in PDF format at www.serdp.org/tes/Southeast.

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EXECUTIVE SUMMARY

The Department of Defense (DoD) is responsible for the management of nearly 30 million acres of land as well as substantial waters and air space used for training Military Service personnel and testing their equipment. Throughout the southeastern United States, the military manages dozens of installations that are critical assets for providing military testing and training areas. These same lands and accompanying sea space often also provide habitat for a great diversity of plants and animals, some of which are found only under DoD stewardship.

To facilitate the recovery of listed and at-risk species and to mitigate against the need for new listings, increased attention must be given to the management of these threatened, endangered, and at-risk species (TER-S) from an ecosystem-based perspective. This perspective must encompass the numerous land management jurisdictions throughout the Southeast region, as installations are often located in areas with significant concentrations of urban, agricultural, and industrial use.

Through a collaborative effort, DoD's Strategic Environmental Research and Development Program (SERDP), Environmental Security Technology Certification Program (ESTCP), and Legacy Resource Management Program (Legacy) sponsored the Southeast Region Threatened, Endangered, and At-Risk Species Workshop held 27 February – 1 March 2007 in Cocoa Beach, Florida. This workshop was the second in a planned series of regional TER-S workshops recommended at a June 2005 national symposium addressing TER-S on DoD and adjacent lands (for more information see www.serdp.org/tes).

The specific objectives for the Southeast Region TER-S Workshop were to: 1) assess TER-S management needs within a regional context, with an emphasis on system-level and cross-boundary approaches; 2) assess these approaches for their potential to keep common species common while recovering or enhancing TER-S populations; 3) examine the current state of the science and practice within DoD for such holistic approaches; 4) identify potential partners and existing partnership structures whose focus is, at least in part, meeting TER-S conservation objectives; 5) identify gaps in knowledge, technology, management, and partnerships that, if addressed, could improve implementation of system-level and cross-boundary approaches; and 6) prioritize investment opportunities to address these gaps. To achieve these objectives, workshop sponsors and organizers assembled a broad spectrum of discipline experts from the research and management communities, including federal and state agencies, academia, and the non-governmental conservation community.

The workshop opened with a plenary session consisting of presentations from the 45th Space Wing Command and workshop sponsors. Overviews of white papers on emerging issues in forest health, aquatic priorities, connectivity in fragmented landscapes, and large-scale natural disturbance events such as hurricanes followed.[1] A subsequent tour of Cape Canaveral Air Force Station (CCAFS) enabled participants to view firsthand how DoD natural resource management personnel address the challenge of ensuring that the military can accomplish its mission while simultaneously meeting stewardship responsibilities for TER-S.

[1] White papers were provided to participants prior to the workshop.

Next, through concurrent breakout group discussions, participants identified issues related to ecological systems, infrequent large-scale disturbance events, maintaining connectivity amidst land-use and climate change, impacts from upland restoration, and fire effects and dynamics, as well as opportunities to overcome management challenges and strengthen DoD partnerships with federal and state agencies, academic institutions, and non-governmental organizations throughout the region.

This proceedings document summarizes workshop discussions and identifies priority information gaps. Participants identified both general information gaps and those specific to a particular species, group of species, or ecological system. These distinctions are captured, as appropriate, in the following list of the top 14 recommendations resulting from the workshop.

- Invasive Species Threats to TER-S Conservation
- Reference Conditions for Ecosystem Restoration in Support of TER-S Conservation
- Impacts of Upland Management Actions on Aquatic Systems
- Restoration Efforts within a Watershed Context
- Silviculture and Vegetation Management of On-Site Open-Canopied Pine Ecosystems
- Prescribed Fire in Upland Fire-Maintained Ecosystems
- Strategies for Recovering TER-S over Large Spatial Scales
- Altered Ecological States of Coastal Ecosystems, Climate Change, and TER-S: Proactive Conservation Strategies
- Multi-Scale Watershed Management
- Inventory of Species and Ecological Assessments of Coastal and Blackwater Streams and Their Associated Floodplains
- Partnerships: Development, Sustained Support, Function, and Lessons Learned
- Support Tools for Species Conservation in Southeastern Landscapes
- Data Collection Methodologies (Species and System Level) and Data Storage, Reporting, and Sharing Across Federal, State, and Local Partners
- Coordination of Species and Metapopulation Management

SERDP, ESTCP, and Legacy are using workshop discussions and outcomes to help guide their investments for addressing TER-S and their associated ecosystems in the Southeast. Advancing research priorities and using the resulting information to better manage listed and at-risk species offers a significant opportunity to benefit TER-S populations and sustain military training and testing lands.

Overall, participants gained a better understanding of existing regional partnerships, and established new personal and professional connections through which they can work to better integrate research, management, and collaborative initiatives to benefit TER-S in the region.

TABLE OF CONTENTS

Page

FOREWORD i

EXECUTIVE SUMMARY ii

ACKNOWLEDGEMENTS ix

1.0 INTRODUCTION AND BACKGROUND 1-1
- 1.1 WORKSHOP SPONSORS 1-1
- 1.2 JUNE 2005 SYMPOSIUM AND WORKSHOP ON TER-S ON DOD AND ADJACENT LANDS 1-2
- 1.3 SOUTHEAST REGION 1-4

2.0 APPROACH 2-1
- 2.1 STEERING COMMITTEE 2-1
- 2.2 READ AHEAD MATERIALS 2-1
- 2.3 PARTICIPANTS 2-1
- 2.4 AGENDA ELEMENTS 2-2
- 2.5 FORMATION OF BREAKOUT GROUPS 2-2

3.0 ESTABLISHING A COMMON GROUND: PLENARY SESSION 3-1
- 3.1 MILITARY INSTALLATION PERSPECTIVE 3-1
- 3.2 REGIONAL CHALLENGES AND OPPORTUNITIES 3-2
  - 3.2.1 Emerging Issues in Forest Health: Rare Species in the Southeast U.S. 3-2
  - 3.2.2 Importance of Connectivity at Multiple Scales in Times of Rapid Climate Change 3-3
  - 3.2.3 Large-Scale Disturbances and Ecological Communities in the Southeast U.S. 3-3
  - 3.2.4 Imperiled Aquatic Resources of the Southeastern United States: Status, Threats and Research Needs 3-4
  - 3.2.5 Southeast Regional Partnership for Planning and Sustainability (SERPPAS) 3-4
- 3.3 FIELD TOUR OF CAPE CANAVERAL AIR FORCE STATION 3-5

4.0 SYSTEM LEVEL ISSUES – SESSION I 4-1
- 4.1 COASTAL SYSTEMS 4-1
- 4.2 LONGLEAF PINE AND ASSOCIATED SYSTEMS 4-3
- 4.3 INTEGRATING BOTTOMLAND HARDWOODS, FLOODPLAINS, AND UPLAND SYSTEMS 4-4
- 4.4 INLAND AQUATIC WETLAND SYSTEMS 4-6

5.0 LAND MANAGEMENT AND DYNAMIC ENVIRONMENTS – SESSION II 5-1
- 5.1 MANAGING FOR INFREQUENT LARGE-SCALE NATURAL DISTURBANCE EVENTS 5-1

TABLE OF CONTENTS (continued)

Page

5.2 MAINTAINING CONNECTIVITY AMIDST LAND-USE AND CLIMATE CHANGE 5-3
5.3 ADDRESSING IMPACTS RESULTING FROM UPLAND SYSTEM RESTORATION 5-4
5.4 FIRE EFFECTS AND PATCH DYNAMICS 5-5

6.0 OVERCOMING MANAGEMENT CHALLENGES – SESSION III 6-1
6.1 RESOLVING WATERSHED VERSUS ECOLOGICAL SYSTEM DICHOTOMY 6-1
6.2 BARRIERS TO CROSS-BOUNDARY MANAGEMENT 6-2
6.3 COORDINATED INFORMATION AND DATA SHARING AMONG STAKEHOLDERS 6-4
6.4 MONITORING ACROSS DIFFERENT SPATIAL SCALES 6-5

7.0 SYNTHESIS AND PRIORITIZATION OF NEEDS – SESSION IV 7-1
7.1 SYSTEM-LEVEL NEEDS 7-1
7.2 LAND MANAGEMENT AND DYNAMIC ENVIRONMENT NEEDS 7-2
7.3 OVERCOMING MANAGEMENT CHALLENGES 7-3

8.0 PRIORITY OUTCOMES 8-1
8.1 INVASIVE SPECIES THREATS TO TER-S CONSERVATION 8-1
8.2 REFERENCE CONDITIONS FOR ECOSYSTEM RESTORATION IN SUPPORT OF TER-S CONSERVATION 8-2
8.3 IMPACTS OF UPLAND MANAGEMENT ACTIONS ON AQUATIC SYSTEMS 8-4
8.4 RESTORATION EFFORTS WITHIN A WATERSHED CONTEXT 8-5
8.5 SILVICULTURE AND VEGETATION MANAGEMENT OF ON-SITE OPEN-CANOPIED PINE ECOSYSTEMS 8-6
8.6 PRESCRIBED FIRE IN UPLAND FIRE-MAINTAINED ECOSYSTEMS 8-7
8.7 STRATEGIES FOR RECOVERING TER-S OVER LARGE SPATIAL SCALES 8-9
8.8 ALTERED ECOLOGICAL STATES OF COASTAL ECOSYSTEMS, CLIMATE CHANGE, AND TER-S: PROACTIVE CONSERVATION STRATEGIES 8-10
8.9 MULTI-SCALE WATERSHED MANAGEMENT 8-12
8.10 INVENTORY OF SPECIES AND ECOLOGICAL ASSESSMENTS OF COASTAL AND BLACKWATER STREAMS AND THEIR ASSOCIATED FLOODPLAINS 8-13
8.11 PARTNERSHIPS: DEVELOPMENT, SUSTAINED SUPPORT, FUNCTION, AND LESSONS LEARNED 8-14
8.12 SUPPORT TOOLS FOR SPECIES CONSERVATION IN SOUTHEASTERN LANDSCAPES 8-15

TABLE OF CONTENTS (continued)

Page

8.13 DATA COLLECTION METHODOLOGIES (SPECIES AND SYSTEM LEVEL) AND DATA STORAGE, REPORTING, AND SHARING ACROSS FEDERAL, STATE, AND LOCAL PARTNERS 8-16
8.14 COORDINATION OF SPECIES AND METAPOPULATION MANAGEMENT 8-18

9.0 SUMMARY AND CONCLUSIONS 9-1

APPENDICES

APPENDIX A: PARTICIPANT LIST
APPENDIX B: AGENDA
APPENDIX C: WORKSHOP CHARGE
APPENDIX D: SESSION CHARGES
APPENDIX E: WHITE PAPERS

LIST OF TABLES

Page

Table 1: Contributing Authors i
Table 2: Workshop Steering Committee ix
Table 3: Southeast Region TER-S Workshop Breakout Groups 2-3
Table 4: Elements to Consider in Integrating Bottomland Hardwoods, Floodplains, and Upland Systems. 4-6

LIST OF ACRONYMS

AFB	Air Force Base
BMP	Best Management Practice
CCAFS	Cape Canaveral Air Force Station
COE	Corps of Engineers
CWA	Clean Water Act
DCERP	Defense Coastal/Estuarine Research Program
DISDI	Defense Installation Spatial Data Infrastructure
DoD	Department of Defense
DOT	Department of Transportation
ERDC	Engineer Research and Development Center
ESA	Endangered Species Act
ESTCP	Environmental Security Technology Certification Program
GIS	Geographic Information System
INRMP	Integrated Natural Resources Management Plan
Legacy	Legacy Resource Management Program
LLP	Longleaf Pine
NBII	National Biological Information Infrastructure
NEON	National Ecological Observatory Network
NGO	Non-Governmental Organization
NIS	Non-Native Invasive Species
NOAA	National Oceanic and Atmospheric Administration
OSD	Office of the Secretary of Defense
SEMP	SERDP Ecosystem Management Project
SERDP	Strategic Environmental Research and Development Program
SERPPAS	Southeast Regional Partnership for Planning and Sustainability
TER-S	Threatened, Endangered, and At-Risk Species
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

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The sponsors extend a special thanks to: Keitha Datillo-Bain for organizing and leading the field tour of Cape Canaveral Air Force Station; members of the DoD/FWS Science Forum;[2] and the organizers and steering committee members (see table below) who helped formulate the agenda, identified appropriate participants, and helped formulate priorities.

Table 2: Workshop Steering Committee

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The sponsors also acknowledge the dedicated efforts of individuals from HGL, including Ms. Alison Dalsimer, project manager; Ms. Alicia Shepard, Dr. Leslie Orzetti, and Mr. William Woodson, session rapporteurs; Ms. Karole Braunstein and Ms. Kelly Magathan, logistics coordinators; and Ms. Jane Mallory, DoD Legacy, who also served as session rapporteur.

Finally, the sponsors wish to thank all the event's participants (see Appendix A), without whom this workshop could not have happened.

Cover Photos: launch (www.patrick.af.mil), armadillo (L. Peter Boice), east coast dune sunflower—*Helianthus debilis Nutt.* (Milo Pyne), and Florida scrub jay (Rich Fischer).

[2] The DoD/FWS Science Forum is an R&D working group of the Endangered Species Roundtable – a group of Washington, DC-based policy makers, managers, and others who meet regularly to discuss TER-S relevant issues. Members include representatives from the U.S. Fish and Wildlife Service (USFWS), DoD, Army, Navy, Air Force, and Marines, as well as the Forest Service (FS), Bureau of Land Management (BLM), U.S Geological Survey (USGS), and National Park Service (NPS).

1.0 INTRODUCTION AND BACKGROUND

The Department of Defense (DoD) utilizes nearly 30 million acres of land as well as thousands of miles of waters and air space to conduct missions vital to National Security. These areas provide habitat for a great diversity of plants and animals, some of which are found only in areas within DoD stewardship. In all, DoD personnel are responsible for 320 threatened and endangered species and nearly 550 species at risk. Through improved understanding of these species, their habitats, and relationships to military training and testing activities, DoD can work with stakeholders to enhance species conservation.

This document presents a summary of results from the Southeast Region TER-S Workshop sponsored by the Strategic Environmental Research and Development Program (SERDP), Environmental Security Technology Certification Program (ESTCP), and Legacy Resource Management Program (Legacy). The workshop took place 27 February – 1 March 2007 in Cocoa Beach, Florida. Workshop outcomes will be used to guide SERDP, ESTCP, Legacy and other interested party TER-S related research, demonstration, and management investments over the next three to five years.

1.1 WORKSHOP SPONSORS

SERDP is the DoD's environmental science and technology program, planned and executed in partnership with the Department of Energy and the Environmental Protection Agency, with participation by numerous other federal and non-federal organizations. To address the highest priority issues confronting the Military Services, SERDP focuses on cross-service requirements and pursues high-risk/high-payoff solutions to DoD's most intractable environmental problems. SERDP's investments range from basic research through applied research to exploratory development needs in the areas of Environmental Restoration, Munitions Management, Weapons Systems and Platforms, and Sustainable Infrastructure. SERDP's Sustainable Infrastructure initiative supports research and development (R&D) efforts to: 1) sustain the use of DoD's lands, estuaries, oceans, and air space; 2) protect its valuable natural, cultural, and built infrastructure resources for future generations; 3) comply with legal requirements; and 4) provide compatible multiple uses of its resources.

ESTCP is DoD's environmental technology demonstration and validation program. ESTCP seeks to promote the use of innovative, cost-effective environmental technologies that target DoD's most urgent environmental needs, including range sustainment, through demonstrations at DoD facilities and sites. ESTCP selects lab-proven technologies with broad DoD application for rigorous field trials. These demonstrations document the cost, performance, and market potential of the technology. ESTCP technology demonstrations address DoD environmental needs in the Environmental Restoration, Munitions Management, Sustainable Infrastructure, and Weapons Systems and Platforms focus areas. These technologies provide a return on investment through improved efficiency, reduced liability, and direct cost savings, while enhancing military readiness. Successful technologies supported by ESTCP often have commercial applicability.

Legacy provides DoD funding to efforts that conserve and protect our nation's natural and cultural heritage. The program assists DoD in protecting and enhancing resources while supporting military readiness. Three principles guide the Legacy Program: stewardship,

leadership, and partnership. Stewardship initiatives assist DoD in safeguarding its irreplaceable resources for future generations. By embracing a leadership role as part of the program, DoD serves as a model for respectful use of natural and cultural resources. Through partnerships, Legacy strives to access the knowledge and talents of individuals outside of DoD. This is accomplished through the funding of management-oriented projects that support one or more of the 12 areas of emphasis. The areas supported by Legacy include Readiness and Range Preservation, Cooperative Conservation, Invasive Species Control, and Regional Ecosystem Management.[3]

Through the conservation aspects of the three programs, SERDP, ESTCP, and Legacy help DoD maintain its dual missions of readiness and environmental stewardship. R&D initiatives begun in SERDP may need to be validated through ESTCP and later implemented via Legacy. Likewise, on-the-ground management funded by Legacy may uncover basic R&D needs for future investment through SERDP and ESTCP. Ultimately, the three programs offer an integrative method of utilizing DoD funding to foster natural resource management.

1.2 JUNE 2005 SYMPOSIUM AND WORKSHOP ON TER-S ON DoD AND ADJACENT LANDS

In June 2005, the U.S. Army Corps of Engineers (COE) Engineer Research and Development Center (ERDC), SERDP, Legacy, and other federal and non-federal partners sponsored a national symposium to examine issues related to TER-S on DoD and adjacent lands. The objectives were to:

- present the most up-to-date information on government and academic TER-S research relevant to DoD,
- stimulate collaboration and foster partnerships among participants, and
- identify additional areas of research needed to address TER-S and associated habitat issues facing DoD and other federal land-managing agencies.

Participants included nearly 200 researchers and managers from DoD, all the Military Services, the USFWS, NPS, U.S. Geological Survey, U.S. Department of Agriculture, and various non-profit organizations, state agencies, universities, and private consulting firms. Findings from this event are described in a proceedings document, available at http://www.serdp.org/tes/National/.

The following were specifically identified as high priority TER-S needs:

- **Conduct research on basic species life history and improve biological information.** There is a serious lack of basic biological information for many listed and at-risk plant and animal species. Only through a clear understanding of the species and the stressors that directly impact population health and viability can suitable management protocols be developed.

[3] See www.dodlegacy.org for more information on the *Areas of Emphasis*, and www.denix.osd.mil for the program's bimonthly newsletter.

- **Increase proactive conservation efforts for species at risk.** When considering the threats to already listed and at-risk species, it is evident that additional resources must be focused on proactive conservation measures to prevent additional species listings. Research is needed to properly and fully evaluate the cost-benefits associated with proactive (versus reactive) conservation efforts, especially with respect to the impacts of non-native invasive species. Knowledge gained could then be used to implement appropriate policies and funding initiatives to conserve resources in the long-term.
- **Develop more consistent peer-reviewed data standards and monitoring protocols.** Monitoring protocols, guidelines, and indicators are not fully developed for many TER-S. Additionally, in cases where protocols exist, they do not necessarily provide meaningful data for decision makers. Therefore, research is needed to develop protocols. This must be done using a rigorous scientific approach and peer review process that incorporates how data are to be collected, managed, analyzed, and reported to ensure efficient collection of data elements directly relevant to key management decisions.
- **Improve predictive models to support management decisions.** To manage and conserve TER-S habitat at a regional scale, land managers must apply a complex suite of management measures across a wide landscape in coordination with other regional landowners to achieve ecosystem goals. While several pilot projects have been completed, additional research is needed to refine, validate, and expand these predictive modeling efforts.
- **Improve information-sharing among stakeholders.** Funds available for monitoring and conserving listed species are limited, with no one organization having the ability to collect all of the necessary data or to fully implement regional conservation restoration measures. It is important to be able to leverage conservation-related information and actions across agencies and in partnership with private initiatives. Through the development and application of new technologies based on significant collaboration, it may be possible for TER-S conservation organizations and partners to yield significantly enhanced results.
- **Focus on protection of endangered ecosystems rather than individual species.** There is a need to focus TER-S conservation efforts on the protection of "endangered ecosystems" at a regional scale, rather than managing the biological needs of single species. Research is needed to develop more sophisticated regional management tools and approaches.

Further, it was determined that TER-S issues are fundamentally regional in nature. For example, the decline of Pacific salmon is no more an issue in Illinois than the decline of the desert tortoise is in New Jersey. In response, and to help further refine and implement the 2005 Symposium results, SERDP, ESTCP, and Legacy developed a plan to host a series of regional TER-S workshops.

Symposium participants specifically identified the need for workshops in the following four prioritized regions: Pacific Islands, Southeast, Southwest, and Northwest.[4] Boundaries for the four identified regions were to be determined by location of military installations and key ecological features, rather than on existing but artificial agency boundary determinations.

1.3 SOUTHEAST REGION

The Southeast region was identified at the 2005 Symposium as the second highest priority based on the number of imperiled species and the imminence and magnitude of various threats to them. For the purposes of this workshop, "Southeast" was defined as the historical range of longleaf pine (LLP) habitat, encompassing issues related to the Atlantic and Gulf Coastal plains, bottomland hardwoods, sandhills, and other associated habitats.

Similar to NEON's southeast region,[5] workshop sponsors defined the Southeast TER-S Workshop region to include North Carolina, South Carolina, Georgia, Florida north of the subtropical zone, Alabama, Mississippi, Louisiana, and the very eastern part of Texas. Together, these states support dozens of military installations and hundreds of imperiled species

[4] Symposium participants did not believe a Northeast region workshop was necessary. Also, at this time, there are no plans to conduct a TER-S workshop in the Northwest.
[5] NEON = National Ecological Observatory Network, www.neoninc.org.

2.0 APPROACH

The stated objectives for the Southeast Region TER-S Workshop were to:

- assess TER-S management needs within a regional context, with an emphasis on system-level and cross-boundary approaches;
- assess these approaches for their potential to keep common species common while recovering or enhancing TER-S populations;
- examine the current state of the science and practice within DoD for such holistic approaches;
- identify potential partners and existing partnership structures whose focus is, at least in part, meeting TER-S conservation objectives;
- identify gaps in knowledge, technology, management, and partnerships that if addressed could improve implementation of system-level and cross-boundary approaches; and
- prioritize investment opportunities to address these gaps.

2.1 STEERING COMMITTEE

Invitations were extended to representatives from the various sectors of the endangered species management and research communities to act as a steering committee for the Southeast Region TER-S Workshop. Nine people, including federal, state, and NGO representatives from the Southeast region and Washington, DC, participated in this committee, whose purpose was to act as an information source and guiding force for agenda development. Specifically, members were asked to help define the scope of the workshop, suggest session and white paper topics, and help identify appropriate workshop participants and session chair candidates.

2.2 READ AHEAD MATERIALS

To prepare participants for the workshop, a variety of read-ahead materials were provided. These included general information about military natural resource activities in the region, information about the sponsoring agencies, and a workshop charge (Appendix C) that described the event's goals and objectives. Additionally, breakout group chairs were provided charges specific to their session (Appendix D), and all participants were provided several white papers on topics relevant to workshop breakout sessions. White paper topics included: *Imperiled Aquatic Resources of the Southeastern United States: Status, Threats, and Research Needs; Importance of Connectivity at Multiple Scales in Times of Rapid Climate Change; Large-Scale Disturbance and Ecological Communities in the Southeast US*; and *Emerging Issues in Forest Health*.

2.3 PARTICIPANTS

Based on Science Forum, steering committee, and organizer input, the sponsors invited local and headquarters-level representatives from all of the Military Services, a balance of federal and non-federal field managers, academic researchers, state natural resource personnel, and representatives from various local conservation organizations. Participants represented a diverse

group of knowledgeable discipline experts who could provide the broad technical basis for input to DoD's out-year research, demonstration, and management agenda for TER-S conservation in the Southeast region. In the end, 63 individuals participated in the workshop.

2.4 AGENDA ELEMENTS

In developing the agenda (Appendix B), the steering committee wanted to ensure that participants were given sufficient background information regarding the state of management and science relevant to DoD TER-S in the Southeast to engage in informed and productive working group discussions. To help achieve this goal, the agenda was structured to include 1) presentations from workshop sponsors and the host military installation; 2) overviews of the four commissioned white papers (see 2.2 above); and 3) a field tour of Cape Canaveral Air Force Station (CCAFS).

With these considerations in mind, the first day of the workshop included sponsor agency overviews on SERDP, ESTCP, and Legacy; a welcome address and environmental program overview from Patrick Air Force Base and CCAFS personnel;[6] and two white paper presentations. In the afternoon, attendees participated in a field tour of CCAFS whose prime mission is launching rockets and communications satellites.

The following two days included two additional white paper presentations, an overview of the SERPPAS initiative (www.serppas.org/), and a series of concurrent working sessions in which participants identified and prioritized relevant information. Following the formal workshop, session chairs, speakers, and organizers met to discuss workshop results and proposed recommendations.

2.5 FORMATION OF BREAKOUT GROUPS

The primary objective for this workshop was to develop a prioritized management and research agenda for TER-S in the Southeast region. Participants were asked to discuss the state of the science for endangered species as a basis for determining gaps in current scientific knowledge, identify and roughly prioritize needs, and develop the initial design for a research and management agenda for Southeast TER-S. To accomplish this, attendees participated in four of the twelve topical breakout groups and one of three synthesis groups. Table 3 illustrates how the workshop discussions and focus areas were organized.

[6] Patrick and CCAFS are managed jointly, with Patrick housing most of the personnel and CCAFS accommodating mission and training activities.

Table 3: Southeast Region TER-S Workshop Breakout Groups

Session Name	Breakout Group 1	Breakout Group 2	Breakout Group 3	Breakout Group 4
System-Level Issues	Coastal Systems	Longleaf Pine and Associated Systems (including Fall Line Sandhills)	Integrating Bottomland Hardwoods, Floodplains, and Upland Systems	Inland Aquatic Wetland Systems
Land Management and Dynamic Environments	Managing for Infrequent Large-Scale Natural Disturbance Events	Maintaining Connectivity Amidst Land-use and Climate Change	Addressing Impacts Resulting from Upland System Restoration	Fire Effects and Patch Dynamics
Overcoming Management Challenges	Resolving Watershed vs. Ecological System Dichotomy	Barriers to Cross-Boundary Management	Coordinated Information and Data Sharing Among Stakeholders	Monitoring Across Different Spatial Scales
Synthesis	System Level	Land Management and Dynamic Environments	Overcoming Management Challenges	

3.0 ESTABLISHING A COMMON GROUND: PLENARY SESSION

The first day of the workshop was devoted to providing attendees with background and contextual information. The workshop began with introductions and program summaries by Dr. John A. Hall, SERDP/ESTCP, and Mr. L. Peter Boice, DoD Conservation/Legacy. Dr. Hall and Mr. Boice also detailed the workshop's goals and expected outcomes. These were followed by presentations on Cape Canaveral Air Force Station (CCAFS) and Patrick AFB (which served to educate participants about installation efforts to manage mission and stewardship objectives), overviews of the commissioned white papers, and a field tour of CCAFS.

3.1 MILITARY INSTALLATION PERSPECTIVE

Military personnel face unique challenges in managing for imperiled species while maintaining training and testing mission objectives. To help provide this contextual background, the plenary session opened with presentations from the installation Commander and Chief of Environmental Conservation Programs from Patrick AFB.

Colonel Bouthiller, Patrick Air Force Base

The opening speaker, Vice Commander Colonel Thomas Bouthiller, provided an overview of the specific mission requirements facing Patrick AFB and CCAFS. He provided an overview of the Air Force Space Command (AFSPC) and 45th Space Wing's mission. He described CCAFS' active launch facilities and size (approximately 16,000 total acres—a significant area for the southeastern United States and particularly for coastal Florida, which has been heavily developed in recent years), and the vast areas of airspace they cover (approximately 15 million square miles). He further described a typical spacecraft processing flow, which is vital to the Air Force remaining the preeminent spacecraft processing and launch professional in the world. In addition to launch facilities, CCAFS has range operation assets and facilities. Range operations encompass areas designed to support and assure safe space and ballistic missile launches and other test operations by providing the activities and resources for safety of flight, range instrumentation, infrastructure, and scheduling. Colonel Bouthiller concluded by describing some of the CCAFS' pending launch programs.

Ms. Robin Sutherland, Patrick Air Force Base

Ms. Robin Sutherland is the Chief of Environmental Conservation Programs for the 45th Space Wing at Patrick AFB. She provided an overview of the habitats at Patrick AFB and CCAFS (scrub, coastal, wetland/marsh, hammock, open water), as well as habitats on installation annex lands (flatwoods, grasslands, wetlands, seasonal forests, desert). Her presentation summarized the extensive and award-winning environmental programs at Patrick AFB, including several natural resource management efforts.

Ms. Sutherland described the 45 endangered species under CCAFS and Patrick AFB jurisdiction, and her team's goals and efforts to manage these species. For example, to protect the several species of sea turtles that nest on CCAFS beaches, personnel are revising lighting procedures and projects, identifying the most effective means of trapping predators, monitoring and enhancing

beach dunes to prevent erosion and damage, targeting invasive species that impact nesting habitat, and providing education both to installation personnel and to the community at large.

Other listed species of note mentioned included the Florida scrub jay, gopher tortoise, indigo snake, various sea turtle and migratory bird species, the southeastern beach mouse, and the manatee. Throughout her overview, Ms. Sutherland helped demonstrate how CCAFS personnel are meeting the challenge of ensuring that species are protected in ways that allow the military mission to continue.

3.2 REGIONAL CHALLENGES AND OPPORTUNITIES

The sponsors agreed that it was important to lay a foundation of common understanding among all participants. To achieve this, they commissioned a series of informational white papers, which were available as read-ahead materials prior to the workshop and presented at the workshop. Overviews of these papers are provided here. Papers are available at www.serdp.org/tes/Southeast, unless otherwise noted.

3.2.1 Emerging Issues in Forest Health: Rare Species in the Southeast U.S.

Dr. Sharon Hermann is a visiting Assistant Professor in the Department of Biological Sciences at Auburn University. Her paper outlined emerging issues in forest health for selected Coastal Plain and Fall Line ecosystems in the southeastern United States, concentrating on issues most relevant to conservation of TER-S and emphasizing vertebrate groups. These forests were once dominated by longleaf, slash, and/or shortleaf pine (*Pinus palustris*, *P. elliottii*, and *P. echinata*). To determine which management activities to target, Dr. Hermann and her co-authors evaluated information for TER-S to establish which factor of forest health is most directly related to habitat requirements of the species, which they determined to be forest structure.

For long-term success in conserving TER-S, the authors concluded, there must be an increase in acreage of healthy forest. Factors such as current species composition, degraded soil quality, presence of exotic species, and past fire exclusion can negatively influence habitat structure, and may impede forest restoration efforts. At the landscape scale, enhancing forest health on private property has benefits for TER-S management on nearby public lands. Improved silvicultural information is essential to encourage landowners to manage for open-canopy forest. Modified selection systems and improved growth and yield models are needed to promote economic feasibility of retaining uneven-aged stands. To facilitate regional planning, a geo-referenced mapping effort should be initiated. As part of the mapping effort, reference sites should be identified. Reference stands displaying exemplary forest health are needed to assess the success of restoration efforts, silvicultural activities, and application of prescribed fire. Monitoring of ongoing management activities is required to evaluate local and regional forest health related to TER-S.

Finally, the authors prioritized various facets of forest health, emphasizing the importance of retaining and improving extant open-canopy forests, as well as the significance of restoration efforts. Most relevant to these goals are forestry actions and prescribed fire.

3.2.2 Importance of Connectivity at Multiple Scales in Times of Rapid Climate Change

Dr. Lawrence Harris is an Emeritus Professor in the Department of Wildlife Ecology at the University of Florida. His talk focused on connectivity in fragmented landscapes.

Institutional programs that explicitly call for strategic analyses of environmental research and management are compelled to consider connectivity. There are many types of connectivity, and several are now subsumed under the rubric of Ecosystem Management (i.e., interdisciplinary or trophic connectivity). Most agencies accept obligations attendant to TER-S and the ecosystems that support them. But spatial connections within landscape systems (e.g., sandhills with embedded ephemeral ponds) and connections between and among adjacent ecosystem types (e.g., longleaf pine next to bottomland hardwood forests) are critical to many TER-S populations for primal evolutionary/ecological reasons. Physical connectivity between military installations and other large conservation areas, such as national forests, are increasingly needed as populations of TER-S are first fragmented and ultimately isolated in habitat ghettos that cannot sustain them. Dr. Harris' paper reviews principal scientific concepts of relevance to this topic, and offers questions to distinguish between what is known and what is not.

3.2.3 Large-Scale Disturbances and Ecological Communities in the Southeast U.S.

Dr. Loretta Battaglia is an Assistant Professor in the Plant Biology department at Southern Illinois University Carbondale. Her presentation outlined ecological consequences associated with major environmental events.

The southeastern landscape is one that has been impacted by water, wind, and fire. Large-scale, infrequent disturbances and their interactions are integral forces that shape and drive the highly diverse plant communities of the region. Timing, frequency, intensity, and scale of these events influence community structure and composition from the coast to the mountains. The sequence of, and interactions between, disturbances are increasingly recognized as important factors that can produce unexpected ecological outcomes in these systems. Human-mediated changes in the landscape and climate are expected to alter disturbance regimes, changing the probabilistic distribution of communities across this diverse landscape. Current climate change models predict rising sea level, increased precipitation and flooding, and reduced frequency but increased intensity of fire and hurricane disturbances. Landscape fragmentation, pollution, and introduction of non-native species further change the extent and characteristics of natural disturbances.

Dr. Battaglia suggested that, to the degree possible, management should mimic historic hydrologic and fire regimes to improve structure and function of floodplain and fire-maintained communities. Restoration of coastal ecosystems will help to buffer effects of hurricanes and rising sea level in the short term. In the long term, landscape connectivity and dispersal corridors will be increasingly critical for successful migration of species as their climatic envelopes shift. A better understanding of the ecological role of large-scale infrequent disturbances in historic, modern, and future landscapes of the southeastern region is needed to develop long-term planning for effective management of this disturbance-driven, diverse system.

3.2.4 Imperiled Aquatic Resources of the Southeastern United States: Status, Threats and Research Needs

Ms. Rachel Muir is an aquatic biologist currently working for the U.S. Geological Survey in Reston, Virginia. Her paper detailed available aquatic resource information for the Southeast.

The southeastern United States is a region of high biological diversity, especially in aquatic habitats. A significant portion of aquatic biodiversity is listed as threatened or endangered, or is at risk of needing such listing. It is important that DoD and other federal, state, and private partner organizations determine conservation priorities, identify coordination opportunities, and develop a research and monitoring agenda relevant to DoD managed areas. For aquatic ecosystems, watershed-level approaches are most effective in addressing TER-S conservation. Jurisdictional or property line boundaries are not fundamental management units for freshwater, estuarine, or coastal habitats. In addition, marine habitats do not lend themselves to the same classification schemes of freshwater systems and therefore require a different approach.

This paper identifies aquatic TER-S resources in the Southeast, and addresses priority watersheds, ecosystems, and species within the region. Included in this discussion are: 1) status and trends of southeast TER-S; 2) threats to TER-S and TER-S habitats; 3) priority setting processes for southeastern watersheds; 4) a discussion of how existing partnership efforts address TER-S priorities and how DoD can fit into and complement ongoing efforts, and 5) how aquatic TER-S priorities might be addressed more holistically in concert with improvements in overall watershed management approaches.

3.2.5 Southeast Regional Partnership for Planning and Sustainability (SERPPAS)

To help attendees better understand some of the partnership efforts in which DoD is already engaged in the Southeast, **Ms. Jan Larkin**, Office of the Secretary of Defense (OSD), Range Outreach, described the formation of SERPPAS and the issues driving this collaborative effort.

Encroachment, broadly defined as the impacts from residential and commercial sprawl, is a major problem facing communities nationwide. The issue is especially significant for military installations in the Southeast. Increasing population and movement away from the major metropolitan areas towards once sparsely populated locales near military installations has forced the DoD to deal with new restrictions on training and testing readiness. Issues such as air, noise and light pollution, wilderness and TER-S habitat designations, and commercial development are become problems when population increases and subsequent off-base development begin to put pressure on military needs. A partnering tool developed and enacted by Congress in 2002 authorized military departments to sign agreements with state or local governments or private conservation groups to limit use or development of property near military bases, and preserve habitat to relieve environmental restrictions on military operations.

Created in 2005, SERPPAS identifies and addresses regional sustainability issues that cross federal, state, and local geographic and civil boundaries in the Southeast. The partnership focuses on promoting effective working relationships among its partners, in part by leveraging resources that mutually benefit multiple stakeholders. SERPPAS' strategic goals are to promote improved regional, state and local coordination, and to manage, sustain and enhance natural, economic and

human resources, and national defense. By enhancing local and regional communication and coordination, partners can make better-informed planning decisions and, by maintaining natural resources and habitats in concert with regional economic viability, military testing and training lands can continue to be accessed and utilized. Partners include the states of North Carolina, South Carolina, Georgia, Florida, Alabama, OSD, and the Military Services. NGOs and other federal agencies are also involved in specific project implementation. This partnership has several ongoing projects of note, including:

- Sustainable Community and Military Partnerships;
- Best Management Practices/"How To" Guide for Stakeholder Engagement;
- Southeastern Network of Agriculture/Forestry Lands;
- Marine/Coastal Scoping;
- Mapping bioregions and Stakeholders;
- Sustaining the Land of the Longleaf Pine;
- Red-cockaded Woodpecker and Gopher Tortoise Conservation;
- Alabama-Florida-Georgia Conservation Partnership; and
- Partnerships with Landowners in the Fort Rucker, Whiting Field, Fort Benning area.

3.3 FIELD TOUR OF CAPE CANAVERAL AIR FORCE STATION

The 45th Space Wing Command includes CCAFS, Patrick AFB, and several annexed properties. Patrick AFB is used for housing military personnel, while CCAFS is used primarily for mission-related purposes. CCAFS encompasses 15,800 acres, 9,988 acres of which are undeveloped. Within this area are coastal (dune, grassland, strand), scrub (hydric, xeric), hammock (xeric, hydric, maritime), wetland/marsh (fresh, brackish, marine-intertidal zone), and open water aquatic (fresh, brackish, marine) ecosystems. Patrick AFB is 2,108 acres, 950 acres of which is undeveloped. These lands contain coastal (dune, grassland), wetland/marsh (brackish-saltbush community, marine-intertidal zone), and open water aquatic (fresh, brackish, marine) ecosystems. Of the remaining 4,750 acres of annexed properties, 2,500 acres are currently undeveloped areas of Malabar – flatwoods (hydric, mesic), wetlands (seasonal, depression marshes); JDMTA[7] – scrub (pine, oak-palmetto, Rosemary), Ascension desert (volcanic ash); and Antigua tropical (island seasonal forest, marine and estuarine wetlands, riparian woodland) habitats. The tour of CCAFS included a wide variety of stops so participants could view and, in part, experience some of the installation's mission activities, TER-S habitats, and base initiatives to manage TER-S. Brief descriptions of each stop follow.

- <u>Prime Scrub Habitat</u>: Conducting regular prescribed burns is an important part of CCAFS management, as it not only helps restore Florida scrub jay habitat, but also enhances security and maintains clear launch zones and lines-of-sight. Yet, restoring the native scrub habitat also poses significant challenges, including

[7] Jonathan-Dickinson Missile Tracking Annex (JDMTA) is situated 95 miles south of the Cape near Jupiter, Florida.

overcoming launch mission issues (e.g., smoke and particulate matter from burn activities impacting launch windows and rocket payload clean rooms) and educating base personnel, who may not understand how controlled burns can benefit the fire-dependent scrub ecosystem and reduce fuel loads that ultimately protect infrastructure from wildfire damage.

- Invasive Plant Removal and Scrub Habitat Restoration: Recent CCAFS invasive species control and restoration efforts have had direct positive impacts to a variety of TER-S, including sea turtles, shorebird populations, Southeastern beach mice, and the native coastal systems. Each TER-S of interest is comprehensively monitored, as are coastal impacts from hurricanes and other major storm events.

- Delta Rocket Launch Pads: These pads launch CX 17 Delta rockets. The group learned that there are different types of rockets and satellites launched at this facility, and a number of different groups for whom the military launches satellites (e.g., NASA). One example of the measures CCAFS personnel take to ensure species protection involved relocating a great horned owl chick to the Bird of Prey rehabilitation center for one day to allow for a launch. Following the launch, personnel returned the chick to its nest where it remained until it fledged.

Rocket launch pad as seen from beach dune restoration area, CCAFS – photo A. Dalsimer.

- EELV Launch Facilities:[8] This site featured a discussion of the installation's historic launch program (Man-in-Space), CX 34 National Historic Landmark and Apollo mission, invasive control to protect cultural resources, CX 37 (EELV- new launch mission), reutilization of old launch complexes and light management for sea turtles, scrub management/burn compartments, migratory bird surveys, and habitat management. With State Historic Preservation Office approval, CCAFS is

[8] EELV = Evolved Expendable Launch Vehicle.

reutilizing old launch complexes for military training. In terms of natural resources, installation personnel have worked to control invasive species infesting hundreds of acres of habitat, and to resolve problems resulting from artificial light, which causes sea turtle disorientation. The CCAFS light program has been so successful that the base is working with the local community to expand the program.

- Wetland and Culvert Restoration: Discussion focused on aquatic/wetland habitat and wildlife use, estuarine systems, and succession after mosquito impoundment opening. Here, CCAFS personnel recreated interchange of natural estuarine waters with formerly impounded (diked) waters using culverts. This exchange eliminated anoxic and superhaline waters resulting in the successful recolonization of mangroves, and subsequent use of the habitat by a variety of fish, shore and wading birds, and other native fauna (alligators, raccoons, etc.).

- Banana River Estuary: As a coastal installation, aquatic resources, boating/fishing policies and enforcement, and base/community natural resource education are all important functions for CCAFS natural resource management personnel.

- Wharf and Manatees: The last stop highlighted the installation's NASA Shuttle booster retrieval system. In addition to the retrieval ships, a thriving manatee population inhabits the wharf. Installation personnel rigorously enforce a "no wake" and "no motor zone" to protect fish habitat, seagrass, and other marine life —including the manatees.

4.0 SYSTEM LEVEL ISSUES – SESSION I

Although DoD's goal is to manage TER-S through ecosystem-based approaches, many important questions must be addressed before successful implementation of such approaches can occur. In this session, participants divided into the following breakout groups: *Coastal Systems*; *Longleaf Pine and Associated Systems*; *Integrating Bottomland Hardwoods, Floodplains, and Upland Systems*; and *Inland Aquatic and Wetland Systems*. The desired outcome for the session was for participants to identify information needs relevant to the management of TER-S within an ecosystem-based context as it applies to each of the above ecosystem divisions.

4.1 COASTAL SYSTEMS

Chair: Mr. Vernon Compton, The Nature Conservancy

Population dynamics (spatial and temporal), habitat requirements, and biodiversity indices inform system-level management of TER-S. However, such information is generally not available for disturbance-dependent species found in coastal systems. While natural disturbance events (e.g., storms) sustain these systems, they also have the potential to negatively affect TER-S populations. This is especially true when population numbers are already reduced because of other external factors, such as development which can cause habitat fragmentation and loss of connectivity, invasive species which can result in altered system composition and function, and global climate change which can lead to sea level rise. In addition, there is the potential for military and non-military upland land-use to impact coastal systems. Restoration of ecosystem function in these systems represents a significant challenge given the lack of reference conditions, development pressures, and impacts from global climate change. An adaptive management framework is essential when considering current and future impacts. Below is the list of identified priority needs for coastal systems in the Southeast region:

- Improved understanding of the population dynamics of disturbance-dependent species, including migratory species. For example, using radar tracking to determine changes in migration patterns, such as changes in flying altitudes resulting from development near coastal areas.
- Improved understanding of habitat requirements for TER-S, and an integration of information on biodiversity with data on projected impacts resulting from global climate change and development/growth projections. By matching species to habitats, and quantifying development threats and climate change impacts to those habitats, management targets can be identified. That is, by synthesizing existing and forecasted data, restoration and management efforts can be better targeted. Biodiversity indices and population projection models may be useful for achieving restoration objectives and for identifying species at risk of needing future protections.
- Assessment of the cumulative impacts to a system (e.g., goods and services provided) resulting from numerous species declining. Impacts should be examined at large scales, include full species range, and consider both spatial and temporal scale impacts.

- Development of watershed modeling and trend forecasting tools to identify restoration opportunities and to better understand upland land-use impacts (e.g., sedimentation, erosion, nutrients) on near-shore marine environments (water quality, habitat, etc.).
- Improved understanding of the potential impacts, pathways of spread, and control of non-native invasive species (NIS) that cause process-level changes in coastal systems.
- Identification of sentinel species to understand system response to impacts. Sentinel species here are defined as species sensitive to ecological processes and dependent on disturbance processes or structure change as threshold indicator (leading rather than lagging indicators).
- Synthesis of data for intact coastal systems to establish reference sites for restoration efforts. Other agencies' efforts to design reserves may provide useful information in this area.
- Development of approaches to restore ecosystem function in coastal systems given impacts from global climate change and anthropogenic factors. This would include:
  - identifying restoration opportunities,
  - defining thresholds for and recovery of barrier island/dune systems subjected to repeated hurricanes, including the associated impacts to TER-S,
  - developing best management practices (BMPs) for coastal system restoration, and
  - implementing tools to monitor and assess impacts on population dynamics and ecological processes.
- Development of approaches to successfully and appropriately connect coastal systems. Due to existing and future potential development pressures, connectivity of coastal systems poses major challenges. Additionally, species-related issues that must be better understood include how animals move within and among coastal systems, and how habitat connectivity and fragmentation may affect genetic diversity. That is, there is a need for improved understanding of the relationship between habitat restoration, population dynamics, and ecological processes. For example, given that species tend to remain in a habitat until it becomes too degraded, there is a need to determine where animals should go and how they should travel there while restoration efforts are underway.

In addition to local data sets, the NatureServe Vista decision support system, which integrates conservation information with land-use patterns and policies, and the Defense Installation Spatial Data Infrastructure (DISDI) may prove useful tools in addressing these needs. The National Oceanic & Atmospheric Administration (NOAA) and U.S. Army Corps of Engineers also were recommended as partners for DoD to engage when addressing coastal systems.

4.2 LONGLEAF PINE AND ASSOCIATED SYSTEMS

Chair: Dr. Joan Walker, USDA Forest Service, Southern Research Station

This breakout group's overarching goal was to identify information needs related to managing longleaf pine (LLP) and their associated habitats in ways that help secure TER-S and maintain the DoD training and testing missions. A significant portion of the discussion focused on how managing LLP and associated systems through burning is affecting embedded and edge habitats, especially in aquatic and wetland areas. Participants also identified a gap in knowledge concerning below-ground processes—what they are, how they have been altered, and how management actions affect them. When discussing the use of fire and other management techniques, the group identified the need to determine feasible outcomes, and to tie these outcomes to current and past local land-use needs as well as to current climate change conditions. Below is the list of identified priority needs for LLP and associated systems in the Southeast region:

- Development of restoration and management BMPs appropriate to current and future conditions (i.e., targets that anticipate likely climate and land-use change).
- Identification or development of seed sources for native ground layer species (e.g., native seed bank). Seed sources must be regionally appropriate.
- Determination as to whether current fire management regimes are sufficient for maintaining embedded habitats and ecotones and, if not, development and/or implementation of methods to restore high-frequency fire regimes to fire-suppressed regimes in LLP systems.
- Examination of the ecological costs of fire regime changes, including a risk assessment and ranking for how far managers can deviate from natural system fire frequencies and still maintain LLP systems. Further, information is needed regarding the impacts/benefits of biofuel, the role of fire in removing duff, the impacts of increased/decreased small patch burning, and estimates for how various fire regimes impact specific management objectives (e.g., smoke in the ecosystem as it relates to meeting air quality PM 2.5 regulation).
- Improved understanding of below-ground soil processes, including nutrient budgets and dynamics, and types and numbers of organisms. For example, how do current soil conditions (quality) alter potential restoration needs, methods, and protocols?
- Examination of the relative importance of groundcover versus overstory restoration for meeting carbon sequestration goals.
- Increased outreach to private landowners, including development of a cross-boundary LLP management methodology. Because large tracts of LLP forests often have multiple landowners, there is a need to work with these landowners throughout LLP range (e.g., LLP ridge in Texas occurs on private lands that are now for sale). Further, a broad-scale assessment of private lands is needed to better target partnership and corridor development opportunities.

- Development of techniques to assess genetics of remnant LLP populations. Genetic diversity for LLP restoration is especially crucial to ground cover.
- Improved techniques for managing water use, especially where water is being withdrawn from embedded wetlands.
- Collection of baseline information on past land-use history and prior use impacts to inform current management guidelines.
- Standardization of accurate inventory techniques—current growth and yield models are based on inaccurate inventory techniques.
- Determination of the functional role and diversity of terrestrial vertebrates, and how best to integrate their management needs on a landscape scale.
- Improved understanding for the appropriate temporal scale for managing listed and at-risk plant species. Need to establish appropriate and feasible habitat restoration targets that incorporate land-use and climate change conditions.
- Identification of biological indicators for change within LLP systems.
- Improved management of native herbivores in LLP systems, especially on non-federal lands.

4.3 INTEGRATING BOTTOMLAND HARDWOODS, FLOODPLAINS, AND UPLAND SYSTEMS

Chair: Ms. Rachel Muir, U.S. Geological Survey

The discussion on integrating bottomland hardwoods, floodplains, and upland systems began with recognition of certain fundamental concepts: 1) aquatic and upslope systems are connected at multiple spatial scales, 2) many tools for conservation are only species-based, 3) partnerships are fundamental, and 4) hydrology is critical. These issues formed the basis for the group's discussions and outcomes, which included identification of priority information needs, suggestions for focal species and habitats, and potential sites for pilot research, demonstration, and restoration efforts. Ecological elements, functions, and processes identified as important included fire, connectivity, downed large woody debris, natural hydrograph/hydrology, biochemical cycling, geomorphology, vegetation dynamics, and population genetics. The group specified that working through partnerships is essential for accomplishing goals across the bottomland hardwood, floodplain, and upland landscape. Below is the list of identified priority needs for integrating bottomland hardwood, floodplain, and upland systems in the Southeast:

- Prioritization of habitats based on broad-scale partnership potential.
- Determination of the key species, habitats, ecological elements, processes, and functions that integrate aquatic and upland systems, and how human/military activities influence them.
- Improved understanding of the role of fire in riparian systems, the interactions between fire in upland and aquatic systems, and what fire management activities

promote ecological sustainability and positive habitat characteristics for species of concern.

- Improved understanding of the impact of hurricanes and major disturbance events on coastal species, including better and more complete information regarding the status of TER-S in systems affected by such events.
- Development of BMPs for restoring and managing these systems for TER-S.

In light of the identified needs, breakout group participants felt that the best way to achieve some or all of the stated priority goals listed above would be to develop a broad-scale demonstration or pilot project, similar to SEMP or DCERP.[9]

Potential sites for this pilot effort included:

- New River (North Carolina)
- Upper Conasauga River (southeast Tennessee, northwest Georgia)
- Chattahoochee River (northeast Georgia, watershed includes eastern Alabama)
- Choctawhatchee River (southern Alabama, Florida)
- Yellow River (north-central Georgia)
- Pascagoula River (southeastern Mississippi)
- Altamaha River (Georgia)
- Savannah River (South Carolina, Georgia, watershed includes Appalachian Mountains just inside North Carolina)

Potential focal habitats included:

- Longleaf pine forests/savannas
- Dry prairies and grasslands
- Limestone seeps and caves
- Ephemeral wetlands
- Large, free-flowing, intact riverine systems
- Functional bottomland hardwood forests

Potential focal species included:

- Wood stork
- Bats (southeastern myotis and Rafinesque's big-eared)

[9] See http://semp.cecer.army.mil/ and http://www.p2pays.org/ref/37/36732.pdf.

- Large mammals (Florida panther, black bear, and red wolf)
- Amphibians (flatwood salamander)
- Indigo snake
- Invertebrate processor guild in coastal streams
- Freshwater mussels

The group also discussed issues relevant to the aquatic/upland landscape. Discussion results are presented in the following table that identifies components of the watershed that warrant consideration, existing tools for integration and resolution, and processes that connect the aquatic and upland ecosystems.

Table 4: Elements to Consider in Integrating Bottomland Hardwoods, Floodplains, and Upland Systems.

Components of Watershed	Tools	Connecting Processes
Erosion	Clean Water Act	Hydrology
Flow	Endangered Species Act	Biogeochemical cycles
Development (urban)	Working with counties and municipalities	Vegetation dynamics
Wastewater	Partnering for conservation	Habitat requirements
Vegetation		Existing infrastructure
Soil		Flow of genes, species, energy
Slope		Key processes that influence integration
		Key factors that influence integration between upland and aquatic systems, including human activities

4.4 INLAND AQUATIC WETLAND SYSTEMS

Chair: Mr. Lewis Gorman, U.S. Fish and Wildlife Service

In this group, participants first identified priority watersheds where TER-S coordination and general information is needed. Of particular interest were the cumulative effects of upstream watershed land-use on aquatic systems, and related TER-S habitats, in conjunction with the proper management techniques to mitigate their effects. In addition, participants felt there was a lack of information and coordination across jurisdictional boundaries within a watershed, and that more research is needed on the linkages between inland aquatic systems. Below is the list of identified priority needs for inland aquatic wetland systems in the Southeast region:

- Adaptation of technologies to use for wetland surveys, and conducting surveys across land boundaries on a watershed basis (including community analyses and linkages between systems).
- Evaluation of appropriate models for determining reference conditions for wetlands/aquatic systems.

- Development of maps for TER-S by watershed. Target watersheds should include:
  - Alabama – Anniston Army Depot (especially freshwater mussels and fish)
  - Southern Mississippi – Camp Shelby, Gulfport Charter Review Commission, Keesler AFB
  - Florida Panhandle – Eglin AFB, Naval Air Station Whiting Field, Fort Rucker
  - Central Florida – Camp Blanding, Pinecastle, Avon Park, Homestead AFB (Joint Reserve)
  - Georgia – Fort Stewart, Fort Benning, Fort Gordon, Moody AFB
  - South Carolina – Parris Island, Charleston AFB/Naval Weapons Station, Beaufort
  - North Carolina/Pee Dee River Drainage – Seymour Johnson AFB, Pope AFB, Fort Bragg, Sunny Point Military Ocean Terminal, NCAS New River

- Land-use planning including integration of multi-jurisdictional plans in high priority watersheds, determination of land-use impact sources, development of partnerships to minimize negative impacts to TER-S and their habitats, and determination of the impacts upland management actions have on aquatic systems (e.g., pocosins, vernal pools, cypress ponds).

- Development of aquatic species-specific recovery and/or management plans to include recovery standards and reference conditions.

- Adaptation of existing monitoring technologies for aquatic systems (e.g., wetlands, seeps, springs).

- Watershed-level coordination of education and training for citizen science volunteer groups and local/regional landowners.

- Improved understanding regarding:
  - effectiveness of mitigating wetland/stream function for optimal TER-S management;
  - impacts of upland management actions on wetland/aquatic ecosystems;
  - the effects of fire on aquatic ecosystems, pocosins, vernal pools, cypress ponds, etc. (e.g., due to time of year, type of management practices);
  - connectivity between and among aquatic communities (wetland plants/primary producers, amphibians, mussels, fish)
  - status of riparian buffer zones (defining minimum width and buffer)

- Integration of state Wildlife Action Plans with installation Integrated Natural Resource Management Plans (INRMPs) within the high-priority watersheds, including identification of potential partners for addressing particular threats.

- Development of guidelines for smart growth for watershed conservation (i.e., in-fill instead of sprawl). Identified tactics included:
  - Engaging land-use planners;
  - Educating/training local landowners on land-use;
  - Identifying partnership opportunities within watersheds;

- Implementing a demonstration project in a targeted watershed for federal/state wildlife and land-use planning agencies to work together; and
- Using natural landforms in development projects.

- Expansion of application for reliable emerging technologies, for example adapting and demonstrating advanced remote sensing (hyperspectral/LiDAR) for wetland aquatic systems/seeps/springs use (e.g., wetland/floodplain assessments).

- Expansion of partnerships for mutually beneficial objectives that benefit TER-S. This includes identifying and engaging potential new partners, especially local landowners (e.g., using established information sharing technologies, ensuring new data is uploaded to NatureServe, creating citizen science groups).

5.0 LAND MANAGEMENT AND DYNAMIC ENVIRONMENTS – SESSION II

The ecosystems of the Southeast, upon which TER-S and other species depend, are dynamic entities that are impacted by large-scale but temporally infrequent disturbance events such as hurricanes, pervasive development patterns, or other anthropogenic influences occurring at regional or greater scales and over long time horizons that often complicate management flexibility and resultant decisions. By taking into account the dynamism of these environments, projected long-term changes in environmental conditions, and the historic and projected patterns of habitat loss and fragmentation, land managers can improve the prospects for the long-term sustainability of TER-S and other species that depend on the same ecosystems. In this session, groups divided into the following topic areas: *Managing for Infrequent Large-Scale Natural Disturbance Events*; *Maintaining Connectivity Amidst Land-use and Climate Change*; *Addressing Impacts Resulting from Upland System Restoration*; and *Fire Effects and Patch Dynamics*. The desired session outcome was for participants to identify information needs relevant to management of ecosystems and TER-S within these dynamic and human-altered environments.

5.1 MANAGING FOR INFREQUENT LARGE-SCALE NATURAL DISTURBANCE EVENTS

Chair: Dr. William Platt, Louisiana State University

The timing, frequency, and intensity of large-scale, infrequent natural disturbance events influence the highly diverse plant and animal community structure and composition in the southeastern United States. Human-mediated changes in the landscape and climate are expected to alter disturbance regimes. To identify threats, assess potential impacts, and implement proactive mitigation measures, a fundamental understanding of ecological systems and processes is needed. As impacts to ecological systems and processes resulting from large-scale infrequent disturbance events also have the potential to impact socioeconomics and military readiness, outreach to diverse stakeholders (e.g., politicians, military leaders, regulators, public) on the predicted ecological states under current altered conditions and in consideration of climate change is needed to generate support for regional partnerships, planning tools, near-term management actions, and response mechanisms. With a focus on coastal systems, below is the list of identified priority needs for managing for major but infrequent disturbances in the Southeast region:

- Improved understanding of the ecological role of large-scale infrequent disturbances in historic, modern, and future landscapes of the southeastern United States as a baseline for developing long-term planning frameworks for effective management of this disturbance-driven, diverse system.
- Understanding of minimum dynamic area impacted by large-scale infrequent disturbance events.
- Assessment of the predicted ecological states under current altered conditions (land-use changes, direct habitat modification, hydrologic alterations, invasive

species) and in consideration of climate change exacerbations through modeling and application of other tools.

- Research on the effects of hurricanes and other large-scale disturbance events on:
  - Species populations and migration
  - TER-S and sentinel species in coastal areas
  - Coastal geomorphology (soils, hydrology, landforms)
  - Fire regimes, fuel levels, and weather patterns
  - Community disassembly/reassembly processes, including belowground (i.e., resiliency)
  - Energy dissipation throughout system
  - Ecological services provided by marshes, barrier islands, wetlands
- Integration of information on biodiversity and attendant processes with data on projected impacts resulting from large-scale disturbance events, and in consideration of global climate change and development/growth projections. By matching species to habitats and quantifying threats and impacts to those habitats, management targets for focused efforts and restoration can be identified. In particular, what natural resources should be managed for persistence over time?
- Assessment of the near-term impacts of large-scale infrequent disturbance events and sea level rise in areas of critical importance for military testing and training missions.
- Identification of near-term mitigation tools to enhance ecological processes and prevent large-scale devastation of species, communities, systems, and landscapes. For example, restoration of coastal systems will help to buffer effects of hurricanes and rising sea level.
- Outreach mechanisms targeting diverse stakeholders (politicians, military leaders, land managers, regulators, public) on the ecological and economic role of biodiversity in the Southeast, and the importance of proactive management measures to minimize the impacts of alterations in the timing, frequency, and intensity of large-scale disturbance events as well as sea level rise. For example, current land-use practices are altering not only systems themselves but also disturbance regimes. In the long term, landscape connectivity and dispersal corridors will be increasingly critical for successful migration of species as their climatic envelopes shift.
- Development of regional frameworks and partnerships to holistically address issues related to integrating planning, near-term management, and response mechanisms. For such frameworks and partnerships to be successful, commitment at the highest levels of leadership are needed.
- Assessment of the status of disaster response plans with regard not only to national security but also ecological systems. Cost-effective techniques are needed to recover and relocate TER-S prior to and after natural disasters as well as to restore degraded systems.

5.2 MAINTAINING CONNECTIVITY AMIDST LAND-USE AND CLIMATE CHANGE

Chair: Dr. Jeff Walters, Virginia Polytechnic Institute and State University

Connectivity at the system level maintains hydrologic and ecological processes in support of TER-S; however, the extent to which corridors affect species movement is not generally known. Additional study of the role of corridors is warranted especially given current and future impacts of climate change and land-use change throughout the region. Based on this information, effective corridor design strategies that take into account scale and multiple uses are needed. At large scales, expanded partnerships (public/private and across agencies) and land-use planning tools are essential to establishing effective corridors. Tools are needed to identify the value of corridors for targeting and leveraging resources. Below is the list of identified priority needs for maintaining connectivity in the Southeast region:

- Research on whether corridors affect species movement with consequence. In other words, do they affect the dynamics of ecosystems and populations at large scales?
- Investigation of how the role of connectivity will change over the long term in consideration of global climate and land-use changes, and increased frequency and severity of large-scale disturbances. Possible functions include:
  - allowing shifts in distribution and population structure,
  - maintaining genetic variability,
  - maintaining species assemblages, and
  - promoting selection.
- Research on the appropriate spatial and temporal scales for connectivity across species.
- Development of design criteria for functional corridors, taking into account the appropriate spatial and temporal scales and purposes of corridors, as well as allowing multiple compatible uses that provide ecosystem benefit (e.g., collocating utilities etc. may also benefit ecology). Similarly, these connections should take into account ecological/hydrological considerations, and not design or implement corridors based solely on convenience.
- Expansion of partnerships to achieve connectivity at large scales through the following:
  - Location-specific partnership structures and land preservation tools that include local land-use planning and public education and outreach;
  - Incentives for private land partnerships;
  - Institutional guidelines to help balance economic/ecologic values;
  - Tools to facilitate reaching scientific consensus;
  - Best management practices (BMP) for transportation planning, including early coordination with state DOTs; and
  - Evaluation of generic principles that may emerge from location-specific efforts.

- Development of tools for identifying the connectivity value of land. It is important to identify the purpose, chances of success (i.e., can it be connected?), and appropriate management in evaluating connectivity value. Specific targets should include riverine corridors and corridors that facilitate large-scale prescribed burning, and should consider the true likelihood of success of "starting from nothing."

5.3 ADDRESSING IMPACTS RESULTING FROM UPLAND SYSTEM RESTORATION

Chair: Mr. Ralph Costa, U.S. Fish and Wildlife Service

Participants in this breakout group began narrowing their discussion topic by defining reasonable restoration targets, and how these might impact associated aquatic habitats. A large part of the discussion centered on identifying reference system characteristics (species indicators, habitat conditions) that help drive desired future conditions, and on identifying metrics to measure restoration success. Participants recognized a need to define both positive and negative collateral restoration activity impacts on non-target species and habitats. Below is the list of identified priority needs for addressing upland system restoration impacts in the Southeast region:

- Determination of indirect impacts resulting from various TER-S restoration efforts. Specific issues raised included need to examine impacts of:
  - upland restoration on embedded wetlands, downstream habitats, and ecotones;
  - patch size (i.e., fragmentation effects) on species dispersal, conservation, and recovery;
  - inland restoration to embedded/downstream/adjacent habitats;
  - herbicides to non-target species
  - quantity and quality of runoff; and
  - TER-S restoration activities on neighboring land owners.
- Examination of consequences of prescribed/natural burning, including:
  - resultant nutrient/sediment fluxes;
  - benthic invertebrate communities;
  - smoke on adjacent habitats; and
  - carbon sequestration/cycling (either release of carbon dioxide to the atmosphere or maintaining carbon pools by no burning).
- Examination of consequences and liabilities from not conducting prescribed burns.
- Identification of the best sequence of restoration activities and methods to promote optimal success, such as improved habitat composition and resistance/resilience to NIS invasions. Specific questions raised included:
  - examining the consequences of putting longleaf where shortleaf should be;
  - investigating new or adapting existing restoration technologies;
  - developing novel methods of producing seed/plant material;
  - determining the sources of propagules prior to restoration;
  - researching optimal resistance/resilience to NIS; and

    - identifying the impacts of these sequences on habitat composition and susceptibility to negative impacts (i.e., NIS).

- Establishment of reasonable/realistic restoration targets given changing climate conditions and land-use regimes (e.g., on what time and spatial scales should restoration programs be planned?).
- Identification of important characteristics (species indicators or habitat conditions) for reference areas to define desired future conditions.
- Development of BMPs for designing meaningful off-site mitigation areas. Need to examine short- and long-term impacts of these areas (i.e., are mitigated sites performing appropriate ecological functions?).
- Understanding the collateral impacts of alternative, non-natural restoration techniques in the context of scale, including the impacts (positive and negative) to non-target species.
- Development of restoration metrics to assess project success in achieving desired ecological functions (nutrients/carbon/sediment fluxes). These metrics should be a part of the experimental design process.

5.4 FIRE EFFECTS AND PATCH DYNAMICS

Chair: Dr. Lindsay Boring, Joseph W. Jones Ecological Research Center

This breakout group framed its discussions in the context of ecosystem management in human-altered environments. Participants noted that fire policy issues will be a significant challenge for resource managers, especially because of local fire ordinances and PM 2.5 air quality regulations. They further emphasized that community interactions are becoming increasingly important, citing Firewise[10] and other educational programs, and participation in fire councils is significant for maintaining good community relations. Below is the list of identified priority needs for fire effects and patch dynamics in the Southeast region:

- Improved understanding of the influence of fire frequency, intensity, spatial/temporal distribution, and patch dynamics on TER-S and non-target species. Associated with this is the need to examine how fire affects seed production, generation/growth processes, smut (i.e., sooty matter), and timing.
- Compilation of a compendium of literature on the impacts of prescribed fire on air quality (and information gaps) vs. other sources inputs. This is particularly needed in light of the new EPA air quality regulations (PM 2.5) and state environmental planning divisions' pursuit of air quality (local ordinances). Further, information may facilitate military use of prescribed fire (acceptance of smoke) through increased public and policy-level awareness of fire's link to healthy ecosystems

[10] A multi-agency effort involving homeowners, community leaders, planners, developers, and others in the effort to protect people, property, and natural resources from the risk of wildland fire - before a fire starts. See www.firewise.org.

and to the protection of human health and safety (i.e., minimizing potential for large-scale wildfires).

- Development of appropriate fire guidelines for management of embedded habitats, coastal wetlands, and other habitats used by TER-S. Post-fire management guidelines also were identified as lacking.
- Improved understanding of effects of the inability to burn at either end of the intensity scale, or extremes of frequency and fire size scales.
- Additional information on the combined effects of insects, fire, pathogens, and human activity on natural systems resulting in guidance on what to/not to emulate. This should include implementation guidance, and an examination of the movement of exotics into post-fire areas.
- Understanding of how fire and patch dynamics can be used in restoring ground cover and converting pine overstories.
- Improved understanding of the role fire plays in coastal prairies and salt marshes, and its influence on all species, especially invertebrates. Post fire management guidelines also were identified as lacking.
- Examination of how patch size and sudden gaps (e.g., from lightening strikes) affect species, especially invertebrates (lepidoptera/flowering), in large patches and in non-pine systems (e.g., mangrove systems).
- A comparative analysis of the differences, if any, between modern ignition patterns and natural lightning ignitions with respect to after-burn conditions and/or patchiness.
- Improved understanding for how soil disturbance associated with silvicultural applications affect patch dynamics/management.
- Examination of the impacts to TER-S from widespread and/or prolonged drought, particularly in isolated ephemeral wetlands.
- Examination of uneven-aged silvicultural systems and site conversion of off-site species.

6.0 OVERCOMING MANAGEMENT CHALLENGES – SESSION III

Working collaboratively to properly manage ecosystems can often be a challenging endeavor because of diverse priorities and diverging missions among land management agencies. In addition, depending on the management question or issue to be addressed, different spatial scales or ecological contexts (e.g., watershed versus a specific type of plant community or ecological system) may provide the appropriate framework within which to assess information and make decisions. In this session, groups divided into the following topic areas: *Resolving the Watershed versus Ecological System Dichotomy*; *Barriers to Cross-Boundary Management*; *Coordinated Information and Data Sharing Among Stakeholders*; and *Monitoring Across Different Spatial Scales*. The desired outcome of this session was for participants to identify management challenges and collaborative opportunities at multiple spatial and temporal scales.

6.1 RESOLVING WATERSHED VERSUS ECOLOGICAL SYSTEM DICHOTOMY

Chair: Mr. Lee Mulkey, University of Georgia – SERDP Ecosystem Management Program

Although there has been debate in the literature with regard to a watershed versus ecological system approach to management, breakout group members indicated that there is not necessarily a dichotomy. Rather, there are applications for each approach. Disagreements occur when limited resources are allocated for day-to-day management needs, or when spatial and temporal scales are taken into consideration (watersheds/landscapes/stand-level). For example, prescribed burning in upland areas for ecological goals may have impacts to water quality. Further complicating matters, there may be multiple watersheds within an ecosystem or vice versa. While aquatic and terrestrial ecological systems and management needs are generally well-integrated in the Southeast, there still exist opportunities to improve stakeholder communication and implementation strategies, especially those that consider linkages and support adaptive management. Improved communication between hydrologists and ecologists would help facilitate this objective. Below is the list of identified priority needs for integrating watershed and ecological system management approaches in the Southeast region:

- Recognition that spatial and temporal scales can have a significant impact on the success of management actions. For example, because estuaries are influenced by the condition of upstream systems, there is a need to identify the appropriate implementation scale for sediment basins on military road networks so that water quality can be improved within a given watershed.
- Development of meaningful reference conditions for watersheds (land-use practices and water quality) that account for legacy impacts prior to the establishment of military bases or stewardship principles. Legacy impacts may make Clean Water Act standards set by states virtually impossible to meet, necessitating close interaction with regulators. Further, there may be a hierarchy of reference conditions across a watershed. Examining increasingly higher order streams, relative one to another, may reveal a hierarchy of change that is important for understanding overall impacts. Constraints and limitations need to be recognized.

- Standardization of approaches to assess mass balance of stressors impacting a watershed. As watershed and jurisdictional boundaries are rarely (if ever) the same, scales of reference for assessing stressors entering and exiting a defined area within watershed are critical when allocating sources and determining impacts for management action. Specific needs identified included techniques to identify point and non-point sources as well as incorporate biotic stressors.
- Development of metrics and associated monitoring approaches to improve understanding of the state of aquatic systems as a basis from which receptors and stressors can be identified.
- Identification of potential impacts from sources and related stressors to receptors, considering scale (i.e., cause and effect needs). Potential approaches include starting at bottom of watershed and working up to address issues (stream quality, condition of riparian corridors) or starting at the top of watershed and working to implement BMPs ("best we can do" mindset). Opportunities to inform adaptive management are an important consideration.
- Assessment of whether reference conditions for water quality standards are protective of TER-S.
- Development of new technologies to diminish known point and non-point sources.
- Development of tools to assess the effectiveness of current and planned watershed management actions not only for water quality but also for land sustainability. Recovery trajectories should document biological and chemical improvements toward desired future conditions. Clusters of acceptable states for various indicators may be used as an assessment tool.
- Improved understanding of TER-S habitat linkages within ecological systems and watersheds, especially based on hydrologic connectivity and informed by potential global climate change impacts. Management efforts must seek to integrate aquatic and upland systems.
- Improved understanding of the interconnections of upland restoration and/or legacy practices to water quality. These interconnections have implications for restoration targets and actions. For example, soil quality issues relate directly to potential erosion and resulting sedimentation impacts to water quality.
- Examination of the relationship between coastal watershed and impacts on near-shore marine environments.

6.2 BARRIERS TO CROSS-BOUNDARY MANAGEMENT

Chair: Mr. Fred Annand, The Nature Conservancy

This group explored the challenges and opportunities for management across boundaries. It was recognized that boundaries can fall into several categories, including natural, land-use, and political, all of which may be characterized by different priorities, agendas, and missions. The group identified multiple barriers to cross-boundary management, including spatial, natural/

physical, land-use, political/jurisdictional, organizational, fiscal, cultural, and information/data gaps. The following are suggestions for overcoming these barriers in the Southeast region:

- Increased exploration of innovative means to overcome existing barriers (e.g., utilizing an unbiased outside facilitator), and the development of new tools and expansion of existing ones. This should include:
  - the creation of a process for trading assets, manpower, and equipment;
  - expanded opportunities for conservation and mitigation banking;
  - improved ways to achieve valuation of services provided by natural resources; and
  - new policies to permit transfer of funds among different organizations and agencies.

- Greater dissemination of Cooperative Conservation examples and an improved process for entering into these initiatives, and more frequent and innovative use of Sikes Act cooperative agreements were both cited as ways to facilitate partnerships that enhance cross-boundary management.

- Examination of rural and urban growth and development to determine what growth patterns (e.g., concentrated vs. dispersed) are best for species conservation. For example, biological impacts of converting an agricultural landscape into an urban one.

- Improved strategic planning at the regional and watershed levels, perhaps through ecoregional partnerships. A necessary component in this process is to prioritize federal and state lands for buffering. When doing this, there is a need for wider recognition that both small (parks) and large land parcels have conservation value, and that by looking broadly at all available natural areas, rather than concentrating on federal lands, widespread recovery can more easily be achieved.

- Increased internal and external (i.e., within agencies and organizations as well as to the public) outreach to communicate successful strategies for overcoming barriers, and facilitate acceptance of new or innovative strategies. Specific suggestions included:
  - Internal: improved, more direct education of military commanders and operations personnel regarding conservation and sustainability, emphasizing their importance to mission and range sustainment.
  - External: creation of community advisory boards to formally address all stakeholder input and concerns – similar to model established through CERCLA.[11]

[11] See www.epa.gov/superfund/community/index.htm for information on the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

6.3 COORDINATED INFORMATION AND DATA SHARING AMONG STAKEHOLDERS

Chair: Mr. Milo Pyne, NatureServe

The purpose of this breakout group was to identify gaps in how information and data are shared not only among federal agencies, but also with state, local and NGO partners. The general consensus was that TER-S information and data exist on many levels; however, either due to a lack of sharing tools or to an unwillingness to share data, information is often not available. The main issues were attributed to a lack of knowledge regarding user needs, a need for a common platform to host existing information, lack of consensus regarding the appropriate scales at which data should be shared, and uncertainty about existing reporting capabilities capable of transferring this type of data and information. During breakout group discussions, several military-specific concerns were raised related to the need to secure geographical and location information and data about TER-S and their associated habitat occurrences. In examining the issue of information and data sharing, participants felt it was important to distinguish between "data" and "information" sharing: the former relating to actual data (e.g., species occurrences) and the latter relating more to end products or results. These two are essentially different and, therefore, have distinct needs. Nevertheless, there exist commonalities, especially related to communication. Below is the list of identified priority needs for coordinating information and data sharing in the Southeast region:

- Establishment of an accessible, reliable, transparent (i.e., can easily identify data source), and comprehensive TER-S information clearinghouse (e.g., includes raw data, habitat modeling information, etc.) that promotes the use of existing web-based resources. While much data exists in both tabular and spatial forms, there is a lack of an agreed-upon central hub for data across all jurisdictional boundaries. In fact, there are many publicized data hubs, and many more that are known only to people within narrowly-defined communities. Having one centralized hub would help ensure that data are reliable and useable (e.g., consistent format), and thus help managers coordinate TER-S activities at a regional scale. The first phase of this effort would be to survey all federal, state, local, and NGO entities to determine if they manage informational hubs.
- Identification of existing TER-S data to determine current data gaps, if any, and the extent of existing spatial and tabular data. While many researchers and managers know data exist for TER-S and their associated habitats, the extent and reliability of these data are unknown. Additionally, issues of common metadata, consensus on data standards, platform compatibility, and institutional barriers to data exchange all must be addressed. The first phase of this effort would be to survey all federal, state, local, and NGO entities to determine what TER-S data they house.
- Identification and definition of potential "end users" for existing and new data and information. Currently, much data is collected without a clear understanding of who will use the information or how it will be used. Once end user needs are clarified and understood, data collection can be streamlined and information

developed more efficiently (e.g., by providing appropriate format rather than have to manipulate existing output).

- Increased education of, and outreach to, researchers and managers regarding existing data and mapping information systems (e.g., DISDI, SERGO maps, Gap Analysis), and how these can be accessed. Similarly, these same researchers and managers need to be encouraged to better publicize the type, format, and location of their data and outputs. This will help inform management decisions while preventing duplication of data collection efforts.
- Improved spatial integration and reporting capabilities for data delivery systems, and better linkages of environmental/biological data habitat/range mapping, as well as existing informational resources (e.g., Natural Heritage Program/ NatureServe data via data sharing agreement/MOU with DoD; Armed Forces Pest Management Board model; Navy's Environmental Information Systems Library, www.ESA.org, library systems).

It was noted during discussions that DoD has developed a system for creating and managing defense facilities' geospatial information resources. DISDI seeks to develop an institutionalized process where installation geospatial data (in GIS, CADD, and imagery formats) are assembled, disseminated, and maintained in a fashion that supports installation management and strategic basing decisions worldwide. The DISDI Portal enables DoD users to access geospatial data and view strategic maps. For security reasons, data ownership and accessibility are a major issue for all DoD data. [12]

6.4 MONITORING ACROSS DIFFERENT SPATIAL SCALES

Chair: Dr. Donald Imm, Savannah River Ecology Laboratory

In discussing the state of monitoring for TER-S, breakout group members overwhelmingly expressed that regular monitoring at all spatial and temporal scales is lacking, and must be bolstered. This is especially true at the regional, landscape, population, and genetic levels as information from these help drive management and compliance goals. There also is a need to better define reference conditions in terms of what is truly attainable, and to define monitoring methodology and reporting standards for single species and their associated habitats so managers can implement recovery plans using standardized procedures. Participants further acknowledged a need for the monitoring of restoration projects to ensure success and to measure projects outcomes. Below is the list of identified priority needs for monitoring across different spatial scales in the Southeast region:

- Standardization of data collection and reporting, including protocols for where, when, what, and how to monitor and report. Standardized baseline data should then be used to assess existing conservation and recovery goals. Increased use of GIS and other standardized tools can be of use for large-scale monitoring.

[12] Defense Installation Spatial Data Infrastructure (DISDI), http://www.acq.osd.mil/ie/bei/disdi.shtml.

- Expansion of monitoring to include temporal, spatial, and ecological scales, including landscape, community, population (i.e., indicator monitoring), and individual species and habitats (baseline, status, trends, etc.).
- Development of guidelines for holistic monitoring that link water quality, habitat, wildlife, and plant monitoring data with military training mission impacts, including guidance for:
  - monitoring in consideration of training requirements (e.g., no net loss training capability);
  - when and how frequently to monitor TER-S to capture natural (vs. mission) variations;
  - increasing TER-S populations without further restricting mission capabilities;
  - dealing with joint land-use situations; and
  - identifying natural resource indicators to better measure military training impacts.
- Research to better determine appropriate scaling parameters for monitoring. For example, can species-specific monitoring data be extrapolated to higher scales?
- Development of usable metrics to ensure compliance with monitoring requirements, and to quantitatively measure project success. This must include clarification of monitoring goals and objectives at representative scales.
- Collection of all current monitoring information and data (across state/federal boundaries) to identify gaps in knowledge. Expansion of partnerships and improved technology transfer are potential opportunities to help achieve this goal, especially when monitoring isolated off-post, boundary, and corridor populations.
- Improved monitoring tools and technologies, and increased use of models (e.g., site occupancy model) for monitoring TER-S. For example, is there a tool to remotely monitor larger scales to minimize field time and resource expenditure?
- Incorporation of monitoring as an integral part of all projects—those done on the installation and those done in cooperation with cross-boundary partners. Both short- and long-term land-use changes resulting from management, restoration, and mission activities should be included. Monitoring regional partnerships, and not simply natural resources, may improve ecosystem monitoring capabilities.

7.0 SYNTHESIS AND PRIORITIZATION OF NEEDS – SESSION IV

Synthesizing and prioritizing information resulting from breakout group discussions was a primary workshop objective. In this session, participants divided into three groups representing each of the main topic areas covered, and were asked to cull out the top research, demonstration, and management needs identified in earlier sessions. The outcome objective was to further refine and prioritize these needs with each breakout group developing a list of high-priority objectives relevant to their respective topic areas. Following the workshop, a working group further refined and elucidated the top priorities.

7.1 SYSTEM-LEVEL NEEDS

Chair: Dr. John Hall, SERDP/ESTCP Sustainable Infrastructure Program Manager

In considering systems, participants in this breakout group focused on several overarching themes, including the importance of habitat corridors and linkages, impacts of management on non-target species and habitats, the need for standardization of methods and tools. The prioritized outcomes from the *System Level Needs* synthesis group are listed below:

- **Improved understanding of potential impacts, pathways of spread, and control of invasives and pathogens that cause process-level changes** (e.g., cogon grass, root fungi, zebra mussel, flathead catfish).
- **Identification and clarification of ecological reference sites** – in terms of structure, composition, and function – to establish baseline for restoration objectives as well as monitoring protocols and metrics of success. By understanding the degree of deviation and direction of deviation, the strategy and/or feasibility of restoration can be determined. Need to identify significant determinants of restoration feasibility given differences in historic land-use and environmental potential (ecological framework for restoration). In addition, need demonstration of existing restoration approaches.
- **Examination of current fire management regimes** to determine if they are sufficient for maintaining embedded habitats, matrix community, and ecotones across the full range of moisture gradients in terrestrial and inland aquatic habitats to meet biodiversity conservation goals. For example, what are the appropriate frequencies and intensities for fire in bottomland hardwoods, pocosins, vernal pools, and cypress ponds?
- **Determination of upland management impacts on aquatic systems** (streams, pocosins, vernal pools, cypress ponds), including whether they maintain appropriate hydrologic regimes and lifecycle linkages for TER-S (e.g., amphibians, bats).
- **Improved linkages between biodiversity data and projected impacts from global climate change and development/growth** to better target management efforts in coastal areas.

- **Establishment of habitat requirements for TER-S and/or sentinel species** (i.e., species sensitive to ecological processes and dependence on disturbance processes or structure change as threshold indicator - leading rather than lagging indicators), especially in coastal areas, to inform system-level management.
- **Implementation of pilot efforts for research, demonstration, and restoration activities in bottomland hardwood systems.**
- **Improved understanding of below-ground processes**, including nutrient budgets and dynamics, and organisms; soil quality, microorganisms and soil organisms (including introduced species); root competition; and ability to maintain ecological function or provision of ecological services.
- **Expanding education and outreach efforts** regarding TER-S and ecoregional management. Issues discussed included how to implement/create citizen science volunteer groups across an entire watershed, and how to educate and train local landowners on conservation land-use practices.

7.2 LAND MANAGEMENT AND DYNAMIC ENVIRONMENT NEEDS

Chair: Mr. Lee Mulkey, University of Georgia – SERDP Ecosystem Management Program

Participants in this breakout group took a holistic approach to their topic, so that all aspects of dynamic land management – from fire to restoration to the tools those activities require – were considered. The prioritized outcomes from the *Land Management and Dynamic Environments* synthesis group are listed below:

- **Improved understanding of the impacts of prescribed fire in upland fire maintained ecosystems.** Specifically, there is a need for information on frequency, seasonality, intensity, TER-S specific responses, and limits on the extremes (variable season burning). Additionally, there is a need to better understand fire impacts on embedded wetlands, ecotones, and downstream habitats. Research needs include fire alternatives or enhancements. Guidelines, best management practices, and adaptive management practices also are needed. Finally, there is a significant need to pursue expanded partnerships and improved public outreach explaining the benefits of prescribed fire activities.
- **Development of a TER-S habitat restoration model specific to military mission requirements**. This model should be spatially explicit and time varying, and should address population viability and recovery goals in a way that can inform land acquisition and protection objectives.
- **Predictive estimates for ecological condition parameters under climate change and related management adjustments**, including ecological assessments of coastal and blackwater streams to set reference conditions. Coastal and blackwater stream assessment needs include linking biodiversity data, population dynamics of disturbance-dependent species, BMPs for restoring ecosystem function, establishing reference sites as baselines, watershed modeling,

and establishing TER-S habitat requirements (including sentinel species) to inform system-level management.

- **Exploration of innovative strategies for recovery of TER-S that incorporate corridor patch design** (corridors, landscape design, genetic aspects, on-site/off-site, population viability modeling).
- **Improved capability for upland restoration.** For example, adapting restoration methods developed for LLP; developing novel methods for producing seed and plant material; consideration of below-ground resources; and broad examination of uneven aged silvicultural system site conversions to off-site species and ground cover restoration.
- **Improved understanding of protection, restoration, and TER-S management for beach front habitat** (i.e., the coastal transition from marine to terrestrial).
- **Integration of a system to track the source, pathway, and effective controls of exotic/invasive species.** The focus needs to be on both capacity building and research.

7.3 OVERCOMING MANAGEMENT CHALLENGES

Chair: Mr. L. Peter Boice, DoD Conservation Team Leader and Legacy Program Manager

Discussion during this breakout group centered on coordinating federal agency approaches to TER-S management. Coordination needs included both approaches to managing TER-S and their habitats, and also the ways in which information and data is shared. The prioritized outcomes from the *Overcoming Management Challenges* synthesis group are listed below:

- **Facilitation of new partnerships, and continued support for existing partnerships.** Support includes direct participation (e.g., participating in land trust and county planning group meetings), as well as providing funding and other resources. A necessary first step is an assessment of existing TER-S partnerships to determine what already exists, and to demonstrate and transfer successful partnering techniques.
- **Identification and prioritization of buffer, corridor, and linkage lands** for later acquisition or protection (e.g., easements, fee simple), including assessments of community-level habitat conservation opportunities, and future utilization of NEON to inform cross-boundary linkages.
- **Standardization of monitoring techniques** (data collection, storage, and reporting methods) across federal, state, and local partners; and development of metrics to assess the effectiveness of various management actions.
- **Greater cooperation and partnership on prescribed fire-related issues**.
- **Examination of TER-S population structures, and improved coordination of species management at the population level**.

- **Consolidation of spatial data** (federal, state, private, easements, county) for conservation lands into a single source/map, and expansion of spatial natural resource data inputs into the DISDI.
- **Development of more multi-species recovery plans** at the habitat level, and improved coordination of species conservation at the population level.
- **Implementation of a survey to users of biodiversity data** to clarify their needs.

8.0 PRIORITY OUTCOMES

After the conclusion of the formal workshop, a small group consisting of breakout group chairs, white paper authors, and the workshop sponsors engaged in a half-day meeting to review, clarify, and refine the recommendations and priorities expressed during the workshop. Following are the prioritized outcomes of this session.

8.1 INVASIVE SPECIES THREATS TO TER-S CONSERVATION

Background

Invasive exotic species jeopardize the biodiversity and integrity of natural, quasi-natural, and human-dominated ecosystems. Second only to land-use changes and concomitant loss of habitat, invasive species are the biggest threat to the survival of native species and hence biodiversity. Once established, invasives can opportunistically colonize other areas and facilitate other exotic invasions, thereby displacing species with similar resource requirements and reducing habitat quality. Impacts of an introduced species may be minimal at first but then rapidly cascade as the population grows and impacts other species, other trophic levels, and ecosystem processes. Assessing the ecological impacts of non-native species invasions is a current research priority, as is dealing with these species from a practical, land management perspective.

Significance

Areas explicitly intended for conservation (e.g., nature preserves and refuges), as well as those set aside for other purposes that serve a secondary conservation function (e.g., military bases), often serve as reservoirs of biodiversity in the modern landscape. These patches function as habitat islands for many TER-S within an often disturbed and fragmented landscape matrix. Despite the physical protection to boundaries of these patches afforded by their status and concerted management efforts to maintain viable populations, TER-S and quality of their habitat are increasingly threatened by exotic species encroachment from the surrounding landscape.

The analogy between habitat islands and oceanic islands holds in many ways for TER-S in terms of estimating dispersal distances among these patches and determining ecological connectivity between patches separated by unsuitable habitat. The analogy breaks down, however, when one considers that many exotic species are weedy ruderals that can gain a foothold in the parts of the matrix that are unsuitable to TER-S, including patch edges, and then gradually invade into core habitat. Further, patches that contain facilities such as military bases with high levels of traffic, both within and between other patches, may be especially prone to invasion. These areas may also be vulnerable to the establishment of exotics that escape or survive decontamination procedures of equipment used at bases abroad.

In the modern landscape, multi-exotic invasions are increasingly common and can be a challenging and costly problem for land managers seeking to conserve islands of critical habitat. In reserves that are part of a highly disturbed landscape, numerous exotics may be present and at different stages of invasion. Many exotics that have not achieved priority status may escape the attention of managers because the first step of its documentation is lacking. Integrated

management plans are often necessary to eradicate and control exotics, but they may not be economically or ecologically feasible.

Recommendations

1. In many areas, a detailed inventory of exotic species is needed.

2. Through partnerships (TNC, National Biological Survey, etc.), survey information needs to be used to develop and update local and regional "risk" priorities. Prioritization should focus on those species that either pose the greatest risk to TER-S habitat or are capable of becoming "foundation" species (e.g., cogon grass, Chinese privet) that affect system function (resource cycling, burning regime), or are capable of displacing "keystone" or "umbrella" species (invasive forest pathogens, cowbird, zebra mussel).

3. Once prioritized, research will be needed to address issues related to habitat breadth, invasion rates and patterns, thresholds for establishment, and impacts on native biota.

8.2 REFERENCE CONDITIONS FOR ECOSYSTEM RESTORATION IN SUPPORT OF TER-S CONSERVATION

Background

Need for appropriate ecological reference models

Ecosystem restoration is challenging on multiple fronts. First, it may be nearly impossible to define the appropriate restoration objectives that are both specific and quantifiable. A common approach to defining objectives is to rely on reference information, which can take various forms. If a relatively undisturbed site with (presumably historically) similar environmental conditions can be identified, it may be used to inform the selections of objectives and performance metrics. In many locations, there are no clearly appropriate reference sites; in such cases, objectives may be established based on various types of information, both contemporary and historical. There is a need to establish reference models (sites or composite models) to inform ecosystem restoration to support TER-S. Such models also suggest metrics for monitoring progress and assessing success. Reference sites also serve as vital foundations for establishing management goals and assessing ongoing actions such as prescribed fire, silvicultural activities, and streamside erosion abatement.

Need for models to assess feasibility of restoration and selection of appropriate restoration strategies

The costs and likelihood of success of restoration are difficult to predict, and methods needed to meet restoration objectives are likely to vary from project site to project site. Knowing the outcomes of a singe restoration project may not be sufficient to predict the costs and likelihood of success on another proposed project or project area. Both the ecological potential of a site and its land-use history are likely to strongly influence cost, success, and effective methods;

however, the relative importance of these factors is not defined and may well vary, either randomly or systematically. There is a need to better understand the factors that drive the costs, likely success of restoration, and selection of methods.

Need to demonstrate existing models and establish operational guidelines

A variety of restoration projects have been undertaken in the southeastern United States, and have produced some generally successful methods for restoring selected ecosystem components. Some approaches and methods may be ready for demonstrating ecological effectiveness and formalizing cost analyses. Controlled and well-documented restoration demonstrations will serve to communicate feasible management options, and if the size of the demonstration area is sufficiently large, will directly benefit resident TER-S populations.

Significance

Advancing the ability to restore ecosystems or critical components of ecosystems will ensure the ability to train military personnel and the future of TER-S on military lands. Reliable restoration tools and strategies will allow managers to respond to possible negative impacts of training and other land-uses on ecosystem function, and specifically on TER-S habitats, and to plan for such impact through restoration. Such tools should increase the flexibility of land-use.

Recommendations

1. Reference models (sites or composite models) to inform ecosystem restoration to support TER-S must be established. The highest priority focus should be on freshwater systems, especially black-water streams. Further, suitable restoration objectives for highly altered landscapes are needed, as are the development of metrics for monitoring progress and assessing restoration success.

2. An ecological framework for understanding restoration feasibility is needed. Such a framework should have the capability to account for the current ecosystem conditions and impacts (e.g., habitats that have high amounts of fuel due to excessive fire protection and habitats undergoing fragmentation by incompatible land-uses). The ecological framework should also be able to account for embedded habitats and ecotones.

3. Existing restoration methods hold the promise for large-scale implementation. Demonstrating application of these methods on larger scales at military installations offers the potential for enhancing habitat restoration efforts for DoD and other large land managers. Methods for restoring stream channels and longleaf pine ground layer vegetation are prime candidates for demonstration efforts.

8.3 IMPACTS OF UPLAND MANAGEMENT ACTIONS ON AQUATIC SYSTEMS

Background

Upland land-use activities (and associated water uses) underway on DoD and neighboring lands may adversely affect wetland ecosystems and small order streams, as well as the TER-S that utilize them for habitat. Wetlands, riparian habitat, vernal pools, embedded ponds and small streams link terrestrial and aquatic landscape components in many ways (transfer of nutrients, detoxification of pollutants, source and sink for carbon and other key elements, and buffer during flood and storm events) in addition to many other ecological linkages/services. They also are a biotic link between terrestrial and aquatic habitats and provide essential habitat for several listed and at-risk amphibian and many reptile species. Because of their high productivity, wetlands provide feeding and nesting habitats for migratory birds. They also serve as important movement corridors and feeding habitats for many mammals, including bats.

Significance

Degradation of aquatic habitats usually results from upstream and terrestrial activities. For this reason, the management and conservation of aquatic resources must be conducted in a watershed context. For example, restoration of TER-S wetland habitat degraded by siltation might only be possible by controlling upstream sources. Maintaining threatened or endangered fish or mussel species might be impaired by downstream dams. Assuring sufficient exchange of genetic diversity for salamander populations and other amphibians may be affected by the loss of adjacent habitats (e.g., ephermal ponds) or by barriers to movement (e.g., roadways).

Activities on DoD lands and waters also may directly affect aquatic resources. Topics of concern include past land-use and current impacts from military training, silvicultural activities, prescribed fire, or pollutants from on-base sewage and storm water run-off.

Recommendations

Upland land-use activities can and do have significant detrimental impacts to aquatic systems throughout the Southeast. To ameliorate these impacts, scientists must first understand the relevant causal factors and how these influence aquatic systems. Specific project priorities include:

1. Determining what key species depend on DoD aquatic habitats, prioritizing aquatic habitats and their associated upland land-use impacts, based on threats to TER-S, and prioritizing and establishing strategic conservation easements for both upland and aquatic habitats.

2. Communicating with partners to identify information needs. For example, coordinating with ARMI (Amphibian Research and Monitoring Initiative) to identify specific research needs for Southeast amphibian species-at-risk.

3. Enabling outreach and partnerships to share and gather habitat, TER-S trend, and land-use information on a watershed basis. This should include encouraging

surveys across land management boundaries, and integrating land management plans within watersheds.

4. Integrating relevant and available information systems (e.g., EPA, Army Corps of Engineers, USDA Forest Service, USGS, state agencies, and NatureServe).

8.4 RESTORATION EFFORTS WITHIN A WATERSHED CONTEXT

Background

Over the history of implementing the Endangered Species Act, the guidance to first "provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved and to provide a program for the conservation of such endangered species and threatened species…." is often overlooked, and recovery efforts suffer as a result. Coordinated efforts within a watershed to restore ecosystem functions or "ecological services" are few, and most have attempted to restore physical attributes of rivers and streams by re-establishing historical hydrologic patterns by removal or modification of dams, levees, or other in-stream structures. Scientific investigations that have examined the effects of watershed-based restoration efforts are even fewer.

Significance

In the southeastern United States, many TER-S are concentrated in relatively few watersheds; yet, the status of aquatic TER-S is inextricably linked with the function and structure of the watershed in which they reside. Because wetlands, streams, and rivers integrate and accumulate impacts from headwaters to coastal regions, restoration efforts that are planned and implemented on a watershed scale are the best solution for the recovery of these species.

Studies to develop restoration techniques for recovering watershed functions and restoring TER-S would result in new tools that could potentially recover entire suites of TER-S rather than single populations or individual species. In order to provide feedback to resource managers and researchers so they can modify or refine conservation actions and direct research activities, it is important that appropriate monitoring be a component of any watershed restoration effort.

Recommendations

In order to demonstrate true impacts of restoration efforts in a watershed context (i.e., improvements in water quality, species abundance and distribution, and hydrologic function), there is a need for a coordinated, watershed-based pilot restoration effort that uses an adaptive management approach to TER-S recovery. The outcome objective for this pilot effort would be to develop projects that can successfully monitor the impacts of conservation actions to TER-S and their habitats. This pilot effort must incorporate three components:

1. conservation actions to restore watershed conditions and needed ecosystem functions,

2. research to inform and guide these actions, and

3. monitoring to assess the effect of conservation actions and make corrections where needed.

The first task in developing this pilot effort is to identify key watersheds where DoD has a significant presence or interest. DoD can use its own resources as well as information from partner agencies (FWS, USGS, NOAA) to identify priority watersheds. Integration with the SEMP and/or DCERP is a possibility. Because of the large scope of a watershed-based approach for such a pilot effort, the watershed chosen should meet the following criteria:

- Function as a habitat to priority TER-S;
- Include significant DoD resources;
- Be modest in size (8-12 digit Hydrologic Units);
- Have adequate baseline physical, chemical, and biological monitoring data; and
- Offer opportunities for public and private partnerships.

Partnership is the key requirement for successful implementation of this watershed restoration effort. Involving multiple landowners will help secure the large amount of resources and long-term commitment required by such an undertaking.

8.5 SILVICULTURE AND VEGETATION MANAGEMENT OF ON-SITE OPEN-CANOPIED PINE ECOSYSTEMS

Background

There is a great need for sustainable maintenance of mature forest cover using uneven-aged silvicultural approaches to best manage woodlands for supporting military training, TER-S management, and forest health. Many southern pine forestlands on military bases have complex land-use histories that include early forest removal, subsistence agriculture, extensive erosion and topsoil loss, and reforestation using short-rotation offsite pine species. Other sites that have maintained forest cover usually have had extensive logging of original pine overstory, successional species conversion, and/or fire suppression for extended periods up to several decades. These scenarios usually result in fragmented forest landscapes with altered soil horizons and high duff accumulations, diminished groundcover species richness, a competitive hardwood midstory/understory competing with any pine overstory, and decreased habitat quality for sustaining critical TER-S.

Significance

Silviculture and vegetation management (including prescribed fire) of onsite open-canopied pines is a key priority topic for research and demonstration. This includes uneven-aged management (using both single-tree and group selection systems) of mature pine grasslands such as longleaf pine, conversion of offsite pine plantations to better adapted species using harvesting and prescribed fire, integration of groundcover restoration, and consideration of influences of prior land-use legacies upon species site relations and belowground ecological processes.

Recommendations

Silvicultural tools must be flexible, restorative, extend to groundcover conditions, and support critical faunal populations and their restoration. Selection systems should be examined for maintenance of stands in desirable condition for TER-S conservation. These tools also should be evaluated with variable overstory removals, restoration of fire, artificial regeneration, and groundcover species restoration for degraded stands. Longleaf pine would be a model upland ecosystem on the coastal plain. Suggested project priorities include:

1. Compare pine regeneration, oak and understory competition, fuel types and loading, and groundcover impacts between single-tree versus group selection silviculture in mature forests based on a context of TER-S objectives.

2. Develop upland pine woodland restoration technologies that include return of high-frequency fire following suppression, variable retention overstory harvests for conversion of offsite pine plantations to appropriate species, and regional seed sources and establishment techniques for native groundcover species.

3. Refine silvicultural and management tools that facilitate smoke management in the wildland-urban interface, to include deadwood removals adjacent to highways and urban dwellings, and enhanced plantings of native grasses to enable frequent burning and preclude high fuel loading scenarios with elevated smoke emissions.

8.6 PRESCRIBED FIRE IN UPLAND FIRE-MAINTAINED ECOSYSTEMS

Background

Increased knowledge is required to improve effectiveness of prescribed fire in restoring and managing vital ecosystems and associated TER-S, facilitate silviculture, and advance needs of military missions. There are increasing challenges associated with applying fire near the wildland-urban interface, and so there is an increasing need to make each burn as effective as possible. Knowledge required to accomplish this requires an understanding of how best to use all components of appropriate fire regimes to enhance TER-S habitat, facilitate ecological restoration, support silvicultural activities, reduce hazardous fuels, minimize emissions and smoke management issues, promote public education, and meet military mission requirements.

Significance

Fire is the critical ecological process uniting needs of conservation, silviculture, and defense training in the Southeast. A majority of vertebrate TER-S depends on frequent fire to maintain critical habitat, and many military missions require the open forest structure created by burning. Incomplete understanding of frequency, season, and severity of fire, coupled with constraints imposed by urbanization, compromises the ability of land stewards to make fully informed management choices. In addition, the modern landscape has been altered by change in fuel composition due to exotic plant species, stress to trees generated by pathogens and insects, excess fuel and duff formation, and disruption of ecotones between upland woodlands and

embedded ecosystems (streams, bogs, pocosins, prairies, cypress ponds, etc.). There is little understanding of interactive effects of these habitat alterations and changes in fire regimes. We do know, however, that exclusion of fire or its ineffective application (too infrequent, too high or too low in severity, and/or lack of growing-season burns) results in degradation of habitat structure, ecosystem composition, and landscape integrity. Furthermore, even small shifts in global climate or short-term variation in weather patterns may require changes in how prescribed fire is applied. Further, insufficient management of prescribed fire may compromise ecological, silvicultural, and military training goals, as well as result in hazardous fuel accumulation and increased risk of wildfires.

Recommendations

A multifaceted approach that spans ecological fire regimes, fuel and smoke management, and silvicultural practices is essential to fill gaps in knowledge of prescribed fire and fire ecology. Goals are to enhance TER-S, develop BMPs and prescribed fire management guidelines, and promote land-uses for military missions. Specific research and demonstration priorities include:

1. Emphasize integrated and long-term research approaches to address effects of variation in fire regimes. Research should target major upland habitats and ecotones, and include fire frequency, intensity, and seasonality. It is important to consider effects of past fire and land-use history, as well as other potential management and restoration actions, including ecological effects of interactions between fire and chemical or mechanical treatments.

2. Improve fire behavior prediction models through field validation, and develop models to consider long-term changes in fire ecology expected in the context of climate change.

3. Examine complex interactions among fire and insects and pathogens, introduced exotic plant species that alter fuels, and excessive fuels and duff that accumulate from fire suppression.

4. Research options for enhancing fuel and smoke management models across the range of Southeast climatic and fuel conditions. These should include modernization of traditional smoke screening models as well as newer emission issues, such as PM 2.5.

5. Aggressively expand fire ecology education through establishment of demonstration areas with effective uses of prescribed fire, and outreach efforts partnered to promote safety and necessity of prescribed fire to protect human health and security, as well as ecological stewardship.

8.7 STRATEGIES FOR RECOVERING TER-S OVER LARGE SPATIAL SCALES

Background

In the western United States, there have been several well-publicized efforts to connect landscapes on very large spatial scales to accommodate mobile species with large area requirements and low population densities (e.g., grizzly bears). Federal land holdings in the West typically are buffered by other federal lands, thus partnerships involving only federal agencies may extend over large geographic areas. Conversely, in the southeastern United States, higher human population densities, smaller federal land holdings, and highly diverse land ownerships make all-federal partnerships infeasible. Instead, partnering requires complex networks of relationships among groups with sometime diverging management objectives, even for species with modest area requirements. In the Southeast, military bases often provide the only available habitats for TER-S. Installation personnel are able to manage for some species' requirements, but not all. Either because its holdings are insufficient or, if their land area is sufficient, because their ability to manage for a species may be constrained due to encroachment-related factors, many installations have initiated conservation partnerships with other federal, state, and private landowners in their vicinity. Examples include the Gulf Coastal Plain Ecosystem Partnership involving Eglin AFB in Florida, the Onslow Bight Partnership involving Marine Corps Base Camp Lejeune in North Carolina, and the Sandhills Conservation Partnership involving Fort Bragg Army Base also in North Carolina.

Significance

The spatial requirements to maintain viable TER-S populations for which military bases have recovery responsibilities often exceed the area that can be provided by the bases themselves. Consequently, DoD has entered into partnerships with other public and private land owners to meet the needs of these species. Such partnerships may enable an increase in available habitat through management of offsite areas, or connection of onsite and offsite populations via conservation and management of movement corridors. These partnerships promote integrative management of the larger landscape in which the base is embedded, which is critical in today's world, given that one can no longer assume source populations for occupation of restored habitats. Instead, one must explicitly provide connectivity to sources on the landscape. In the face of climate change that will likely alter distribution of habitats at a landscape scale, the need for such partnerships will increase so as to enable shifts in species distribution. These partnerships have been effective, but each involves specific conservation strategies evolved from local needs and opportunities.

Recommendations

There is a need to continue and to expand partnerships to benefit TER-S in the southeastern United States. These partnerships should be developed based on prior partnership outcomes and on the innovative but general principle that TER-S recovery on military bases must be embedded within larger landscapes that incorporate corridor and landscape matrix design, as well as habitat patch configuration. Specific activities that would help address this need include:

1. Research examining the functionality of corridors. Do corridors affect movement with consequence, thereby affecting population dynamics at large scales? Corridors should serve the greater good, allowing multiple, compatible uses while serving the ecosystem, but what constitutes an appropriate, functional corridor design in southeastern landscapes is an open question.

2. Research to develop models for landscape planning. These should be spatially explicit models that allow for comparison of alternative strategies for habitat restoration in space and time, of alternative landscape designs, and of population viability of target species under these alternatives. They should also incorporate military mission requirements.

3. Demonstration of effective use of landscape planning in recovery strategies through conservation partnerships. An example of a possible project would be to identify a landscape where partnerships currently exist and where habitats can be managed to create corridors to facilitate increased movement between disconnected patches of TER-S habitats. Another example would be an effort to develop an adaptive management strategy, whereby corridor design would change depending on tested effectiveness of different corridor designs with respect to promoting linkages between target species populations.

8.8 ALTERED ECOLOGICAL STATES OF COASTAL ECOSYSTEMS, CLIMATE CHANGE, AND TER-S: PROACTIVE CONSERVATION STRATEGIES

Background

Many DoD lands serve a secondary conservation function as reservoirs of biodiversity in the modern landscape. These military bases are essentially critical habitat patches for TER-S within an often degraded and fragmented landscape matrix. Despite the physical protection to the boundaries of these patches, which are afforded by their status and by concerted management efforts to maintain viable populations, TER-S and quality of TER-S habitats are threatened by altered conditions that stretch across base boundaries, as well as long-term chronic changes associated with climate change that have no obvious entry point into the system.

The landscape is currently altered by a number of impacts, both anthropogenic and natural. Examples are land-use changes, losses of coastal vegetation as a buffering system, altered fire regimes, invasive species, pollution, and hydrologic alterations. Anthropogenically-driven climate change is likely to result in sea level rise, global temperature increase, and more frequent violent storms that will exacerbate the degradation of regional ecosystems. The result will be patchiness in resources, changing land cover, expanding NIS, and landscape fragmentation.

Significance

In the southeastern United States, military bases tend to be concentrated in the Gulf and Atlantic Coastal Plains. While the boundaries of the bases (and hence biodiversity reserves) are geographically fixed, altered habitat conditions and future conditions influenced by climate change will produce spatial shifts in envelopes of suitable habitat for many species. Species that

are constrained by limited dispersal and a matrix of unsuitable habitat dividing current source populations from suitable parts of their projected climatic envelope will not successfully complete their range shift, and may face extinction. TER-S conservation and management plans that do not consider current fragmentation or, especially, sea level rise in coastal landscapes will not successfully protect these species from extinction risks. Additional information is specifically needed regarding large-scale disturbance impacts to:

- Species populations and migration
- Coastal geomorphology (soils, hydrology, landforms)
- Fire regimes, fuel levels, and weather
- Barriers to movement
- Community disassembly/reassembly processes (including below ground)
- Energy dissipation
- TER-S and sentinel species in coastal areas
- Ecological services of marshes, barrier islands, and wetlands.

Recommendations

To better predict ecological states under altered habitat conditions and in consideration of climate change, scientists must develop a fundamental understanding of processes in coastal ecosystems, and better understand the near-term impacts of those processes on military training. Suggested project priorities include:

1. Improvements and innovations in predictive modeling components, cause-and-effect studies, leading indicators, near-term mitigation tools to enhance ecological processes, outreach to improve recognition of the value of biodiversity, linking biodiversity data and attendant process with projected impacts of climate change, development/growth projections, and basic understanding of minimum dynamic area.

2. Consideration of dispersal distances and likely shifts in climatic envelopes in conservation and management plans for species targeted for conservation.

3. Development of species representation targets that overlay predicted climatic envelopes with climate change to facilitate planning. In some cases, intervention and assisted migration may be necessary. Predictions for climatic envelopes are needed for TER-S, as well as the matrix-forming species that are part of their habitat. The collection of military lands in the Gulf and Atlantic Coastal Plains form a natural seaward-landward progression. This gradient of sites could be used to test hypotheses of species responses to climate change, and to implement assisted migration experiments whereby populations of TER-S from bases located more seaward are transplanted to lands further inland. Certain target species could be identified for use as demonstration targets.

8.9 MULTI-SCALE WATERSHED MANAGEMENT

Background

There is a need to develop a watershed management tool that is capable of incorporating across-scale monitoring information into a predictive modeling system that reflects differences in ownership and land management objectives. Such a model would need to be multi-scalar, capable of integrating multiple sources of information, and focused toward addressing prioritized land-use and resource needs (ESA, CWA, and other compliance issues). Currently, most watershed monitoring is either reactionary or overly standardized, and monitoring efforts do not reflect land-use and land condition. Effective monitoring could be better focused toward priority issues that are influenced by land-use planning and day-to-day land-use. Besides forecasting estimates of critical parameters, as a watershed management tool, models can play three roles: 1) identification of information gaps useful for monitoring plans; 2) integration of multi-source information to develop projected outcomes used in developing decision-based approaches, and 3) through sensitivity analysis, identification of features sensitive to change for land-use specific monitoring approaches.

Because of issues related to jurisdictional boundaries, the watershed management tool needs to emphasize adaptability to differences in land management objectives and concerns, yet still address compliance-based criteria. Further, the development of such a model should either result from modification of an existing model, adapted to fit the needs of multiple users, or be developed by a diverse group of stakeholders, including federal, state, regional, and local groups.

Significance

At watershed scales, the southeastern United States continues to undergo changes in land-use patterns and patchiness of use. At various scales, an increasing need exists to improve the effectiveness of monitoring and to account for the effects of multiple land-users at varying scales. Further, issues related to water quality and water-use demands continue to develop as human-use patterns change. Added to these issues is an expectation of continued efficiency and effectiveness of wetland habitat. Further, for many species, stream drainages reflect potential wetland and terrestrial habitat patterns and serve as movement corridors; thus, TER-S habitat prioritization based on land-use patterns within agglomerative watershed units is satisfactory for landscape planning.

Recommendations

Certain parameters must be met to successfully develop a multi-scale watershed management system that allows priority-setting and program resources to properly consider both species and compliance objectives (e.g., TER-S needs and meeting CWA requirements). Following are recommendations for implanting such a system:

1. Development of integrated step-wise monitoring protocols that can be incorporated into a platform suited for watershed modeling and management. These protocols need to be question-driven and reflective of land-use impacts as well as legacy conditions.

2. Continued evaluations of differential cumulative effects that arise from differences in past and current land-use conditions (habitat-units). Evaluation of wetland effectiveness and habitat unit sustainability thresholds would also be included within these evaluations.

3. Development of a decision-based forecasting model (e.g. Bayesian networks) that incorporates relevant watershed attributes with qualitative or discrete conditions associated with various land-use scales.

4. Continued development and evaluation of the sensitivity of water and habitat quality parameters to changes in watershed conditions that are reflective of land-use decisions. These assessments of sensitivity should be focused on compliance, sustainability, and functional efficiency (ecosystem services).

8.10 INVENTORY OF SPECIES AND ECOLOGICAL ASSESSMENTS OF COASTAL AND BLACKWATER STREAMS AND THEIR ASSOCIATED FLOODPLAINS

Background

The Atlantic and Gulf Coastal Plains of the southeastern United States include aquatic and wetland habitats utilized by many TER-S. These habitats include coastal rivers and streams, wetland habitats (e.g., Carolina bays, pocosin wetlands, bottomland hardwood swamps, oxbow lakes, ponds, seeps and springs). While the plant communities associated with these habitats are relatively well known, the diversity and use of these habitats by animals, and particularly invertebrates that may play a central role in ecological processes, are poorly studied compared to other southeastern habitat types. With increasing human population pressures and a large DoD presence in coastal ecosystems, it is important to establish reference conditions (both biodiversity and supporting ecological processes and structure) for these habitats to guide current and future conservation and restoration activities by DoD and its partners.

Significance

As in other large river-floodplain ecosystems, coastal rivers in the Southeast historically maintained close hydrologic connections to adjacent floodplain habitats. Floodwaters supplied the floodplain with nutrients, water, and sediments, and fluvial geomorphologic processes produced shifting microhabitats that shaped the distributions of species across the floodplain. The periodic flooding that links streams and rivers to the floodplain physically and ecologically contributes to high ecosystem productivity and diversity. In coastal areas, these linked river-floodplain ecosystems process upstream inputs of nutrients and sediments, provide nursery habitat and organic energy sources for aquatic and semi-aquatic species, and attenuate floods. They also buffer inland habitats from the effects of hurricanes and storm surges.

Recommendations

Research to increase knowledge of the biodiversity and ecological functions of these coastal habitats is needed to effectively manage and conserve coastal TER-S and the ecological services they provide. Specific needs include:

1. A survey of aquatic species (including terrestrial species that utilize aquatic habitats, such as migratory birds) and communities that are primarily confined to the Atlantic and Gulf Coastal Plains.

2. An analysis of survey data to determine which species and communities are at greatest risk from habitat loss due to development, loss of ecosystem function resulting from hydrological modifications, pollutants, and tropical storm events.

3. Description of the current status of coastal plain TER-S, and a prioritization or ranking of taxa and habitats at greatest risk.

4. Development of management guidelines to establish what steps can be taken to reduce the risk of species extirpation.

8.11 PARTNERSHIPS: DEVELOPMENT, SUSTAINED SUPPORT, FUNCTION, AND LESSONS LEARNED

Background

The DoD balances the need for use of natural resources for military training purposes with its stewardship responsibility. In some areas, habitat surrounding military installations has been eliminated creating islands of biodiversity, thus leaving only DoD lands to harbor TER-S. In other areas, public and private lands surrounding military installations maintain abundant wildlife habitat, providing TER-S with larger and more connected natural landscapes. These lands are very important to DoD, and provide an opportunity for landowners and stakeholders to work cooperatively. Partnerships are key to successful natural resource management because of the added benefits partners offer.

Significance

Recognizing the importance of managing natural resources at a larger scale, DoD and many other landowners now manage TER-S and other species using a partnership ecosystem approach. Such an approach takes into consideration watershed and natural community boundaries, recognizing that water, plant, and wildlife movement are not bound by jurisdictional lines. Partnerships allow for cooperative management outside of jurisdictional boundaries, providing for more effective TER-S management, potentially at a landscape level. However, successful partnerships require support beyond the developmental phase. DoD has been instrumental to many partnership successes. DoD-involved partnerships require DoD support from startup to functioning phases to long-term sustainment. Support in the areas of staffing, equipment, project funding, and sharing of successes and lessons learned are all important.

Recommendations

Increased emphasis on the development, continued support (funding and other), and functioning of priority partnerships is crucial. Emphasis should be given to those partnerships that offer a landscape or regional overview and to those that provide TER-S protection and management. DoD support for the development, implementation, and expansion of partnership efforts will heighten the conservation and protection of imperiled plant and animal species and their habitats, thereby providing a positive impact to DoD's operational and stewardship missions. Specific project suggestions include:

1. Creating a landscape/watershed-based matrix that prioritizes areas of highest DoD military mission and TER-S needs.

2. Development of a management and funding template with a core set of partners, including states, NGOs, federal land managers, and DoD.

3. Development of a partnership development handbook for military installations and organizations.

4. Development of a citizen-scientist conservation corps manual and demonstration project(s) to support natural resource management on military installations.

5. Exploring the costs and benefits of DoD adopting U.S. National Wildfire Coordinating Group prescribed fire training standards.

8.12 SUPPORT TOOLS FOR SPECIES CONSERVATION IN SOUTHEASTERN LANDSCAPES

Background

Targeting lands of highest priority for TER-S conservation on and near military installations in the southeastern United States is a need not yet totally met. Focusing conservation efforts outside the boundaries of a military installation will support military operational and stewardship missions.

Significance

It is seldom the case that a single military installation can meet the requirements to maintain a viable population of any species, let alone wide-ranging ones. Consequently, DoD is increasingly compelled to work with neighboring landowners to achieve conservation goals and help avoid restrictions to military operations. This has created a need for support tools to enable more effective conservation.

Recommendations

In developing support tools for regional TER-S conservation, it is important to first consider what the conservation objectives are (e.g., acquisition vs. easement vs. partnership). Following are scenarios that address potential objectives, and the tools that should be used to meet them:

- When acquisition of noncontiguous land is the most effective means to achieve DoD stewardship objectives, an inventory of tools that help to identify the best lands to acquire and facilitate cost-effective acquisition will be needed.

- Where military installation buffer establishment is required to promote the stewardship mission, tools like decision-support systems for prioritizing conservation needs and consolidated spatial data sets for land-use planning need to be applied to DoD natural resource management.

- When partnering with nearby landowners or those who control the use of neighboring land in order to promote integrated management of the surrounding landscape, cooperative conservation tools need to be applied.

Some specific projects that may be of value include:

1. Conducting research on how the relative effectiveness of easements and fee simple acquisition varies with conservation goals (e.g., buffer vs. corridor vs. breeding habitat).

2. Development of a decision-support tool that assigns connectivity value based on the integration of chances of success in achieving connectivity, cost of required restoration and management, cost of acquisition, and changes in other land-use values.

3. Inventory of existing techniques for prioritizing buffer or other lands supporting TER-S management.

4. Promoting the application of successful buffer land acquisition techniques that combine TER-S needs and non-conservation DoD encroachment requirements.

8.13 DATA COLLECTION METHODOLOGIES (SPECIES AND SYSTEM LEVEL) AND DATA STORAGE, REPORTING, AND SHARING ACROSS FEDERAL, STATE, AND LOCAL PARTNERS

Background

Department of Defense lands not only play an essential role in national security, they also are critical for safeguarding America's natural heritage. From Eglin AFB to Fort Stewart, from White Sands Missile Range to Camp Lejeune, military installations are well-documented as important havens of biodiversity and relatively untouched natural habitats. DoD-managed lands support more federally listed species than those of any other federal agency (NatureServe 2000).

In addition, a recent analysis for the Legacy Program by NatureServe in collaboration with the U.S. Fish and Wildlife Service, "Species at Risk Assessment and Recommendations," (project #03-154) found that of 729 DoD installations analyzed, 30% contain species at risk (those that are highly rare, but not federally listed), representing a total of 523 different species. Forty-seven of these species are already candidates for federal listing. Furthermore, 24 species at risk are restricted to only one DoD installation, and 82 species at risk have at least half of their known occurrences on DoD installations. Clearly, federal listing of so many species with very restricted ranges could seriously affect DoD's ability to carry out its training and readiness activities.

There are separate but related charges and objectives associated with the recovery and management of habitat for listed species and management and other activities designed to obviate the listing of other at-risk species. Increasing development pressure, from population growth in nearby communities, encroachment on installation buffer zones, and BRAC-related growth on selected bases themselves, pose difficult management challenges.

Significance

Because the survival of many TER-S is so highly dependent on military management activities, DoD natural resource managers have both a unique opportunity and an important responsibility to manage their habitats effectively, and to collaborate with other agencies and land stewards to prevent further species imperilment. Yet, different types of TER-S data are collected, managed, and stored by a variety of people and institutions and by a variety of means, with different currency and standards. There are casual observations, records of population fluctuations (monitoring), detailed element occurrence records (maintained by Natural Heritage Programs), and many other types of data.

DoD natural resource managers may have a great deal of information on the resources on their base, but their data typically ends at the installation boundary. It is neither reasonable nor practical to expect staff at individual installations to be able to conduct regional analyses. If existing data were assembled into an integrated system, with means for distribution, analyses could then be conducted that would show a more accurate picture of the status and distribution of target species across the region. Similarly, managers could determine opportunities for conservation of these species on and off of military lands, thereby enhancing protections for already listed species and obviating the need for additional future listings.

Recommendations

There is a need to assemble, integrate, manage, protect, and distribute TER-S data so they may be used effectively to achieve conservation goals across the region. A geodatabase that integrates field-based inventory information, species distribution models, environmental data (soils, wetlands), socioeconomic data (projected human population increase), as well as recovery plan goals for listed species would enable users to depict and analyze conflicts and opportunities related to listed species. Specific recommendations include:

1. Holding a workshop with project partners (e.g., USFWS, academic researchers, NatureServe) to review objectives, and to assess data availability and security issues.

2. Collecting existing relevant data.

3. Developing and refining data as needed into a project geodatabase that can accommodate a variety of data types yet have sufficient fields in common to allow for data integration.

4. Using a GIS-based decision-support system, conducting an analysis for a pilot group of target species to test the system.

5. Training DoD managers in the use of the system so that they can carry out future assessments.

8.14 COORDINATION OF SPECIES AND METAPOPULATION MANAGEMENT

Background

Land ownerships create boundaries that may impede species and habitat management at the population or subpopulation level. The Endangered Species Act also may contribute to fragmentation by assigning different responsibilities to federal agencies, states, and private or nonprofit organizations. Federal agencies, states, and others may further subdivide management tasks based on unique missions and land-uses. Barriers to population and subpopulation management include political boundaries, lack of organized efforts to manage outside boundaries, policies that hamper cross-boundary management, and funding inflexibilities.

Significance

In the case of military installations, a short-term mentality may exist since garrison commanders rotate often. This tends to make long-term concerns, such as maintaining genetic variability of TER-S, a relatively low priority. The result is an inability to institute integrated management of populations and subpopulations. The opportunity to survey and monitor populations consistently and effectively becomes increasingly challenging, while restoration and management across the range of the species may be inconsistent in application and adoption of workable techniques. In simpler terms, managers may be missing opportunities to achieve effective communication and synergy.

Recommendations

To improve coordination of species/subspecies management at the population/subpopulation level, it is necessary to improve management across land management boundaries. Conservation easements or buffering may play a role in connecting population/subpopulation habitats, but more is needed. Specific recommendations for improving cross-boundary management of TER-S and other species include:

1. Consideration of genetics through increased exchange of DNA. This will conserve genetic diversity and avoiding genetic homogeneity.

2. Development of methods to maintain demographic structure across species and subspecies ranges, including partnering with appropriate agencies or organizations, using mitigation banking, seeking policy changes, and planning at the regional level.

3. Development of informational materials and “how to” guidelines for establishing partnerships, exporting successful partnership outcomes, and developing and implementing regional/multi-agency plans.

4. Improved information regarding the potential biological impacts of development patterns.

5. Prioritization of lands for buffering.

6. Development of market incentives and tax code improvements to encourage non-regulatory participation.

7. Increased information on the appropriate scale for management of specific species/subspecies (e.g., small scale vs. large scale).

9.0 SUMMARY AND CONCLUSIONS

A primary objective for the Southeast Region TER-S Workshop was to help inform DoD how best to invest its limited conservation resources. By bringing together relevant managers and researchers from various sectors, it is hoped that outcomes from this workshop will create a common platform among federal, state, and non-governmental organizations for future research, demonstration, and management action that benefits TER-S, their associated ecosystems, and the sustainment of training and testing operations.

Participants identified several topics of particular importance for TER-S management in the Southeast. These included gaining a better understanding of fire, restoration, and ecological system linkages, as well as how related management activities impact species, habitats, and the military's training mission. Further, a general consensus emerged that improving existing partnerships and forming new alliances can provide synergistic benefits to all stakeholders.

By implementing workshop outcomes outlined in the Executive Summary and detailed in Section 8, DoD can help address TER-S management challenges by targeting their program dollars towards conservation efforts that achieve species and habitat protection goals while maximizing training and testing flexibility. By removing the threats that impair at-risk species, recovering listed species, and using an ecosystem-based adaptive management approach that considers ecological processes as well as multiple spatial and temporal scales, DoD's conservation programs strive to keep common species common while preventing the need for additional species listings. Advancing research priorities and using resulting information to better manage listed and at-risk species offers a significant opportunity to benefit TER-S populations in the future. Working together, SERDP, ESTCP, and Legacy strive to tackle conservation challenges holistically, comprehensively, and proactively.

Although no one group or agency can undertake all the actions enumerated in this document, recommendations captured are relevant to many stakeholders. Therefore, these proceedings should be viewed as a source document when prioritizing annual planning and resource allocation activities. Overall, it is hoped that workshop outcomes will prove valuable for multiple interested stakeholders throughout the Southeast for the next several years.

APPENDIX A: PARTICIPANT LIST

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APPENDIX B: AGENDA

Tuesday, February 27 - PLENARY SESSION AND FIELD TRIP				
Start	**End**	**Topic/Title**	**Speaker**	**Organization**
7:30 AM	11:30 AM	**Registration Open**		
7:30 AM	8:00 AM	**Continental breakfast**		
8:00 AM	8:15 AM	Conference Welcome and Announcements	Dr. John Hall Mr. L. Peter Boice	SERDP/ESTCP DoD Conservation
8:15 AM	8:45 AM	Patrick AFB Welcome	Colonel Thomas Bouthiller Ms. Robin Sutherland	45th Space Wing
8:45 AM	10:15 AM	Overviews: SERDP, ESTCP, Legacy Program	Dr. John Hall Mr. L. Peter Boice	SERDP/ESTCP DoD Conservation
10:15AM	10:30AM	BREAK		
10:30 AM	11:00 AM	Emerging Issues in Forest Health	Sharon Hermann	Auburn University
11:00 AM	11:30 AM	Connectivity in Fragmented Landscapes at Varying Scales	Larry Harris	University of Florida
11:30 PM	12:30 PM	**Lunch Provided**		
12:30 PM	4:45 PM	Field Tour of Cape Canaveral		
4:45 PM	5:15 PM	Board buses and return to hotel		
6:00 PM	8:00 PM	**Evening Mixer and Reception**		
Wednesday, February 28 - TECHNICAL SESSIONS				
Start	**End**	**Topic/Title**	**Speaker/Chair**	**Organization**
7:30 AM	8:00 AM	**Continental breakfast**		
8:00 AM	8:15 AM	SERDP/ESTCP Projects Overview	Dr. John A. Hall	SERDP/ESTCP
8:15 AM	8:30 AM	Legacy Projects Overview	Mr. L. Peter Boice	Legacy
		Technical Session 1: System Level Issues		
8:30 AM	9:00 AM	SE Aquatic Priorities	Rachel Muir	USGS
9:00 AM	9:10 AM	Session Charges		
9:10 AM	9:30 AM	**Break**		
9:30 AM	12:00 PM	1-1: Coastal Systems	Vernon Compton	The Nature Conservancy
9:30 AM	12:00 PM	1-2: Longleaf Pine and Associated Systems (including Fall Line Sandhills)	Joan Walker	USDA-Forest Service Southern Research Station
9:30 AM	12:00 PM	1-3: Integrating Bottomland Hardwoods, Floodplains, and Upland Systems	Rachel Muir	USGS
9:30 AM	12:00 PM	1-4: Inland Aquatic Wetland Systems	Lewis Gorman	US Fish and Wildlife Service
12:00 PM	12:30 PM	Morning sessions report		
12:30 PM	1:30 PM	**Lunch Provided**		

		Technical Session 2: Land Management and Dynamic Environments		
1:30 PM	2:00 PM	Ecology of Large-Scale Natural Disturbance Events	Loretta Battaglia	Southern Illinois University Carbondale
2:00 PM	2:10 PM	Session Charges		
2:10 PM	2:15 PM	Proceed to breakouts		
2:15PM	3:30 PM	2-1: Managing for Infrequent Large-Scale Natural Disturbance Events	Bill Platt	Louisiana State University
2:15 PM	3:30 PM	2-2: Maintaining Connectivity Amidst Land-use and Climate Change	Jeff Walters	Virginia Tech University
2:15 PM	3:30 PM	2-3: Addressing Impacts Resulting from Upland System Restoration	Ralph Costa	US Fish and Wildlife Service
2:15 PM	3:30 PM	2-4: Fire Effects and Patch Dynamics	Lindsay Boring	Joseph W. Jones Ecological Research Center at Ichauway
3:30 PM	3:45 PM	**Break**		
		Technical session 2 cont.		
3:45 PM	5:00 PM	2-1: Managing for Infrequent Large-Scale Natural Disturbance Events	Bill Platt	Louisiana State University
3:45 PM	5:00 PM	2-2: Maintaining Connectivity Amidst Land-use and Climate Change	Jeff Walters	Virginia Tech University
3:45 PM	5:00 PM	2-3: Addressing Impacts Resulting from Upland System Restoration	Ralph Costa	US Fish and Wildlife Service
3:45 PM	5:00 PM	2-4: Fire Effects and Patch Dynamics	Lindsay Boring	Joseph W. Jones Ecological Research Center at Ichauway
5:00 PM	5:30 PM	Afternoon sessions report		
		Dinner (on own)		
Thursday, March 1- TECHNICAL SESSIONS				
Start	**End**	**Topic/Title**	**Speaker/Chair**	**Organization**
7:30 AM	8:00 AM	**Continental breakfast**		
		Technical Session 3: Overcoming Management Challenges		
8:00 AM	8:30 AM	Overview of the SERPPAS Partnership	Jan Larkin	Office of the Secretary of Defense, Range Outreach
8:30 AM	8:40 AM	Session Charges		
8:40 AM	8:45 AM	Proceed to breakouts		
8:45 AM	10:00 AM	3-1:Resolving Watershed vs. Ecological System Dichotomy	Lee Mulkey	University of Georgia/SEMP
8:45 AM	10:00 AM	3-2: Barriers to Cross-Boundary Management	Fred Annand	The Nature Conservancy
8:45 AM	10:00 AM	3-3: Coordinated Information and Data Sharing Among Stakeholders	Milo Pyne	NatureServe
8:45 AM	10:00 AM	3-4: Monitoring Across Different Spatial Scales	Don Imm	Savannah River Ecology Laboratory

10:00 AM	10:15 AM	**Break**		
		Technical Session 3: cont.		
10:15 AM	11:30 AM	3-1:Resolving Watershed vs. Ecological System Dichotomy	Lee Mulkey	University of Georgia/SEMP
10:15 AM	11:30 AM	3-2: Barriers to Cross-Boundary Management	Fred Annand	The Nature Conservancy
10:15 AM	11:30 AM	3-3: Coordinated Information and Data Sharing Among Stakeholders	Milo Pyne	NatureServe
10:15 AM	11:30 AM	3-4: Monitoring Across Different Spatial Scales	Don Imm	Savannah River Ecology Laboratory
11:30 AM	12:00 AM	Morning sessions report		
12:00 AM	1:00 PM	**Lunch Provided**		
		Technical Session 4: Synthesis		
1:00 PM	1:10 PM	Session Charges		
1:10 PM	1:15 PM	Proceed to breakouts		
1:15 PM	3:15 PM	4-1: System Level	John Hall/Alicia Shepard	
1:15 PM	3:15 PM	4-2: Land Management and Dynamic Environments	Lee Mulkey/Bill Woodson	
1:15 PM	3:15 PM	4-3: Overcoming Management Challenges	Peter Boice/Leslie Orzetti	
3:15 PM	3:30 PM	**Break**		
3:30 PM	4:30 PM	Afternoon Session Reports & Discussion	John Hall/Alicia Shepard	
4:30 PM		**FORMAL WORKSHOP ENDS**		

APPENDIX C: WORKSHOP CHARGE

Southeast Region Threatened, Endangered, and At-Risk Species Workshop: *Developing a Blueprint for System-Level and Multi-Partner Solutions*

Sponsors: This event is being sponsored by the Strategic Environmental Research and Development Program (SERDP), Environmental Security Technology Certification Program (ESTCP), and Legacy Resource Management Program (Legacy). SERDP and ESTCP are Department of Defense (DoD) programs designed to support research, development, demonstration, and transition of environmental technologies required by DoD to perform its mission. Sustainable infrastructure, including natural resources, is an important focus area for these programs. Legacy supports DoD efforts to protect, enhance, and conserve our nation's natural and cultural heritage through stewardship, leadership, and partnership while contributing to the long-term sustainability of DoD's land, air, and water resources for military use. All three programs seek to improve DoD's management of natural resources through investments in research, development, demonstration, or management initiatives.

Background: The DoD serves as steward for approximately 30 million acres of land and associated air and water resources. These lands harbor more threatened, endangered, and at-risk species (TER-S) per acre than any other federal lands. DoD is committed to protecting its lands, waters, and airspace, as well as the native ecosystems and species that inhabit them, and has established a range of policies to ensure proper stewardship while sustaining military mission readiness. The DoD can improve its management of military lands through greater understanding of native ecosystems, TER-S, TER-S habitats, and their relationships to military training activities. This will ensure the availability of military lands for training and testing, as well as enhance conservation of our nation's biological diversity. In June 2005, the Department of Defense sponsored a national symposium on issues related to TER-S on DoD lands (http://www.serdp.org/tes/). A major outcome of this event was the determination that regional workshops were needed to develop appropriate research, demonstration, and management agendas.

Many installations critical for military training are located throughout the southeastern United States. For the purposes of this workshop the Southeast region encompasses those portions of North Carolina, South Carolina, Georgia, Florida north of the subtropical zone, Alabama, Mississippi, Louisiana, and eastern Texas that roughly correspond with the Atlantic and Gulf Coastal Plains, including the near-shore environment and the Fall Line Sandhills. The installations within this region provide essential habitat for numerous TER-S, many of which have been studied extensively at the individual species level (e.g., red-cockaded woodpecker). In addition, many southeastern installations are in areas with significant concentrations of urban, agricultural, and industrial use that impact TER-S. The aquatic and terrestrial ecosystems across the region on which these species depend have been reduced significantly, or their condition has been significantly altered when compared to historic amounts and conditions.

To facilitate the recovery of listed species and mitigate against the need for new listings, increased attention must be given to the management of listed and at-risk species from an ecosystem and watershed perspective. This perspective must encompass the numerous land management jurisdictions throughout the region. Some efforts are already underway, for example:

- The SERDP Ecosystem Management Project (SEMP), a ten-year project being carried out at Fort Benning, Georgia, which is attempting to help the Army and other DoD managers implement science-based ecosystem management approaches to support sustainable use of DoD lands, waters, and airspace.

- The Southeast Regional Partnership for Planning and Sustainability (SERPPAS), a pilot effort to develop an effective working regional partnership between DoD, four Southeastern states (Florida, Georgia, North Carolina, and South Carolina), and other stakeholders that addresses a variety of land management issues.
- The April 2006 Legacy-sponsored workshop that included DoD, U.S. Fish and Wildlife Service, and fish and wildlife representatives from the four SERPPAS states to develop and implement regional projects that integrate recommendations from DoD's integrated natural resource management plans (INRMPs) and the State Wildlife Action Plans.

Objective: SERDP, ESTCP, and Legacy must determine how their limited research, demonstration, and operations and management funds can best be invested and coordinated with other federal, state, and non-governmental organization (NGOs) resources to improve DoD's ability to effectively address its TER-S management requirements in the Southeast while maintaining its military testing and training mission. To strategically guide future investments, and to facilitate long-term cooperation and coordination, this workshop will:

1) Assess TER-S management needs within a regional context, with an emphasis on system-level and cross-boundary approaches;
2) Assess these approaches for their potential to keep common species common, while recovering or enhancing TER-S populations;
3) Examine the current state of the science and practice within DoD, associated with such holistic approaches;
4) Identify potential partners and existing partnership structures whose focus is, at least in part, meeting TER-S conservation objectives;
5) Identify the gaps in knowledge, technology, management, and partnerships that, if addressed, could improve implementation of system-level and cross-boundary approaches; and
6) Prioritize investment opportunities to address these gaps.

Species-specific research, demonstration, and management requirements are not a workshop focus. Management of habitats for specific species may used as examples for region-wide approach assessment.

Approach: This workshop is scheduled to take place February 26 to March 2, 2007 near Cape Canaveral Air Force Station (AFS) and Patrick Air Force Base (AFB), Florida. Invitees include senior researchers and managers from DoD, other federal and state agencies, academia, and the NGO community. Workshop elements include presentations of commissioned papers, a field tour of Cape Canaveral AFS, and concurrent breakout groups on relevant topics. A steering committee was formed to assist in defining topics for presentations and breakout group assignments.

Product: The outcome of this workshop will be a strategic research, demonstration, and management document that provides recommendations for SERDP, ESTCP, and the Legacy program, as well as other interested parties, to guide TER-S and ecosystem management related investments over the next five years. To promote coordination and cooperation, relevant information also will be provided to the SERPPAS.

APPENDIX D: SESSION CHARGES

Session I—System Level
Although DoD's goal is to manage TER-S through ecosystem-based approaches, many important questions still remain to be addressed before successful implementation of such approaches can occur. In this session, we will divide groups into the following topic areas: Coastal Systems; Longleaf Pine and Associated Systems (including Fall Line Sandhills); Integrating Bottomland Hardwoods, Floodplains, and Upland Systems; and Inland Aquatic and Wetland Systems. The desired outcome of this session is for participants to identify information needs relevant to the management of TER-S within an ecosystem-based context as it applies to each of the above ecosystem divisions.

Session II—Land Management and Dynamic Environments
The ecosystems of the Southeast upon which TER-S and other species depend are dynamic entities that are impacted by large-scale but temporally infrequent disturbance events—such as hurricanes, pervasive development patterns, or other anthropogenic influences occurring at regional or greater scales and over long time horizons that often complicate management flexibility and resultant decisions. By taking into account the dynamism of these environments, projected long-term changes in environmental conditions, and the historic and projected patterns of habitat loss and fragmentation, land managers can improve the prospects for the long-term sustainability of TER-S and other species that depend on the same ecosystems. In this session, we will divide groups into the following topic areas: Managing for Infrequent Large-Scale Disturbance Events, Maintaining Connectivity Amidst Land-use and Climate Change, Addressing Impacts Resulting from Upland Restoration, and Fire Effects and Patch Dynamics. The desired outcome of this session is for participants to identify information needs relevant to management of ecosystems and TER-S within these dynamic and human-altered environments.

Session III—Overcoming Management Challenges

Working collaboratively to properly manage ecosystems can often be a challenging endeavor because of diverse priorities and missions among land management agencies. In addition, depending on the management question or issue to be addressed, different spatial scales or ecological contexts (e.g., watershed versus a specific type of plant community or ecological system) may provide the appropriate framework within which to assess information and make decisions. In this session, groups will divide into the following topic areas: Resolving the Watershed versus Ecological System Dichotomy, Barriers to Cross Boundary Management, Coordinated Information and Data Sharing Among Stakeholders, and Monitoring Across Different Scales. The desired outcome of this session is for participants to identify management challenges and collaborative opportunities at multiple spatial and temporal scales.

Session IV—Synthesis
Synthesizing and prioritizing information resulting from the previous breakout group discussions is a primary workshop objective. In this session we will divide participants into the following breakout groups: System Level, Land Management and Dynamic Environments, and Overcoming Management Challenges. Participants will synthesize and prioritize needs identified in earlier sessions, focusing on the highest priority information needs and most critical issues relevant to management of TER-S within an ecosystem-based approach. The desired outcome of this session is to provide a prioritized list of the top information needs.

APPENDIX E: WHITE PAPERS

Emerging Issues in Forest Health and Their Significance for Rare Species of the Southeast United States

Sharon M. Hermann, Auburn University
John S. Kush, Auburn University
Dean H. Gjerstad, Auburn University

Large-Scale Disturbances and Ecological Communities in the Southeast US

Loretta Battaglia, Southern Illinois University Carbondale
Brian Beckage, University of Vermont

Imperiled Aquatic Resources of the Southeastern United States: Status, Threats and Research Needs

Rachel Muir, U.S. Geological Survey
Steven Travis, U.S Geological Survey

Importance of Connectivity at Multiple Scales in Times of Rapid Climate Change

Larry Harris, University of Florida

*White Papers are also posted at www.serdp.org/tes/southeast**.**

EMERGING ISSUES IN FOREST HEALTH AND THEIR SIGNIFICANCE FOR RARE SPECIES OF THE SOUTHEAST UNITED STATES

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NOTE FROM THE AUTHORS:
Our topic for the workshop was limited to emerging issues in forest health as they specifically relate to species of special concern in the Department of Defense Southeast region of the United States (generally the area below the Piedmont Fall Line). This paper targets upland, open-canopy pine forests (woodlands) and provides insight into applying metrics associated with forest structure to develop an umbrella approach to management of these ecosystems. We are currently expanding some of the ideas presented in the current paper and will submit this companion manuscript to a scientific journal; contact S.M. Hermann for further information. We thank C. Guyer and H. Balbach for comments on the current paper. We appreciate the assistance of B. Estes in gathering literature sources and summarizing information.

Abstract: In this paper we outline emerging issues in forest health for selected Coastal Plain and Fall Line ecosystems. We concentrate on conservation of threatened, endangered, and at-risk species (TER-S), emphasize vertebrate groups, and consider aspects of umbrella management. Our focus is on open-canopied forests because, prior to European settlement, they accounted for much of the region and because many vertebrate TER-S are dependent on these ecosystems. The forests were once dominated by longleaf, slash, and/or shortleaf pines (*Pinus palustris*, *P. elliottii*, and *P. echinata*). To determine which management activities to target, we consider information for vertebrate TER-S determine that forest structure is the most significant factor of forest health that is most directly related to species requirements. Habitat structure is a complex issue and includes placement and individual size of trees as well as of other woody plants and herbaceous species. This wide range of structural elements varies in space and time.

We recognize that open-canopy forests are dependent on fire to maintain habitat structure. Prescribed fire is applied within a framework of a burn regime and multiple factors, especially fire frequency and month-of-burn, must be incorporated into long-term management plans. At many sites, alteration of fire regimes or total fire exclusion has potential to drastically degrade forest health in less than a decade. Specific issues of immediate concern include the on-going ability to use prescribed burns as a significant land management tool in the context of a growing wildland-urban interface, and efficacy of potential options for mimicking some affects of fire. We remind readers that pre-emptive use of prescribed fire is the most effective land management tool to minimize negative effects of wildfire.

Traditional site conversion produces an immediate loss of native forest. Acting over a slightly longer time period, alteration of forest structure also causes decline of forest health issues specific to TER-S. This type of alteration may result from inappropriate logging and/or total exclusion or misapplication of prescribed fire. In addition, invasive exotic species, shifts in species composition and/or decline in tree health all have potential to depress forest health in the near future.

For long-term success in conserving TER-S, there must be an increase in acreage of healthy forests accomplished by planting extirpated species and/or increasing effectiveness of prescribed fire. There is

growing interest in returning longleaf pine ecosystems to the landscape and we note gaps in knowledge needed to successfully re-establish the tree as well as associated ground layer species. Factors such as current species composition, degraded soil quality, presence of exotic species, and past fire exclusion also can negatively influence habitat structure. These alterations may impede forest restoration efforts. Currently, many planted plantations that replaced much of the open-canopied forests may be in danger of contracting pathogenic root-fungi. Associated decline of off-site stands may compromise management for TER-S that forage in these areas. Off-site trees are native species that have been planted on sites where they naturally did not occur or were not dominant. We discuss options for off-site planted pines.

At the landscape-scale, enhancing forest health on private property has benefits for TER-S management on nearby public lands. Improved silvicultural information is essential to encourage landowners to manage for open-canopy forest. Modified selection systems and improved growth and yield models are needed to promote economic feasibility of retaining uneven-aged stands. To facilitate regional planning, a geo-referenced mapping effort should be initiated. As part of the mapping effort, reference sites should be identified. Reference stands displaying exemplary forest health are needed to assess success of restoration efforts, silvicultural activities and application of prescribed fire. Monitoring of on-going management activities is required to evaluate local and regional forest health related to TER-S.

Finally we discuss ways to prioritize aspects of forest health. We emphasize the importance of retaining and improving extant open-canopy forests, as well as the significance of restoration efforts. Most relevant to these goals are forestry actions and prescribed fire. These management tools create and maintain elements of complex habitat structure required by TER-S and other components of open-canopy forests.

INTRODUCTION TO FOREST HEALTH

Forest health has many definitions. Society of American Foresters adopted language from Helms (1998) that includes "condition of a forest derived from concerns about such factors as its age, structure, composition, function, vigor, presence of unusual levels of insects or disease”. Each factor spans a continuum with end points that depend on a specific view of forest health. Barnard (2006) noted “tree health” is not synonymous with “forest health” and Helms (1998) stated "perception and interpretation of forest health are influenced by individual and cultural viewpoints, land management objectives, spatial and temporal scales, the relative health of the stands that comprise the forest”.

The concept of forest health provides a framework for identifying and prioritizing ecosystem-level management. If a goal is to re-establish a tree species then forest health is defined in terms of survivorship and vigor of seedlings and planting a plantation is a useful objective. If management goals are more complex (i.e. recreating more natural forest structure or composition), the challenge of assessing forest health increases. When ecological conservation is a major interest, assessment of forest health depends not just on metrics that target tree health but also those that are related to factors that sustain TER-S. To determine what factor(s) is most relevant in assessing forest health for many upland vertebrate TER-S, we briefly review literature on regional forest types, consider complex aspects of forest structure and then examine habitat needs of species of special concern.

DOMINANT UPLAND FORESTS OF THE COASTAL PLAIN AND FALL LINE REGIONS

Landscape in the 1800s: Descriptions exist of the southeastern landscape before European settlement (e.g. Bartram 1791). Quantifying of habitat types began in the mid-1800s and was reported in publications at the end of that century (cf. Sargent 1884 and Mohr 1896). Hardwood forests were present but were such a small part of the area that acreages were not reported in timber values (Sargent 1884). South of the Fall Line, much of the region supported pine-dominated ecosystems (Mohr 1896), most maintained by frequent, low-severity fire. Fire regimes varied across the landscape depending on topography, soil-type and biotic factors related to abiotic differences; current estimates suggest burn frequencies of 1 to 5 or

more each decade. Open-canopy pine forests served as landscape matrix with other ecosystems imbedded in them. Imbedded habitats of conservation concern include seepage savannas, mixed pine-oak stands, and small-scale oak "domes" or thickets (Greenberg and Simons 1999).

Loblolly pine (*Pinus taeda*) is currently common but this is an artifact of human activity. Although found in all southeast states, 150 years ago loblolly was a minor component of the landscape, generally limited to narrow areas along streams and other mesic sites (Ashe 1915) where it experienced fire very infrequently. In places, it was mixed with hardwood stands and longleaf or shortleaf pines (Mohr 1896). Slash pine (once called Cuban pine) dominated some flatwoods in Florida and near the coast of other states; Mohr (1896) noted that it might extend as far as 60-100 miles inland following flatwoods associated with river drainages. In some sites it was mixed with longleaf and/or loblolly. Although shortleaf pine was common in east Texas, northern Louisiana, and Mississippi, when found along the Fall Line it was scattered or mixed with longleaf and hardwood stands (Mohr 1896). Sand pine (*Pinus clausa*) was important in isolated areas on the Lake Wales Ridge in central Florida. This ecosystem experiences periodic high-intensity fires and is characterized by a dynamic structure. The ecology of this forest differs from the other pine ecosystems and will not be considered here. In the modern landscape, however, some challenges of applying fire are shared among all types.

Prior to regional logging that ended by 1920, longleaf pine defined most upland areas on over 60 million ac although the open forest rarely exceed 4000 board feet/ac (Mohr 1896). It was the forest type most likely to burn. Critical to effective management is understanding longleaf ecology, especially its dependence on fire. Chapters in Jose et al (2006) provided useful background information.

Modern Landscape: In the modern landscape, acreage of open-canopied forests has dramatically declined due to conversion to agricultural use, urban development or plantation forestry. Of the undeveloped land that remains, naturally regenerated stands are often fire suppressed or burned only infrequently. This is especially problematic for longleaf stands. Longleaf has been reduced to ~ 3% of the original acreage and much of that receives inadequate fire; this forest type has been labeled as one of the most endangered ecosystems in the country (Noss et al. 1995). Natural regeneration of longleaf is generally unsuccessful unless seed falls on bare soil; in addition native ground layer declines without fire. Although Outcalt (2000) estimated that slightly more than 80% of natural longleaf stands on public property had been burn at least once in the pervious five years, less than 40 % of private property stands were burned in the same time period. In addition to fire exclusion, there are other anthropogenic disturbances that degrade remaining open-canopied pine stands. At one time in Florida, longleaf or slash pine flatwoods accounted for 50% of the uplands (Davis 1967). Today, remaining stands are often ditched in attempts to create drier stands to increase the success of planted pines.

Of the extensive areas in pine plantations in 1997, ~62% was in loblolly and ~16% in slash pine (South and Buckner 2004). The majority of these stands were established on sites that once supported longleaf. In addition, loblolly and/or shortleaf pine have seeded into former longleaf stands that had been cut-over and fire-suppressed or were fallow agriculture fields. Despite these pines being "off-site", they have value for many conservation needs, including foraging habitat for some TER-S.

HABITAT REQUIREMENTS OF SOME VERTEBRATE TER-S

Evaluation of habitat needs of TER-S narrows the range of forest health topics to be considered in management decisions. We focus attention on vertebrate TER-S (see Van Lear et al. 2005). Requirements directly related to forest health were summarized for 16 vertebrate species of concern. Fourteen of sixteen vertebrate species have habitat requirements that include grassland, sandhills, and/or sparse woodlands with open midstory and fire maintained understory (Table 1). This supports the idea that forest structure is a significant aspect of TER-S habitat requirements and is important for a wide-range of species, including

red-cockaded woodpeckers (RCW) and gopher tortoises, plus Bachman's and Henslow's sparrows and other ground-nesting birds not on a federal list (e.g. bob-white quail). These species required an open-canopy structure with sparse midstory and most also need a grass-forb ground layer. For RCW, old-growth trees are preferred. Fire is consistently listed as an important factor and so fuel type (species composition of ground layer) is indirectly related to healthy forest structure (see below).

The two species that are limited to habitats imbedded in open-canopy forests (Table 1) are likely to have been relatively rare prior to habitat lose. This is in contrast to the fourteen that require open forest structure; that habitat structure was once common on the landscape and it is likely that this was also the case for the vertebrates that are currently TER-S. These species are likely to be rare in the modern landscape due to habitat loss and other anthropogenic disruptions. Some species (Bachman's sparrow, bobwhite quail, and others) are often listed as requiring early successional vegetation however this habitat type was rare prior to European settlement. In the modern landscape, early successional vegetation provides some but not all of the habitat components that are common in the grass-forb dominated ground layer of open-canopy pine forests.

Currently, there has been some quantification of habitat structure requirements for gopher tortoises, and RCW, and to a lesser extent for Bachman's and Henslow's sparrows. The most specific and complete documentation over a large part of the range was been carried out for RCW. The existing studies primarily have targeted aspects of timber and affects of fire. The four best-studied TER-S occur over much of the southeast and so may have use as "umbrella" and/or indicator species.

Red-Cockaded Woodpecker: The recent revision of the RCW recovery plant provides a useful review of literature on quantification of habitat requirements for the species (U.S. Fish and Wildlife Service 2003). Reports on acceptable forest structure for clusters of cavity trees spans a relatively wide range of basal areas for overstory longleaf pine (8-60 ft^2/ac) and this is slightly sparser than for cavities in loblolly and/or shortleaf pines (reviewed in U.S. Fish and Wildlife Service 2003). The point at which encroachment of midstory causes cavity abandonment has been estimated for woody stem basal area as well as midstory height.

Gopher Tortoise: Forest structure influences gopher tortoises (Auffenburg and Franz 1982), but data have often simply demonstrated that tortoises persist in open pine forests and decline in hardwood encroached stands or pine plantations (Hermann et al. 2002). Since tortoises are herbivorous, it is often suggested that the ground layer may limit tortoise density. However, measurements of ground cover have produced mixed results and there is no clear pattern between percent cover of the ground layer and habitat use by tortoises (literature reviewed in Guyer et al. 2007 and Florida Fish and Wildlife Conservation Commission 2007). Burrows are often in the most open areas available to tortoises (Tuberville et al. 2007) and there is a strong relationship between high rate of burrow abandonment and tree canopy cover (Aresco and Guyer 1999). In addition, there is a report of burrow density increasing immediately after growing-season fires (O'Meara and Abbott 1987), suggesting that tortoises move to areas with increased openness. Taken together, this information suggests that preferred tortoise habitat is open, not just at the canopy level but also in the mid-story and ground layer levels of forest structure (Guyer et al. 2007).

Knowledge Gaps: Forest structure is important to at least some TER-S. 1) More information is required on needs of additional species, including common ones. 2) Although there is information on forest structure tolerated by RCW and gopher tortoise, data are lacking on ideal habitat for these and other species. 3) Canopy cover has been a factor most often measured. Better understanding of other elements in complex forest structure (see below), especially temporal shifts in vertical structure, is important. Of specific concern is identifying density and/or height of hardwood stems in the ground layer that indicate when to burn next. 4) It s unclear how creating forest structure for TER-S influence ability of forest management to maintain a fire-dependent forest in an anthropogenic landscape.

COMPLEX FOREST STRUCTURE

Landers and Boyer (1999) defined old-growth characteristics for longleaf and south Florida slash pine ecosystems. Varner and Kush (2004) reviewed conditions associated with old-growth longleaf forests, including the wide range of tree sizes and a patchily-distributed uneven aged canopy coupled with scattered coarse woody debris and a highly species rich ground layer. These and other ecological factors are related to components of forest structure. Forest structure is a complex of at least four elements: 1) horizontal or canopy openness (open canopy due to widely-spaced trees), 2) gaps among mature longleaf, 3) vertical openness (general lack of mid-story), and 4) patchiness in the ground layer. In addition, there are spatial and temporal aspects to differences in tree age and vigor (reviewed by Mitchell et al. 2006). For longleaf pine forests, age of trees is important but it may not be the most important factor for determining health (Kirkman and Mitchell 2006). A minimum age of 40-70 year is important to assure a periodic seed source for natural regeneration. In addition, the needles of longleaf are an important component of fuel that promotes effective use of prescribed fire (see below). RCW rely on adult-sized trees for foraging and cavity sites; older trees may have special significance (Table 1).

A more succinct view was offered by early explorers who described southeastern pine forests as “barrens” and “open, park-like” (e.g. Bartram 1791). The modern technical classification for these ecosystems is woodlands (Peet 2006) although the term forest prevails in common usage. There are many subdivisions of longleaf forests (Peet 2006), however a universal characteristic is one of open canopy. To manage for structure, we must understand processes that influence it. Mitchell et al. (2006) list agents of disturbance that affect forest complexity. Fire is the primary process that maintains significant components of structure in longleaf forests (see fire section); wind and logging patterns are also important.

Knowledge Gaps: There is a strong need for quantified assessments of fire effects on many aspects of longleaf forest health. Structure, by default, is a key component of open-canopy forests and measurement of canopy openness are usually reported as percent cover or basal area. However there is little data on other elements of complex structure. 1) There is immediate need for information the dynamic nature of change in vertical structure, especially between burns. 2) Tree gaps have been studied as individual units (McGuire et al. 2001, Moser et al. 2002) but there is little information on gap placement and density across a landscape. 3) Also, the spatial and temporal pattern of patchiness in the midstory (Greenberg and Simons 1999) and ground layer (Hermann 1993) is poorly documented. 4) A broader understanding of species composition of the ground and midstory layers plus soil types is relevant to understanding the dynamic nature of forest structure. 5) There is also little information on how large of an area is needed for a longleaf pine stand to be self-staining if an appropriate fire regime is applied. 6) Other issues that relate forest structure to prescribed fire and to silviculture are discussed subsequent sections.

FIRE IN THE MODERN LANDSCAPE

Prior to European settlement, fire was nearly ubiquitous, in both time and space, and was the most important ecological process responsible for persistence of longleaf pine forests, not only because other species are less able to withstand frequent fire but also because regeneration is not successful unless seeds germinate on mineral soil. Fire is also required by other open-canopy pines, although burn frequency may be somewhat less. For all open-canopy forests, total fire exclusion results in dramatic alterations to the ecosystem; within a few years many features of forest health are lost. How forest health is affected by under-application of fire is less clear. It appears as if this ineffective use of prescribed fire may be relatively common. Outcalt (2000) discovered that ~50% of longleaf stands had gone 5 or more years with out fire. Although many of the unburned stands were on private property, at least 20% of stands on public lands also received no fire in a five year window (Outcalt 2000). There are no similar data on other open-canopy forest types. Lack of frequent of fire is of concern, not only for management of TER-S but also for protection from wildfire; reduction in fuel makes wildfire suppression more likely.

Fire Regimes: Prescribed burning has long been used as a forest management tool but only lately has the concept of fire regime formally been applied to meet management goals. Burn frequency may have been the major factor in determining relative abundances of pines in the southeast prior to European settlement and that fire regime factor has garnered most attention in management. It is estimated that most locations in the upland landscape burned on average every 2-5 years (Chapman 1932) but at some sites and/or during some time periods fire frequency varied. Over many decades, differences in frequency of as small as one year may alter the landscape. This has been suggested in two different long-term studies in mix-pine forest (Waldrop et al. 1987, Hermann 1995) and clearly documented in longleaf pine flatwoods (Glitzenstein et al. 2003). No studies have targeted dry sites or the frequency required to re-introduce fire.

Fire regimes include many factors in addition to burn frequency: month-of-burn, day-of-burn weather, ignition pattern, and fuel type/load among others. A study at St. Marks National Wildlife Refuge (Platt et al. 1988) provides some of the first insight into month-of-burn and increased use of growing season prescribed fire has been championed by Platt et al. (2006) and others. For example, growing season burns may enhance nectar resources at critical times for migrating butterflies (Hermann et al. 1998). However other studies have not documented significant differences related to month-of-burn for some plant groups, e.g. legumes (Hiers et al. 2003). However shifts in any combination of the elements a burn regime have the potential to alter the landscape. Many researchers interested in ecological integrity have promoted attempts to mimic natural fire regimes (cf. Platt et al. 2006). Although there is mounting evidence to support this idea, there are many effects that remain unknown. Streng et al. (1993) reviewed season of fire studies in longleaf pine and included suggestions for improving future work. Some research has documented difference in fire effects based on soil texture or type. In the modern landscape, sites with altered vegetation and/or fuel are of special concern.

Fire Regime and Species of Special Concern: In addition to the relationship between forest structure and the vertebrate species discussed above, there is incomplete information on fire frequency and other species of special concern, although Van Lear et al. (2005) provide a useful overview of habitat structure requirements for TER-S. Walker (1993) listed almost 200 rare plants. For 36 of these, population extinctions declined and colonizations increased with increasing fire frequency (Gray et al. 2003). Frequent fire was also associated with increased nesting success and/or bird density for Bachman's and Henslow's sparrows (Tucker et al. 2004 and 2006, Tucker and Robinson 2003). Finally, a series of recent papers on amphibians exemplify continuing debate over use of fire frequencies thought to enhance longleaf specialists (Means et al. 2004, Robertson and Ostertag 2004) compared to frequencies designed to promote a higher amphibian species richness (Schurbon and Fauth 2003, 2004). The debated burn frequencies differ by just 1-2 years. Flatwoods salamanders breed in wetlands imbedded in longleaf pine savannas; Bishop and Haas (2005) suggested that fire applied in the growing season was more likely to create vegetation structure around the wetlands that is most appropriate for the salamanders.

Re-introduction of Fire: After a decades-long fire suppression and more recently under-application of fire (Outcalt 2000) many mature, remnant longleaf pine stands are unhealthy and risk catastrophic fire. Although mature longleaf have persisted on the landscape, fire exclusion has created stands unable to repopulate themselves. Today, most natural resource professionals recognize the necessity of fire to restore degraded longleaf pine forests. However, the biggest threat to the restoration of these stands is the inappropriate re-application of fire (Kush et al. 2004). There are numerous instances where fire (prescribed or wild) under inappropriate conditions has resulted in many dead, mature trees.

Fire Surrogates: Acknowledging that fire is vital to many native ecosystems across the country but also understanding that in the modern landscape it may be a challenge to apply, the United States Forest Service is supporting a nation-wide study designed to evaluate the efficacy of surrogates for fire. Results from other studies indicate that there are combinations of mechanical and/or chemical treatments that may

enhance fire effects (cf. Provencher et al. 2001a, b). However, to-date no project using any combination of actions, has been successful in duplicating the effects of fire in open-canopied pine forests.

Smoke Management and Air Quality: As wildland/urban interface and "smoke sensitive areas" increase it becomes more difficult to direct smoke away from developments. Smoke litigation is a growing concern and, in some areas, problems of air quality attainment also limit use of prescribed fire and may have a strong seasonal component. It is unlikely that fire in all months will be possible at all areas in the modern landscape because of seasonal differences in weather patterns.

Carbon Sequestration: Fire-maintained, open-canopy pine forests may offer one of the best options for carbon sequestration among southeastern ecosystems. In addition to long-lived trees with timber products that sequester carbon, these fire-maintained forests support a productive ground layer that may provide significant carbon storage. However Tilman et al. (2000) suggested that fire exclusion in wildlands across the country could account for up to 20% of the world's "missing carbon". This is in contrast to estimations of Leenhouts (1998) that indicate that, in the modern continental United States, there has been substantial decrease in biomass consumed by wildland fire compared to pre-European settlement time.

Knowledge Gaps: 1) With growing interest in ground layer restoration, there is need to understand that effect of fire regime on seed production and seedling establishment, especially of grasses. 2) Literature reviews on other aspects of burn regimes in open-canopy forests could help direct additional research. 3) Given that as much as 50% of extant longleaf may not be burned frequently enough to maintain healthy forest structure, there is a strong need to experimentally evaluate difference in effects of small differences of 1-2 years in fire frequency. 4) More information is needed on fire regimes required to maintained open-canopy forests compared to those specific to various TER-S. Currently, fire is often applied in a highly regimented regime (i.e. once every three years in a specified season). There is strong reason to think that more varied application of fire would be likely to maintain a wide range of ecological values (Robbins and Myers 1992). 5) There is currently not sufficient information to provide quantified guidelines for re-introduction of fire and burn plans designed to minimize duff consumption at the bases of large pine trees. 6) Field trials that combined chemical and/or mechanical treatments to facilitate re-introduction of fire could provide ideas on how to maximize fire effectiveness. 7) Sites should be evaluated for smoke and air quality issues. Region-specific models are needed and where smoke and air quality factors have potential to compromise fire management, modified burn regimes must be designed. 8) Currently there is little information on carbon sequestration in open-canopy pine forests and so it is difficult to countermand the suggestion of Tilman et al. (2000) to suppress fire, nation-wide, to enhance carbon sequestration; research is needed. 9) Although there is preliminary information that indicates that use of prescribed fire lessens extreme effects of wildfire (cf. Martinson and Omi 2006), many more observations are needed to assess this benefit so as to be useful in public education.

FOREST RESTORATION

When the primary interest is management of TER-S, achieving forest management goals likely will require some degree of ecosystem restoration because almost all longleaf pine forest sites have been degraded due to past human activity. Ecosystem restoration is often viewed as a process designed to recreate a specific historical or old-growth condition; if old-growth parameters are used as a basis for assessing forest health of existing second-growth stands, results will be discouraging. Most sites would be classified as low quality. A more pragmatic view of ecosystem restoration was offered by Walker (1998) who described ecosystem restoration as "incremental change along a continuum of site conditions". When restoration is a goal, employing benchmark or reference sites is particularly useful in assessing not only success of management activities but also forest health.

Johnson and Gjerstad (2006) present a continuum of conditions describing states of sites under consideration for restoration of overstory longleaf. A subset of these conditions most relevant to management of TER-S include 1) totally degraded sites that support few native species, 2) off-site pine plantations, 3) longleaf plantations, many supporting some ground layer species (Smith et al 2001), 4) long fire-excluded with mature second-growth trees but also duff accumulation and few ground layer species and, 5) fire-maintained, mature second-growth with native ground layer. Some sites lack overstory trees, while others also lack much of the ground layer.

Planting Longleaf: In recent years there has been improvement in technology to ensure successful planting of longleaf pine however there remain aspects of planting that may affect seedling vigor. In other instances, problems with tree vigor are related to external factors such as a pathogen (see below).

Knowledge Gaps: There are aspects of planting that warrant study; they include 1) planting depth for containerized seedlings, 2) spacing appropriate to maintain ground layer plants, 3) degree of site preparation needed to minimize fungal root pathogens (see below), and 4) long-term differences in ground layer composition related to different types of tree establishment.

Re-establishment of Ground Cover Layer Species Composition: The ground layer in open-canopy pine forests are species rich and spatially complex. To-date most ground layer studies have targeted longleaf ecosystems. To maintain the highest degree of forest health, this native flora should be restored and maintained. In some areas and for some soil types, species lists have been generated for the ground layer floras (cf. Drew et al. 1998, Sorrie et al. 2006, Walker and Peet 1983) but detailed information is lacking in other areas (but see Platt et al. 2006). This is especially true in the portion of the longleaf range that is outside the range of wiregrass (*Aristida stricta* and *A. beyrichiana*).

Forb species are important in their own right as well as food sources for native pollinators (Hermann et al. 1998), and other arthropods. In addition, they contribute to the fine fuel mixture critical for successful burning (see below). However, grasses may make the largest contribution to maintaining structure and function of the forest because they, in conjunction with pine needles, often make up the bulk of the fine fuel. Species of bunch grass may be especially important in promoting fire.

A CRP program, new in 2007, encourages private owners of fallow agricultural lands to seed native grasses within a few years of planting longleaf seedlings. Announcement of this program created new interest in seed from local or regional sources. In addition, there is concern that planting techniques still under development may not meet the needs of the new program. This is in addition to the active projects focused on ground layer restoration both via direct seeding as well as planting of “plugs”.

Knowledge Gaps: There are on-going projects to re-introduce native species to degraded ground layers (Cox et al. 2004, Glitzenstein et al. 2001, Kirkman et al. 2004, Walker and Silletti 2006, and others). 1) There is a significant shortage of available seed; ways are needed to increase supply. 2) Although wiregrass is an important fuel, significance of other native grasses merits study. Bluestems and other bunch grasses are easier to establish and are found over a wider range that wiregrass; research on fire management of non-wiregrass species may greatly increase restoration options. 3) There are no studies on re-introduction of native grasses to fallow fields and techniques must be developed for direct seeding.

SOIL QUALITY

There are few studies on fire effects on soil in longleaf pine forests. In general, heat from a fire does not penetrate very deep in to mineral soil. Soil moisture prevents soil temperature from exceeding 95^0C until moisture vaporizes and there is usually no change in temperature below 20cm deep (e.g. Debano et al.

1998). Many factors influence effect of fire below the soil surface however some researchers propose that duration may be the most important attribute of a burn regime that affects soil (Certini 2005).

Reviews of fire effects on soils suggest a wide-range of outcomes for a variety of ecosystems (cf. Certini 2005). What appear to be contradictory results may be related to the wide range of conditions spanned by various studies. Boring et al. (2004), controlled conditions among treatments, including litter composition, and their results indicate that "frequent, dormant season, or even variable season burning should not seriously deplete long-term nitrogen balance of longleaf pine ecosystems". In addition, Lajeunesse et al. (2006) demonstrated that a single fire did not alter herbaceous vegetation but that soil texture may influence fire effects in mixed pine forests.

Soil Quality and Past Land Use: For open-canopied forests, there is poor understanding of effects of past land use on soil quality. A pilot project considered three long-term (25-100+ years) treatments: 1) row crops, 2) loblolly pine plantation managed with infrequent fire, and 3) multi-aged naturally regenerated longleaf stands (some trees >100 yrs) and native groundcover managed with frequent (1-2 years) fire. The project focused on long-term past land use and not any changes related to a single burn. Preliminary results suggest that some soil parameters show a gradation consistent with past land use and that effects of land use diminish with increasing soil depth. General patterns in preliminary results from Levi et al. (2006, 2007) indicate that similar soil types in frequently burned longleaf pine forest contain higher levels of Microbial Biomass Carbon and Total Organic Carbon compared to other land uses.

Knowledge Gaps: Long-term anthropogenic use of land has potential to alter soil quality. Most or many of the lands targeted for restoration to longleaf pine spent many decades in agriculture, which both depleted nutrients and resulted in the physical loss of more than a meter of soil across hundreds of thousands of acres. Many important aspects of soils on sites slated for restoration efforts are likely not the same as they were when they supported native forests. It is not clear how these changes affect success of restoration or how soil alterations interact with prescribed fire. 1) Region-wide surveys covering all major upland soil types are needed to determine how a) factors in soil quality have been changed by past land use, b) how these changes influence success of forest restoration, and c) what modifications to degraded soils can enhance success of restoration.

Soil and Fire Exclusion: Exclusion of fire may have greater effect on characteristics of longleaf forest soil than does prescribed fire. When fire is suppressed, litter accumulates above usual amounts and a deep layer of duff (organic matter) may form. This is expected to increase soil fertility above usual levels as well as increasing likelihood that fire will harm roots; organic matter burns and mineral components of soil do not. In addition, mechanical disturbance, including compaction, has potential to alter soils.

Knowledge Gaps: More study is needed on effects of frequency and severity of burns on soil in open-canopy forests. 1) In general, do low-severity, frequent fires produce only relatively short-term alterations in soil? Are results related to effects of time-since-burn and perhaps month-of-burn? 2) What does fire exclusion do to soil characteristics and the effects of re-introducing fire. Of special interest is the effect of high levels of organic matter? 3) What are the affects of past intensive agriculture and/or soil? Soil compaction is of special interest for restoration projects.

PATHOGENS

Historically pathogens and disease in naturally regenerated longleaf pine, pathogens and disease were not problems, especially for management of TER-S. Brown spot disease (*Scirrhia acicola*) can infect grass-stage longleaf but is usually kept in check with frequent fire. Although insects often attack off-site and/or densely growing loblolly, particularly when trees are stressed by drought or crown scorch, this problem is monitored and, where feasible, spots are cut in an effort to keep beetles from spreading. However, there

concern is developing for the potential of root-fungi, especially *Leptographium*, to harm southern pines and consequently affect TER-S.

Off-site Pine: Eckhardt et al. (2007) evaluated loblolly decline and noted that symptomatic trees were associated with sandy and/or loamy soils that are moderately to well-drained. In addition, higher incidence of symptomatic loblolly roots was associated with *Leptographium* sp., topography and tree age (Eckhardt et al. 2007). It is generally thought that loblolly is not native to these soils and so sites with a high proportion of symptomatic trees may fall under the classified as "off-site" for this species. Currently Eckhardt and her students are assessing the influence of these factors on decline symptoms in longleaf.

Plantation Longleaf: Although longleaf is regarded as being relatively pathogen-free, Otrosina et al. (1999) documented root-infecting fungi with decline in 35 year-old longleaf plantations. There were higher concentrations of live fungal biomass in soil organic layer root clumps compared to samples that did not contain both root clumps and soil organic matter (Otrosina et al. 2002). Fire consumption of duff was positively correlated with higher burn temperatures and more symptoms of decline were observed in longleaf 2-3 yrs post-burn (Otrosina et al. 2002).

Fire, Root-Fungi, and Planted Pine: Otrosina (1998) suggested that when burning is re-introduced after prolonged fire exclusion, a once fire-dependent forest such as a longleaf pine ecosystem may become an "exotic ecosystem". One result of lack of burning is the accumulation of organic material and formation of duff. Burning on sites with duff likely imposes greater stress on off-site trees than when duff is absent. Duff smolders, increasing residence time of fire. We propose that this concept may be especially appropriate for off-site 30-40 year old planted loblolly pine. In declining loblolly, application of fire may require modification of typical site preparations and/or management of planted pine.

Although shortleaf pine is more adapted to fire than loblolly, neither species is likely to tolerate fires necessary to effectively top-kill hardwoods on many sites suitable for longleaf. The burn regime (frequency, month and/or severity) required to accomplish this management objective may be more extreme than 7-9 year frequency suggested by Martin and Smith (1993) for shortleaf in Louisiana. On longleaf sites, this frequency may be insufficient to maintain stand structure that is useful to TER-S.

Future of Planted Pines: Currently there are no simple treatments to enhance health of deteriorating off-site pines. Before management options can be considered, stand-specific evaluations are required. Managers must weigh current and future ecological values of a stand against potential economic ones. If off-site pines are relatively young (small) and the primary goal for the stand is to provide resources for TER-S, it may be prudent to sacrifice accumulated growth in favor of initiating restoration on the site. The older the stand, the more likely stop-gap measures (see below) may be worth the effort. Fire may exasperate root-fungi associated decline. Off-site pines have always been a challenge to manage with fire because juveniles of loblolly and shortleaf are easily killed. One suggestion has been to vary burn frequency to include periods of ~5 years with no fire to permit establishment (Cain et al. 1998). This approach may be able to be modified for root-fungi infected off-site plantations.

Knowledge Gaps: In addition, to the on-going work by Eckhardt, Otrosina and others, there are additional topics on root fungi to be considered. These include: 1) In naturally regenerated longleaf pine stands (no soil degradation, frequently burned, multi-aged, open stand with no duff), are pathogenic root fungi present? If so, are trees symptomatic? 2) Are off-site pines on degraded soils (e.g. former cotton field) more likely to support root-fungi and display decline symptoms compared to those on higher quality soil? 3) Is the presence of organic matter (duff and/or excessive coarse woody debris) or degraded soil on a plantation associated with an increased risk of root-fungi and decline? 4) If presence of duff and coarse woody debris proves to be a problem, can site preparation techniques be modified/improved to minimize these factors before planting? 5) When fire is applied to create habitat structure useful to TER-

S, does it pose a significant stress to off-site trees? If so, what component of the fire regime contributes most to the problem (frequency, month of burn, and/or ignition pattern, etc.)? Can chemical and/or mechanical treatment be substituted for some/most of the burns? Otrosina et al. (2002) demonstrated that delayed mortality in plantation longleaf was related to high fire severity and that a variety of root-fungi were present. Research may aid in prolonging availability of off-site pine plantations as resources for TER-S.

EXOTIC PLANT SPECIES

There are a large number of exotic plants that have potential to depress health of upland native forests. Perhaps the most significant for conserving TER-S are those exotic species that not only tolerate fire but significantly alter fuel characteristics. Examples include cogongrass (*Imperata cylindrical*) and two species of non-native climbing ferns, Old World (*Lygodium microphyllum*) and Japanese (*L. japonicum*). These and many other exotic species are becoming increasingly wide-spread pests in southeastern pine stands. Some exotic species are controlled by fire but that is not the case for these species.

Cogongrass grows in dense patches and crowds out most other plant species. In addition, its foliage significantly elevates temperatures of prescribed burns and this can alter the ecological effects of fire (Platt and Gottschalk 2001). The climbing ferns also have potential to alter fire effects and are documented to add ladder fuel in pine plantations. Introduction of cogongrass is thought to be often via small pieces of rhizomes clinging to logging, road or construction equipment. Once the rhizome is established, it has potential to flower and fruit. Spores of climbing ferns are easily dispersed by wind.

There has been limited success in locally eradicating cogongrass using an aggressive combination of chemical and mechanical treatments plus prescribed fire (Faircloth et al. 2005, MacDonald et al. 2006). A complex approach may also provide relief from non-native climbing ferns but currently there is no effective control regime. In both cases, prevention is likely to be the most cost effective approach. Eradication of an invasive species once it is established is likely to be expensive and difficult, at best.

Knowledge gaps: Although there are many unknowns related to exotic species, an immediate need is for effective programs to minimize introduction coupled with monitoring to identify recent establishment so that eradication methods may be applied. 1) There is the obvious need for research on more effective ways to eliminate problem exotic species. 2) Creation of regional guidelines to minimize transfer of seed and rhizomes is vital. 3) In addition, regulations to minimize availability of similar species are necessary. Many species of *Imperata* are currently sold for landscaping and there are reports of *Lygodium* being transported in bales of pine straw. 4) Evaluation is also need to identify likely problem exotic species of future concern; for example weeping lovegrass (*Eragrostis* sp.). Like native wiregrass (*Aristida stricta* and *A. beyrichiana*), weeping lovegrass is a large bunchgrass that responds positively to burning. It also promotes the spread fire, so much so that it has potential to create hazardous fuel conditions.

PRIVATE LANDS AND TER-S

To conserve and enhance southeast forest health at the landscape level, private lands must be considered. Approximately 90% of all regional forested land and about 51% of longleaf stands is privately owned (Outcalt and Sheffield 1996). Many private, non-industrial landowners in the region have diverse management objectives and may be interested in restoring longleaf ecosystems when presented with a reasonable chance of success exists and if technical and/or financial assistance is available. Cost-share programs make longleaf establishment affordable and most programs encourage management to promote ecosystem values beyond timber. Several initiatives emphasize prescribed fire and other practices to restore ecosystem structure and function.

There are private lands of significant size; many are managed for bobwhite quail and are located in close proximity to each other, creating additional ecological significance. However potential changes in ownership and/or objectives are on-going challenges to conservation. Retention of these sites is important to TER-S as well as regional forest health at the landscape level.

Knowledge Gaps: Additional information is needed to support economic and ecological arguments for promoting easements or direct acquisition of significant tracts. Also, tools for managing smoke and predicting growth and yield are needed to encourage owners to promote longleaf on non-public lands.

SILVICULTURE

Appropriate growth and yield models are required to make prediction of economic costs and benefits. In addition, they can provide insight into some aspects of future forest structure. Because most of the area once occupied by these forests was dominated by longleaf, this is the primary species of interest.

Uneven-Aged Silviculture: Guldin (2006) reviews aspects of successful application of uneven-aged silviculture in mixed loblolly-shortleaf pine stands in the upper Coastal Plain and then discussions how this information might apply to longleaf. Although Engstrom et al. (1996) suggest the Stoddard-Neel (S-N) approach to uneven-aged management of longleaf as useful tool for conserving RCW, there is debate over how best to integrate regeneration into the selection method and there is concern over how far a stand can deviate from a reverse J-shaped age-class structure and be sustainable (Guldin 2006). Jack et al. (2006) review aspects of the S-N approach and note the challenge associated with the lack quantification of the method. Moser (2006) describes case studies of application S-N and stresses the need to expand consideration of values of forest products to include ecological attributes of the forest.

Growth and Yield: There has been research on growth and yield of longleaf pine in natural even-aged stands, although development of models has lagged behind the data (Kush et al. 2006). USDA Forest Service established a regional longleaf pine growth study in the mid 1960's. To-date, the best estimate of longleaf pine growth and yield for natural stands can be found in Farrar (1979). Uneven-aged stands are more complex structurally and thus more difficult to model. Farrar (1996) provided guidelines for uneven-aged management of longleaf pine. Nature managed longleaf pine as small patches of even-aged stands across an uneven-aged landscape. The main drawback with uneven-aged management with longleaf pine is that it takes frequent assessment to keep up with how a stand is growing (Kush et al. 2006). The fact that it takes extra effort to manage open canopy pines under an uneven-aged system has discouraged use of this management approach although some agencies are attempting it.

Knowledge gaps: There is need for better information on how best to extract forest product value and concurrently promote ecological attributes important for TER-S management. This mandates quantification of the S-N approach and/or development of additional management systems. While growth and yield models exist for loblolly pine, especially for plantations, there is nothing comparable for longleaf pine. Models for natural stands have not been updated since the 1980's despite new data. For longleaf pine plantations, most models are for bare-root material while the majority of seedlings planted in the last decade have been from containerized stock. In addition, most of the plantation data are from Mississippi and Louisiana, a small portion of the longleaf pine range.

REFERENCE SITES AND, MONITORING

Measurements of forest health have little meaning unless compared to values associated with a desired condition. Unfortunately, old-growth longleaf forests account for a very small fraction of the original extent, and there are large areas of the range that lack any example of extant old-growth (Varner and Kush 2004, Landers and Boyer 1999). Although almost all existing longleaf forests has been degraded in

varying degrees by past human activities, there remain second-growth sites that are adequately maintained by prescribed fire. Some of these have use as reference sites. Care must be taken in selecting sites to be used as a basis of comparison (Goebel et al. 2005) and reference (benchmark) sites should not be viewed as experimental controls but rather as a means to comparing quantified values of improvements in forest health with values derived from reference sites representing desired future conditions. Craul et al. (2005) provides documentation that longleaf forests were once found across several climate zones and physiographic provinces plus many soil types. This observation emphasizes the importance of identifying appropriate reference sites in guiding and evaluating success of restoration efforts.

Knowledge Gaps: Identification and quantification of criteria of high-quality, second-growth reference sites should be a priority for evaluating restoration or enhancement of habitat for TER-S. In addition, because benchmark sites are of superior forest health, locating and documenting these sites will add to knowledge of areas of significant to conservation. It is important to select reference sites, based on soil type, hydrology and topography. In addition, repeated sampling of important elements of structure will provide a range of values that span time between fires. Information, such as number and height of hardwood stem re-sprouts, is important for refining aspects of prescribed fire regime.

CONCLUSIONS

Open-canopy forests were once the ubiquitous matrix ecosystem in Southeast uplands and region-wide longleaf pine was the dominant tree; slash pine was common in the flatwoods of central Florida. Habitat structure is the aspect of forest health with the greatest significance for management of TER-S; preliminary evaluation indicates that it provides a pragmatic basis for umbrella management of significant TER-S species associated with upland southeastern ecosystems. Periodically extreme wind or other forces not under management control dramatically alter structure. However, in the modern landscape the two additional factors that have strong, direct influence on forest structure are silvicultural systems and prescribed fire. Both activities are traditional components of management plans for open-canopy forests. There are other elements related to forest health of open-canopy ecosystems that were not considered until relatively recently. These include pathogenic root-fungi, compromised soil quality, fire-adapted exotic plant species, and altered fuels due to fire exclusion; each has potential to be very important on some sites and warrants increased attention from researchers.

Root-fungi create challenges for maintaining off-site pine plantations. Experimental trials may help determine what management options are most useful. Where trees are young and have minor ecological value, it may be pragmatic to replant with a species adapted for the soil type of the site. In declining plantations with mature trees that are of value to TER-S, some applications of fire may need to be replaced with chemical and/or mechanical treatments in order to maintain foraging stand structure for RCW. This would be expensive and so must be balance against value to TER-S. There is a pressing need to determine how likely this problem is to occur in uneven-aged, natural regenerated stands and how prevalent pathogen-related decline is in off-site pine species compared to longleaf pin.

Fire-adapted exotic plants pose a threat to both off-site pine plantations and to natural multi-aged stands. Currently, prevention of dispersal and early detection hold the best promise for avoiding degradation of forest health due to invasion by fire-adapted exotic species. Additional research is strongly warranted.

In many areas, restoration of trees and/or ground layer will be necessary to increase acreage of healthy forests required to support sustainable populations of TER-S. Many techniques necessary for cost-effective restoration remain to be developed. Selection of sites for forest restoration should depend on how stands fit into a matrix of high-quality forests at the landscape level. Research, development of techniques and establishment of field trials are currently underway and are worthy of support and

expansion. Depending on past land use history, compromised soil quality may pose challenges for restoration projects. This issues warrants investigation as does potential effects of altered hydrology.

Development of new silvicultural tools is a high priority. Growth and yield models must be updated to take advantage of data accumulated over the last two decades. This is necessary to encourage landowners to become more interested in managing open-canopy pines and to facilitate increase of uneven-aged forests into the landscape. Additional work is required to create tools to facilitate application of S-N or another appropriate selection system. Traditional silviculture has focused on one aspect of complex forest structure: canopy openness. This element of habitat structure in healthy forests can be accommodated by existing selection systems. However there is increasing data that documents importance of another element of forest structure: spatial and temporal placement of canopy gaps across the horizontal plane of the landscape. Additional work on this topic is vital for sustaining forest health in multi-aged stands.

In addition to the elements of healthy forest structure that determine canopy tree placement in the landscape there are at least two additional elements of significance: vertical openness (general lack of mid-story) and patchiness in the ground layer. The direct significance of ground layer patchiness to TER-S is unknown but should be explored. This element of complex structure does affect aspects of natural regeneration of canopy trees and likely interacts with fire (cf. Estes 2006).

There is strong evidence of the importance of vertical openness (minimal midstory) to many TER-S. Prescribed burning is the most important management tool for achieving this objective, although silviculture actions often interact with fire effects. Although there is wide-spread acceptance of the ecological value of vertical openness there is surprisingly little data that describes how much midstory (height, number of stems, and/or patches) is tolerable and at what point in re-growth after fire are the stems not likely to be top-killed by the next burn. Additional information on this highly dynamic aspect to structure is critical for improving the effectiveness of prescribed fire.

The single most immediate issue in health of open-canopy pine forests may be the under-use of prescribed fire. Outcalt (2000) reported that ~ 50% of survey stands had not been burned in the most recent five years. This is insufficient to maintain or restore forest health in most systems. Although month-of-burn has importance to forest health, burn frequency may be even more basic. Both components of a fire regime may be greatly compromised over much of the modern landscape and fire surrogates alone will not solve the problem. Short periods of fire exclusion may create vegetation structure that cannot be reclaimed using fire alone and mechanical and/or chemical treatments may be required to recover a stand to the type of composition and structure that can be maintained by fire alone. Longer periods of exclusion result in altered fuels, excessive duff accumulation and changes in many soil characteristics. These degraded sites will require special management attention before they are self-sustaining, healthy open-canopy forests. Studies on effects of fire regimes have not addressed what is required to recreate open forest structure following fire exclusion.

Potential forest health problems associate with ineffective use of fire are poorly documented. As noted above, we lack quantified information on temporal changes in vertical structure that indicate that another burn is mandated. Rather land managers often use a set burn frequency to decide when to apply the next fire. If that frequency is inadequate by 1-2 years, over a long time, the habitat structure and consequently forest health will decline and TER-S may suffer. However, it may require decades for this negative affect to become clearly visible. Although this management tool has been employed for many years, there is pressing need for better information on what fire regime will be most effective in meeting management objectives. Ideally, when management targets TER-S, prescribed fire is applied to mimic “natural” burns but this is not always possible. In some cases, vegetation (fuel) may not be in a natural state; this limitation may be transitory. In other cases, local conditions, including spatial relationship to developed areas, may not permit fire in all months or under all weather patterns.

Fire effects will vary depending on amount and composition of fuel; a burn plan designed to maintain a stand in good health cannot be the same as one needed to recover forest health of a degraded stand. Even when burn plans are appropriate for management objectives, application of fire as a rigid regime does not guarantee management goals will be met. The objective is not to burn but rather is related to outcomes that promote forest health via ecological work accomplished by fire. To best assess degraded stands, it is useful to make comparisons to reference conditions or benchmark sites. In this way, if compromises must be made on month-of-burn, ignition, and/or intensity, managers will be better able to consider what other options might be available to compensate. Concurrent monitoring for exotic plants would be valuable.

Finally, there is need to promote forest health at the landscape level. Geo-referenced mapping will help meet this need and will also assist in identifying private property that may provide important values to TER-S that currently occupy public land. Only with large-scale prioritization of forest restoration, effective application of prescribed fire, and other management activities can the value of all efforts be maximized. Good forest health over areas large enough to maintain forest integrity means that recovery and enhancement of TER-S is likely. Without it, success in managing for a TER-S species is possible but only with extensive effort and on-going micro-management.

Reversing 100+ years of decline in forest health will be difficult, but many groups and individuals are currently attempting to do just that. State and federal agencies, research institutions, NGOs, and private landowners have a renewed interest in longleaf as a tree and as an ecosystem. They are working separately and cooperatively to encourage maintenance and restoration of open-canopy forest. Better appreciation of the ecological and historical significance of the longleaf forest has spurred some of this interest, as has the realization that its decline is so precipitous and its potential demise a reality. Past and proposed listing and subsequent protection of several species endemic to the longleaf ecosystem through the Endangered Species Act has spurred activity by state and federal agencies charged with recovery of those species on public lands. Developing technology for reforestation and management of longleaf based on modernized silviculture information will improve the long-term prognosis for health of open-canopy pine forests. Reversing the anthropogenic disturbance of inadequate or non-existent fire (Moser and Wade 2005) is critical for revitalization of landscape-level forest health. Increasing acreage of healthy open-canopy pine forest coupled with aggressive use of prescribed fire appear to be the factors of most consistent concern that span the entire region. In addition, burning to reduce fuel accumulation is likely to be an effective tool in minimizing wildfire risk on both public and private lands. Land stewards are not able to influence the occurrence of lightning strikes or military training exercises but they are able to pro-actively reduce fuels and consequently the degree of hazard associated with wildfire. Unfortunately in addition to fire exclusion there are a number of other factors that may negatively affect forest health at different points in the landscape. Determination of forest health related to specific, non-landscape level threats requires stand-by-stand assessment. Factors that negatively influence forest structure are likely to have the most immediate influence on TER-S. These same factors should be targeted in efforts to develop umbrella approaches to management of TER-S.

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Table 1. Preliminary habitat assessment of federally-listed vertebrate species associated with longleaf pine forests. Primary information sources are NatureServe 2006 and Van Lear et al. 2005. Citations for additional reference sources are available from S.M. Hermann.

Federal Status: C – candidate species, E – endangered, S – species of concern, T – threatened
General Habitat Required/Important: ES – early successional clearcuts, FL – flatwoods, GR – grasslands, OA – oak midstory, OG – old growth or mature pines, RI – riparian or embedded wetland, SA – sandhills, SN – snags, stumps, downed trees, SW – sparse woodlands with open midstory and fire maintained understory

Group	Scientific Name	Common Name	Federal Status in ≥ 1 State	Historic Range in SE States*	General Habitat(s) Required or Important
Bird	*Aimophila aestivales*	Bachman's sparrow	S	AL, FL, GA, LA, MS, NC, SC, TX	ES, GR
	Ammodramus henslowii	Henslow's sparrow	S	AL, FL, GA, LA, MS, NC, SC, TX	GR, SW
	Falco spiverius paulus	Southeastern American kestrel	S	AL, FL, GA, LA, MS, SC	GR, SN, SW
	Picoides borealis	Red-cockaded woodpecker	E	AL, FL, GA, LA, MS, NC, SC, TX	FL, OG, SA, SN, SW
Mammal	*Geomys pinetis*	Southeastern pocket gopher	S	AL, FL, GA	GR, SA, SW
	Myotis austroriparius	Southeastern myotis	S	AL, FL, GA, LA, MS, NC, SC, TX	RI
	Sciurus niger shermani	Sherman's fox squirrel	C	FL, GA	OA, OG, SW
Amphibian	*Ambystoma cingulatum*	Flatwoods salamander	T	AL, FL, GA, SC	FL, RI, SW
	Rana okaloosae	Florida bog frog	S	FL	RI
	Rana sevosa	Dusky gopher frog	E	AL, LA, MS	RI, SW
Reptile	*Drymarchon corais couperi*	Eastern indigo snake	T	AL, FL, GA, MS, SC	RI, SN, SW
	Gopherus polyphemus	Gopher tortoise	T	AL, FL, GA, LA, MS, SC	FL, SA, SW
	Heterodon simus	Southern hognosed snake	S	AL, FL, GA, MS, NC, SC	SA, SN, SW
	Pituophis melanoleucus lodingi	Black pine snake	C	AL, LA, MS	SN, SW
	Pituophis melanoleucus mugitus	Florida pine snake	S	AL, FL, GA, SC	SN, SW
	Pituophis ruthveni	Louisiana pine snake	C	LA, TX	SW

* See NatureServe (2006) for details on species status in various states.

Large-Scale Disturbances and Ecological Communities in the Southeast US

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Abstract: The southeastern US landscape is one that has been shaped by water, wind, and fire. Large-scale, infrequent disturbances and their interactions are integral forces that shape and drive the highly diverse plant communities of the southeastern US. Timing, frequency, intensity, and scale of these events influence community structure and composition from the coast to the mountains. The sequence of and interactions between disturbances are increasingly recognized as important factors that can produce unexpected ecological outcomes in these systems. Human-mediated changes in the landscape and climate are expected to alter disturbance regimes, changing the probabilistic distribution of communities across this diverse landscape. Current climate change models predict rising sea level, increased precipitation and flooding, and reduced frequency but increased intensity of fire and hurricane disturbances. Landscape fragmentation, pollution, and introduction of non-native species further change the extent and characteristics of natural disturbances. To the degree that it is possible, management should mimic historic hydrologic and fire regimes to improve structure and function of floodplain and fire-maintained communities. Restoration of coastal ecosystems will help to buffer effects of hurricanes and rising sea level in the short term. In the long term, landscape connectivity and dispersal corridors will be increasingly critical for successful migration of species as their climatic envelopes shift. A better understanding of the ecological role of large-scale infrequent disturbances in historic, modern, and future landscapes of the southeastern US is needed to develop long-term planning for effective management of this disturbance-driven, diverse system.

Natural Disturbances and Ecological Communities

Disturbance is an integral component of biological systems (Pickett and White 1985), central to maintaining both biodiversity within communities (Connell 1978) and the variety of communities found across the landscape. Early community concepts considered disturbances to be disruptions that resulted in deviation from the inevitable successional trajectory toward a climax state (Cowles 1899, Clements 1937). The recognition that disturbances produce spatial and temporal heterogeneity in resources that influence regeneration, species coexistence, and community structure has led to an emphasis on the importance of variation and dynamics of patches in plant communities (Watt 1947, Bratton 1976, Beatty 1984, Collins and Pickett 1982, Pickett and White 1985 and references therein, Ehrenfeld 1995, Foster et al. 1998).

Each disturbance interacts with the physical environment and biotic characteristics of the pre-disturbance community (Foster et al. 1998) such that no two disturbances are identical in their effects. Different types of disturbances vary in terms of their duration, scale, intensity, spatial pattern, and return interval. For example, tornadoes are very intense, of short duration, impact a relatively small area, and have long return intervals (Peterson 2000). In contrast, hurricane winds are less intense, of longer duration, and can affect areas as large as 1000 km. Flood pulses are generally linear disturbances that cause relatively minor damage ecologically, as long as they occur within the bounds of the natural hydroperiod to which floodplain species are adapted (Sharitz et al. 1990). All of these disturbances create patchiness in resources, survivors, and generally create a mosaic of uneven-aged patches across the landscape (Pickett and White 1985).

The concept of a stable or equilibrial community implies an 'averaging' over space and time in a landscape comprised of a mosaic of patches of various successional stage and structure (Clark 1991). The equilibrial state of a landscape may be better described by a probability distribution of potential community states rather than a fixed and deterministic progression to a climax community. In this stochastic model, the probability of a community being in a given state is described by a one dimensional vector of probabilities (Fig. 1a). The range of possible community states in the model is the result of multiple disturbances operating with differing frequencies, intensities, magnitudes, and order on the landscape. The initial state and progression of communities generates pattern in the landscape that reflects the compounded legacies of past disturbances (Foster et al. 1998, Paine et al. 1998).

The underlying assumption of the model above is of climatic stationarity: the climatic regimes that provide the broad environmental conditions and disturbance regimes that support a range of potential communities in a landscape are constant and unchanging. Climate clearly shifts naturally on longer time scales (centuries to millennia) so that our one dimensional vector of probabilities can be generalized to a surface or series of one-dimensional vectors (Fig. 1b) that correspond to shifting climatic conditions. Anthropogenically driven climate change is occurring a rate that is much more rapid than most natural variation (IPCC 2001) and is expected to alter the frequency and intensity of natural disturbances in the southeastern U.S., changing the probabilistic distribution of communities across the landscape. One goal of ecology is to anticipate the likely shifts in disturbance regimes and ecological communities.

Ecological communities are affected by anthropogenic alteration of the natural landscape in addition to climate change. In some cases, the disturbances that species rely upon to regenerate and persist in the landscape have been altered or even eliminated. Fires that would have swept across large regions of the southeastern U.S., for instance, are contained in much smaller areas by a landscape fragmented by roads and development (Gilliam and Platt 2006), resulting in a less frequent occurrence of more intense fires. Similarly, floodplain communities once intimately linked with rivers during flood pulses are increasingly hydrologically disconnected and isolated (Sparks 1998, Sparks et al. 1990) or have highly altered hydrologic regimes. Further, a given disturbance may have different ecological consequences in a more highly modified modern landscape setting. Water quality, for example, was greatly diminished in coastal Louisiana following Hurricane Katrina because of numerous sources of toxic pollutants (e.g., oil spills) (http://www.epa.gov/katrina/).

Land managers are charged with applying ecological theory to everyday problems on the ground, while ecologists are challenged to develop sound theory that encompasses the changing landscape and climate. The penultimate challenge is to synchronize development and application of theory such that there is feedback between the two. Periodic reviews of the literature and theory are key steps in this process. The objectives of this paper are threefold: 1) to summarize key literature on infrequent, large-scale disturbances as it pertains to the southeast US; 2) to discuss natural disturbances in the context of global climate change and anthropogenically-induced changes in land use; and 3) to address implications of these changes for managers and future research.

Disturbance Ecology of Southeastern US Communities

The landscape of the southeastern US is one that has been shaped by water, wind, and fire (Platt and Schwartz 1990, Putz and Sharitz 1991, Hupp 1992, Hall and Harcombe 1998, Battaglia et al. 1999, Platt et al. 1999). The high biodiversity of this region is in part a manifestation of biological responses to these disturbances (Sharitz et al. 1992), played out against an unglaciated backdrop (Watts 1980). The life history traits of many species in the southeastern US are tied to defined disturbance regimes (Brewer et al. 1996, Tucker et al. 2003, Tucker et al. 2006, Van Lear et al. 2005, Schneider and Sharitz 1988, Platt et al. 2006a), but in the modern landscape, the disturbance regimes upon which these species are dependent have been altered by humans in many instances, leading to extensive compositional shifts, and ecosystem

degradation (Bragg 2002, Drewa et al. 2002, Drewa et al. 2006). Changing land cover, landscape fragmentation, and an ever-expanding non-native flora also affect type, frequency, intensity, extent, and timing of disturbance, which in turn may further diminish ecosystem function and integrity (Matlack 2002). The additional layer of climate change challenges the scientists and managers seeking to understand these relationships and the ecological repercussions of human alternation of the climate system. Climate change will further modify disturbance regimes in the southeast US. We first review the major modes of disturbance and their ecological effects on the southeastern US and then project global climate change effects on disturbance regimes and resultant ecological effects. We identify knowledge gaps that should be priorities for future research.

Floods

Floods are major events that influence floodplain communities along streams and rivers throughout the southeastern US (Sharitz and Mitsch 1993). Historically, these lotic ecosystems and their floodplains were hydrologically connected when floods periodically linked the two. The floodwaters formed an ephemeral bridge between land and water that supplied the floodplain with nutrients, water, sediments, and propagules, thus contributing to high ecosystem productivity and diversity (Junk et al. 1989, Ward et al. 2002). The sediment-laden waters also shaped the geomorphology of this system (National Resource Council 2002), creating a shifting mosaic of topographic features (Hupp 1992). Floodplain communities are driven by a dynamic interplay between vegetation, hydrology, and fluvial geomorphology (Hupp 2000).

Most floodplains in the southeast US are occupied by bottomland hardwood species, which are highly adapted to and dependent upon appropriate hydrologic regimes. The timing, periodicity, and extent of flooding events for nutrient cycling, migration corridors (Junk et al. 1989), dispersal avenues (Schneider and Sharitz 1988), and regeneration opportunities (Sharitz and Mitsch 1993) are important selective mechanisms that have shaped their evolution. The topographic heterogeneity of the floodplain, including backswamps, oxbows, natural levees, swales, and pit and mound topography, creates a diverse physical template that enables coexistence of many species (Battaglia and Sharitz 2005, 2006). Variation in elevation is associated with differences in flooding depth, frequency and duration, which in turn influence regeneration, scale of seedling recruitment patterns, and composition (Huenneke and Sharitz 1986, Titus 1990, Battaglia et al. 2000, Collins and Battaglia 2002, Battaglia and Sharitz 2006). In forested portions of the floodplain, tree growth (Keeland and Sharitz 1995), litterfall, and forest productivity are strongly related to hydroperiod (Megonigal et al. 1997). In turn, net primary productivity of floodplain plant communities contributes a substantial portion of the detrital food web base, which supports both the aquatic and terrestrial components of the river-floodplain system (Vannote et al. 1980). The river-floodplain coupling is essential for the maintenance of ecosystem structure and function, and alterations to the system that sever this connection are themselves disturbances, albeit undesirable ones.

Fire

Fire is a recurrent disturbance that influences many aspects of southeastern communities, including patterns of species diversity (DeCoster et al. 1999, Beckage and Stout 2000), tree recruitment and mortality (Doren et al. 1993, Glitzenstein et al. 1995, Platt et al. 2000) and the distribution of community types on the landscape (Veno 1976, Givens et al. 1984, Platt and Schwartz 1990). The southeastern U.S. is characterized by what are among the highest frequencies of lightning-initiated fires and tropical storms in the world (Platt 1999). The frequency of cloud-ground lightning strikes ranges from1-10 strikes/km^2 annually along most of the Gulf coast (Hodanish et al. 1997). As a result, fires historically occurred every few (1-10) years during the growing season in many southeastern habitats (Huffman et al. 2004). While frequent, these ground-layer fires are usually of low intensity (Platt 1999, Stout and Marion 1993); catastrophic stand replacing fires are much less common.

Landscape configuration, connectivity, and fuel characteristics influence the extent and frequency of fire. In the largely uninterrupted historical Gulf and Atlantic Coastal Plain landscapes, vast areas burned (Duncan and Schmalzer 2004). In interior areas, fires likely burned unchecked until encountering natural fire breaks such as ravines, waterways, or a break in the fuel load. Along much of the Gulf Coast, these fires would have burned toward the ocean from points of ignition and pine savannas would have been the upland terrestrial habitats rather than closed-canopy forests. Expansive longleaf pine savannas with highly diverse understories dominated by species adapted to and dependent upon fire were common (Platt 1999, Gilliam and Platt 2006). Mesic bluffs and floodplains would have burned during droughts (Bragg 2003), but fire return intervals would have been much lower. In these communities where fire was presumably seldom, its role is less clear. In coastal ecosystems such as the marshes of southeast Louisiana, fire has long been recognized as an important component in maintaining the natural ecosystem (Nyman and Chabreck 1995, Ford and Grace 1998). In the absence of fire, woody species can encroach upon the marsh, displacing the dominant herbaceous marsh species (Shirley and Battaglia 2006, Battaglia et al. 2007). Thus, the suppression of fire or alteration of fire regimes can be considered disturbances as well, but in a negative sense.

Windstorms

Hurricanes and tropical storms are frequent disturbance events with return periods of <1 to 2 decades in the southeastern US (Stone et al. 1997, Batista et al. 1998, Batista and Platt 2003). Southern Florida, for instance, has experienced 35 tropical cyclones in the period from 1886 to 1992 (Platt et al. 2000). Hurricanes can produce high levels of overstory damage and mortality in forests (Putz and Sharitz 1991, Platt et al. 2000), storm surges that increase salinity levels when coastal communities are inundated (Blood et al. 1991, Baldwin and Mendelssohn 1998), deposit large amounts of wrack (Brewer et al. 1998) produce microtopographic variation (Battaglia et al. 1999, Battaglia and Sharitz 2006), and can alter hydrologic regimes in interior regions (Beckage et al. 2003).

The effects of hurricanes on ecological communities can persist long periods following the hurricane event as damaged trees die (Craighead and Gilbert 1962, Turner et al. 1997, Batista and Platt 2003) and as communities are transformed to new ecological states (multiple equilibria). These storms are not considered ecologically catastrophic, however, as many survivors are typically left behind (Platt and Connell 2003). Species that resist wind damage (Batista and Platt 2003), are adept at sprouting (Bond and Midgley 2001, Vesk and Westoby 2004), survive in the advance regeneration layer (Harrington and Bluhm 2001) or recruit from the seedbank are "first responders" that contribute to the regenerating community (Bellingham et al. 1992). Many species require this kind of disturbance to regenerate and persist in the community. For example, species that persist in the advance regeneration layer may still require canopy opening to advance to the overstory (Battaglia et al. 2004). Seedbank species, which contribute to the high diversity of longleaf pine (*Pinus palustris*) communities for example, often depend upon these openings to complete their life cycle and persist in the landscape (Platt et al. 2006).

Multiple Disturbances

Large-scale disturbances can interact to have compounded effects on ecological communities (Paine et al. 1998). Fires and hurricanes, for instance, can interact to produce large multiplicative effects on tree mortality that are unanticipated from the study of either disturbance in isolation (Platt et al. 2002). Tree mortality in upland communities following Hurricane Andrew's landfall in southern Florida varied depending on the preceding fire regime: total mortality was 95% in dry-season burned plots, but only 31% in wet-season burned plots. Fire disturbance may be more likely following a hurricane because of increased fuel loads. The post-hurricane fire can alter the direction of ecological change leading to alternative ecological states (Smith et al. 1997), for example, mediating community transitions between

closed canopy forests and savannas (Myers and van Lear 1998). Similar interactions are likely to occur between other disturbance types: fire and flooding events occurring in close proximity may lead to the presence of treeless prairies that are distributed across the southeastern US (Platt et al. 2006b).

Global change impacts on disturbance

Global climate is currently warming at an unprecedented rate with potentially profound and widespread effects on the distributions of ecological communities. Mean global temperature has risen by about 0.6˚C over the past century, the rate of warming since 1976 has been greater than any other period during the last 1,000 years, and the decade 1990–1999 was the hottest in recorded history (Mann et al. 1998, Easterling et al. 2000a, IPCC 2001). However, ecological communities in the southeastern US are likely to be most strongly influenced by the *indirect* effects of global warming on disturbance regimes and sea level rise rather than by increasing temperatures. The predicted spatial pattern of global warming is not homogenous; most pronounced warming is expected at far northern latitudes with more modest temperature increases expected at lower latitudes (Zwiers 2002). The frequency and intensity of natural disturbances such as fires and hurricanes are expected to be altered by global climate change (Dale et al. 2001, Beckage et al. 2003, Emanuel 2005, Webster et al. 2005, Westerling et al. 2006) and sea level rise will affect low-lying and coastal communities through increasing flooding and saltwater encroachment (Williams et al. 1999).

Anthropogenically driven climate change is likely to continue at the same or an accelerated rate for the foreseeable future (Hansen et al. 2005, Meehl et al. 2005) with a rise in global temperature between 1.4 and 7.5°C this century (Stott and Kettleborough 2002). The challenges these changes pose are increasingly apparent to people outside of science. Global climate change and extreme weather events are shaping policy and influencing decisions made by insurance companies nationwide (Mills and Lecomte 2006).

Global climate change is expected to result in altered precipitation patterns, including increased frequency of extreme precipitation events (Overpeck et al. 1990, Easterling 2000b). The United States has generally experienced increasing rainfall most noticeably since the 1970's (Easterling et al. 2000b) along with more frequent extreme precipitation, which can be defined as days with more than 51 mm (2 in) or 102 mm (4 in) of rainfall, since 1910 (Easterling et al. 2000a). Precipitation from extreme precipitation events are responsible for a disproportionately large portion of the 5 to 10% observed increase in total precipitation for the United States (Easterling et al. 2000a,b).

Related to shifts in precipitation, most scenarios of climate change predict an increase in the frequency and magnitude of floods (IPCC 2001, Olsen 2006). In the southeast US where forecasts point to increasing precipitation, floods of greater magnitude and frequency are expected. Hydrographs of rivers that drain watersheds where snowmelt occurs earlier or there is less snow and more rain will also reflect shifts in timing of inputs. Species that cannot spawn, disperse, or otherwise respond to novel flood pulse signatures may be extirpated (Tibbs and Galat 1998, Galat and Zweimuller 2001, Smith et al. 2005). Shifts in the flood pulses will also have implications for floodplain management and determining flood risk with changing climate. Unfortunately, current flood control systems and infrastructure are not necessarily capable of withstanding more extreme flood events (Kintisch 2005).

Today, many river-floodplain exchanges are highly altered or even severed because of channel maintenance structures, levee systems, and various other hydrologic modifications. This has caused erratic flood pulses ranging from continuous (e.g., impoundments) to inverted (Sparks 1998). Some floodplains now have an unnaturally long hydroperiod (Sparks et al. 1990), reduced productivity (Megonigal et al. 1997), shifts in species composition, loss of diversity, and high mortality if the stand is semi-permanently or permanently flooded (King 1995). Other areas have been dewatered and may no

longer function as wetlands. Disruption of sediment transport and delivery in their watersheds has left many coastal wetlands sediment-starved and highly degraded (Denslow and Battaglia 2002). Restoration efforts that restore connectivity will enhance goods and services of these floodplain ecosystems, including flood control (Sparks 1998, Sparks et al. 1998) and improve integrity of coastal ecosystems (Snedden et al. 2007).

Sea level has been rising at a rate of 3 mm per year over the last decade in response to global warming (i.e., 1993-2003; Cazenave and Nerem 2004) with approximately half of this increase due to thermal expansion of oceans (Levitus et al. 2005). Along low-lying southeastern US coasts, sea level rise (SLR) will have a pronounced effect on coastal communities, which should be among the first and most strongly affected by increased rates of SLR (Day et al. 2000, Bourne 2000). SLR along the Gulf of Mexico coast, now ~1.5 mm/yr, is projected to reach at least 5-7 mm/yr, a 320% increase, by 2100 (Penland and Ramsey 1990, Warrick et al. 1996, Meehl et al. 2005). Park et al. (1991) projected loss of up to 82% of coastal land in the US from SLR, the vast majority of which should occur along low-lying coasts in Florida, Texas, and Louisiana (Titus et al. 1991). Actual area lost will depend on elevation gradients along aquatic-terrestrial transitions, rates of subsidence, and rates and amounts of accumulation of inorganic sediments and accretion of organic material by vegetation (Reed 2002). Where sea-level is rising faster than accretion, *in situ* loss of land is inevitable (Michener et al. 1997). Such changes in sea level will result in saltwater intrusion and increased flooding, resulting in loss of inland vegetation in terrestrial habitats to more salt-tolerant vegetation and open water (Brinson et al. 1995, Williams et al. 1999). Because land loss occurs on the seaward end of coastal transitions, species eventually must either migrate upslope, replacing more upland species (Brinson et al. 1995), or disappear from the landscape.

The coastal systems of the southeast US have a long history of human use, with a several century history of European settlement during which natural landscapes have been converted to human-dominated ones. Remaining natural landscapes are fragmented and scattered in locations that have been the least conducive for humans (areas where extensive marshes separate uplands and the ocean) (Shirley and Battaglia 2006). Human-induced changes also have disrupted ecological processes, such as hydrology and fire regimes (Platt 1999, Beckage et al. 2003) and created barriers to dispersal, impeding migration of species across the landscape following disturbance. Landscape connectivity and dispersal corridors will become increasingly critical for successful migration of coastal species as their climatic envelopes shift inland.

Global climate influences fire regimes in the southeastern United States through the periodicity and amplitude of climatic cycles such as the El Niño-Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO). These climatic cycles are characterized by atmospheric or oceanic conditions in well-defined global regions but with effects that extend globally. ENSO cycles, for example, are characterized by alternating periods of warm (El Niño phase) or cold (La Niña phase) sea surface temperatures in the central and eastern Pacific off the west coast of South America, but exert a strong influence on regional rainfall patterns and temperatures across the globe (Allan et al. 1996, Stenseth et al. 2003). In the southeastern United States, ENSO conditions exert a strong influence on fire regimes because of the resonance between the state of ENSO and the annual hydrologic cycle (Beckage and Platt 2003, Beckage et al. 2003). Wildfires in the southeastern US primarily occur during the transition from the winter dry-season to the summer wet-season; this is the period when lightning strikes from summer thunderstorms provide an abundant ignition source but hydrologic conditions have not yet rebounded from the preceding dry season. Most rainfall is received during the summer months from convective thunderstorms with little precipitation during the winter dry-season. The severity of the dry-season is mediated by the state of the ENSO cycle because winter precipitation is increased during the El Niño phase of ENSO and decreased during the La Niña phase (Ropelewski and Halpert 1986). In addition, the ENSO cycle influences the frequency of lightning strikes, increasing the probability of fire ignitions in years with severe La Niña droughts (Beckage et al. 2003). ENSO effects on drought conditions and lightning strike frequency result

in strong concordance between the La Niña phase of the ENSO cycle and wildfire severity in the southeastern United States (Simard et al. 1985, Brenner 1991, Beckage et al. 2003). If the El Niño phase becomes predominant, as predicted (Timmerman et al. 1999), fire frequency in the southeastern United States should be reduced.

Hurricanes

Hurricanes and tropical cyclone frequency and intensity have been linked to both warming global temperatures and periodic climatic events such as ENSO and NAO. Global warming is likely to result in increased hurricane frequency and intensity (Overpeck et al. 1991), with increased wind damage of trees and flooding of coastal regions, particularly in conjunction with rising sea levels. The number of category 4 and 5 hurricanes observed globally has doubled over the last 35 years; in the North Atlantic basin the number of category 4 and 5 hurricanes increased from 16 from 1974-1989 to 25 during the 1990-2004 period in conjunction with warming sea surface temperatures (Webster et al. 2005). Similarly, the total energy dissipated by hurricanes has doubled in the north Atlantic basin over the last 30 years (Emanuel 2005). ENSO conditions also affect the frequency of hurricanes and tropical cyclones. Hurricanes are more frequent and intense during La Niña phases and less frequent and intense during El Niño phases (Wilson 1999, Elsner and Bossak 2001). The incidence of hurricanes on the southeastern U.S. is also dependent on the North Atlantic Oscillation (NAO). The NAO is a north-south difference in atmospheric pressure between the subtropical high-pressure over the Azores and the subpolar low-pressure over Iceland that is related to the strength of the westerly winds in the northern Atlantic Ocean. The significance of the NAO for the southeastern United States is in its influence on the tracks of hurricanes and tropical cyclones. A negative NAO results in hurricanes that track predominately in a westward direction with a high likelihood of hitting the southeastern U.S. A strong positive NAO index results in increased likelihood of more northerly hurricane tracks and decreased likelihood of landfall in the southeastern U.S. ENSO and NAO events are related such that during La Niña conditions when hurricanes are most frequent, landfall in the southeastern U.S. is most probable.

Global warming is expected to affect the frequency of ENSO events, which will influence future disturbance regimes in the southeastern US. The El Niño phase of ENSO is expected to become increasingly frequent with global warming, with La Niña events decreasing in frequency (Timmermann et al. 1999, Tsonis et al. 2003). These changes to the ENSO cycle will create conditions that favor less frequent but more severe large-scale fires and decreased hurricane frequency in the southeast US. In addition, if the current relationship between ENSO and NAO remains intact with global warming, then the hurricanes that do form will be more likely to track toward the northeastern rather than the southeastern coast of the United States (Stenseth et al. 2003). Thus, global warming is predicted to result in fewer, but more intense fires, more powerful hurricanes, and increased risk of coastal flooding in conjunction with sea level rise.

Management recommendations and future research needs

Human actions influence direct and indirect effects of climate change. Such actions may have larger, more immediate effects than climate change (Dale 1997), particularly if they reduce habitat availability and connectivity and alter disturbance regimes. By their very nature, most natural disturbances historically claimed or required vast areas. The widespread fragmentation of the landscape into smaller patches has had major impacts on disturbance characteristics. For example, the spread and extent of fires on smaller patches of land may be disproportionately lower than expected based on patch size (Duncan and Schmalzer 2004). Floodplain communities in the modern landscape are not only frequently disconnected from watercourses, but are often also internally fragmented. Once extensive along streams and rivers, floodplain forests have been reduced by conversion to agriculture and urban development (Sharitz & Mitsch 1993, King and Keeland 1999). In addition to fragmentation, active suppression of the

disturbances that sustain many species in the landscape has driven community shifts to alterative, often degraded states.

Management should be guided by ecological principles and as far as possible, mimic ecologically appropriate disturbance regimes. In many cases, restoration of disturbance regimes has a positive effect in the long-term (Van Lear et al. 2005). Special care must be taken, of course, if there are threatened and endangered species involved. Restoration of ecological communities that have long been modified by anthropogenic activities or invasion of exotic species may not necessarily have the intended result or immediately positive consequences. For example, Varner et al. (2005) found that reintroduction of fire to a longleaf pine forest after many years of fire exclusion and organic matter buildup led to unforeseen high mortality of large *Pinus palutris* individuals. In areas long degraded by fire suppression, repeated burns may be necessary (Heuberger and Putz 2003). Another key challenge for managers is simulating natural disturbances on small parcels of land in a highly fragmented and human-dominated landscape.

Direct and indirect effects of global climate change might interact with human-induced changes, producing magnified and unexpected effects not amenable to prediction using simple climate change models (e.g., Paine et al. 1998, Platt et al. 2002). For example, fire suppression might magnify effects of climate change on woody species; rapid seaward spread of such species in areas without pronounced flooding could eliminate the capability of marsh vegetation to respond to sea level rise by inland shifts in distribution. Active management (e.g., prescribed fires) is known to influence rates of change from human effects, but how such actions alter rates of change when interactive effects involve global climate change is unknown. Accurate prediction of global climate change effects will require knowledge of direct and indirect effects, both alone and in concert (Williams et al. 2003).

In the short term, incorporating disturbance regimes that approximate historic ones into management schemes should help to improve and maintain structure and function of the disturbance-dependent communities of the southeast US. Restoration of degraded ecosystems may also help to buffer effects of climate change. For instance, restoring coastal vegetation should reduce hurricane damage to inland areas and retard the effects of rising sea level. Creation of corridors to reconnect isolated populations in the landscape will facilitate dispersal (Battaglia et al. 2007) and genetic exchange, in addition to providing additional flexibility for integrating more ecologically realistic disturbances into management of the landscape.

In the long term, landscape connectivity and dispersal corridors will be increasingly critical for successful migration of species as their climatic envelopes shift. Also, the historic disturbance regime for a given site may not be a suitable model if the climate has changed appreciably. What are the proper restoration and management prescriptions in a time of rapid climate change? (Fig. 2). Should we use historic disturbance regimes as guides or regimes predicted with climate change? Should we manage for species that historically occurred at a site or assist the migration of species into new areas? Clearly, a better understanding of climate change and the ecological role of large-scale infrequent disturbances in historic, modern, and future landscapes of the southeastern US is needed to develop long-term planning for effective management and restoration of this disturbance-driven, diverse system (Beckage et al. 2005, Beckage et al. 2006).

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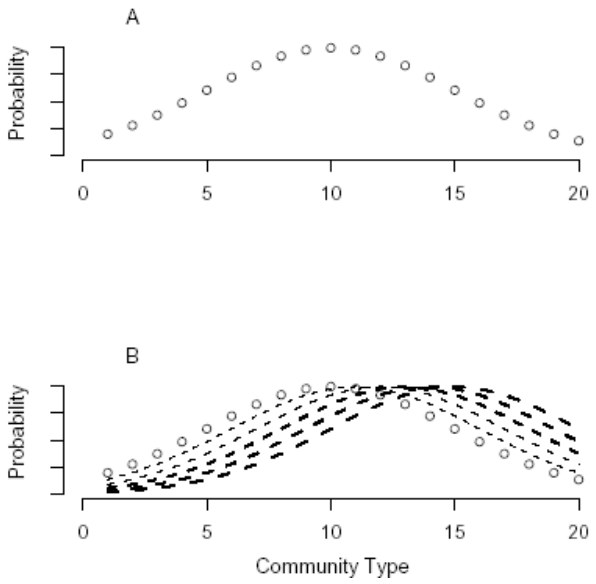

Figure 1. Distribution of community states across the landscape. A) The probability of a given community type occurring in the landscape is stochastic with certain communities more likely to occur than others. B) The probability distribution of community states shifts with climate change. The broken lines indicate future community probabilities with climate change: increasing line widths correspond to increasing climate change.

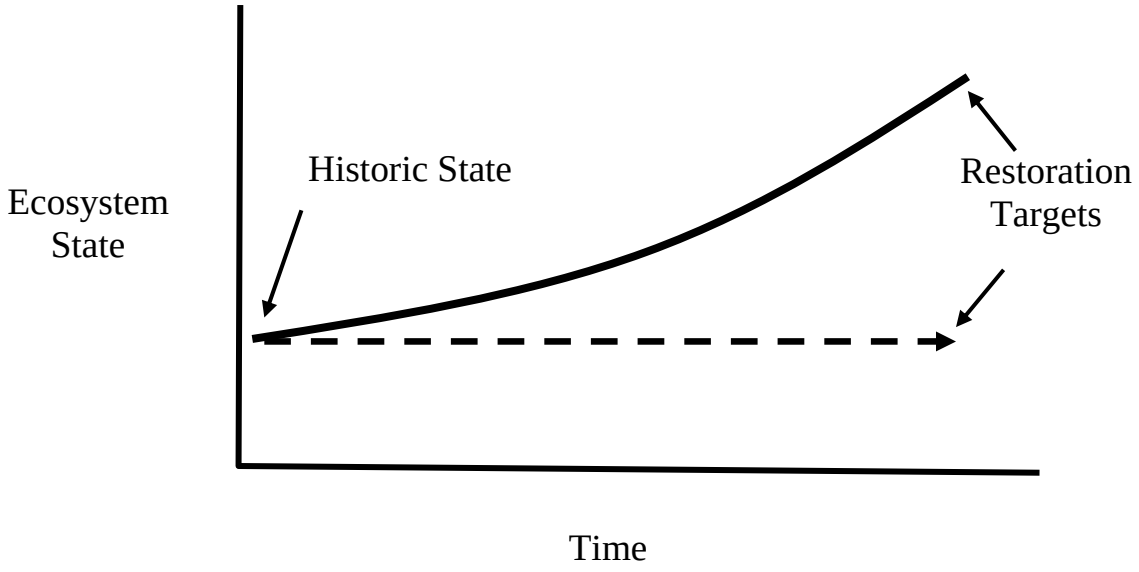

Figure 2. Suitability of restoration targets and climate change. The solid line represents a hypothetical trajectory of change in ecosystem state with climate change. The dotted line illustrates the historic ecosystem state that was the original restoration target.

Imperiled Aquatic Resources of the Southeastern United States: Status, Threats and Research Needs

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Abstract: The southeastern United States is a region of high biological diversity, especially in aquatic habitats. A significant portion of aquatic biodiversity is threatened, endangered, and at-risk species (TER-S). It is important that Department of Defense (DoD) and other Federal, State and private partner organizations determine conservation priorities, identify coordination opportunities, and develop a research and monitoring agenda relevant to DoD managed areas. For aquatic ecosystems, watershed level approaches are most effective in addressing TER-S conservation and therefore watersheds, not jurisdictional or property lines are the fundamental unit for freshwater, estuarine and coastal habitats. Marine habitats do not lend themselves to the same classification schemes of freshwater systems and therefore require a different approach. This paper identifies the aquatic TER-S resources in the Southeast and address priority watershed, ecosystems and species for the region. Included in this discussion is 1) status and trends of southeast TER-S; 2) threats to TER-S and TER-S habitats; 3) Priority setting processes for Southeastern watersheds; and 4) discuss how existing partnership efforts address these TER-S priorities and how DoD can fit into and complement these ongoing efforts. Finally, we will discuss how aquatic TER-S priorities might be addressed more holistically in concert with improvements in overall watershed management approaches. Major gaps in our knowledge should be identified.

I. The Biogeography of the Southeastern United States.

Among the temperate regions of the world, none has greater biodiversity than the southeastern United States. Over the course of geological time, the southeast has had a relatively stable and moist climate. Combined with diverse landforms that include the ancient Appalachian and Ouachita Mountains, Piedmont, coastal plains, deltas, estuaries and barrier islands, these conditions provided the physical and biological setting for the adaptive radiation of many major groups of organisms and produced a remarkable diversity of flora and fauna. The southeast is the epicenter for diversity for major taxa groups such as salamanders, freshwater mussels and crayfish. Great Smoky Mountain National Park, a single preserve of approximately 800 square miles, contains within its boundaries an astounding 4000 species of plants. This includes over 100 species of native trees --more than all of Europe. A single state – Tennessee, has over 300 species of freshwater fishes within its borders (Mettee et al, 1996

Contributing to the biodiversity of the Southeast is the diversity of landforms and aquatic resources. Bailey (1995) categorizes the major ecoregions of the nation into the Polar, Humid Temperate, Dry Domain and Humid Tropical Domains. Within Bailey's hierarchical classification system, the southeastern region of the United States falls within the Human Temperate Domain. For the purposes of this review, only the Humid Temperate Domain is discussed, excluding the Everglades Province of south Florida (Humid Tropical Domain) and the Southwest Plateau and Plains Dry Steppe Province of west Texas (Dry Domain).

The diversity of this region reaches its apex in its freshwater habitats – southeastern rivers and streams are home to most of the nation's species of freshwater mussels and snails, crayfish, and remarkable number

of freshwater fishes. Alabama alone has records for approximately 200 species of freshwater mussels. Tennessee has over 300 species of freshwater fishes including 91 species of darters (Etnier and Starnes, 1993). Figure 1 illustrated areas of high biodiversity and threat for the continental United States. Other aquatic invertebrates exhibit a pattern of high diversity in the Southeast, however many taxa, such as crayfish, remain poorly known. This is particularly true for the invertebrates of the extensive coastal rivers, streams and wetlands of the Southeast. Many new species which are the foundation for the aquatic foodweb in coastal ecosystems remain to be discovered.

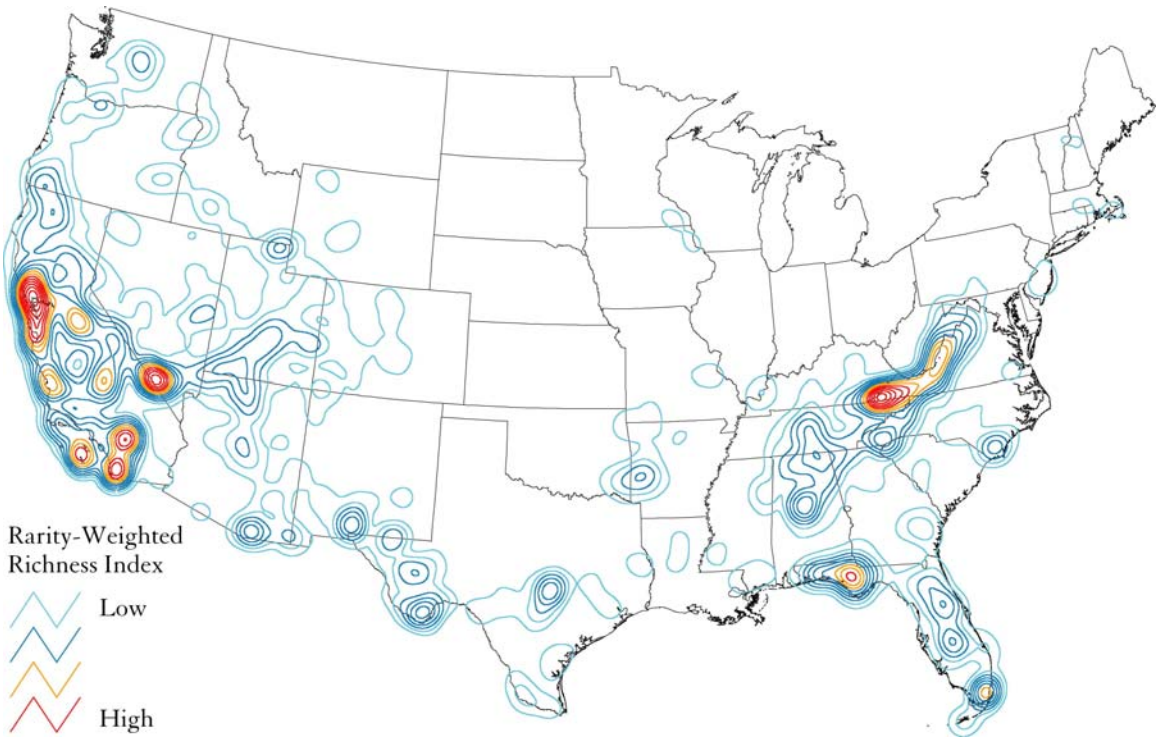

Figure 1. **A depiction of biodiversity hotspots in the United States.** Isopleths encompass regions of high concentrations of imperiled species (G-1 through G-3). In the Southeast, these "hotspots", are largely driven by freshwater aquatic species. Examples include the Upper Tennessee, Lower Apalachicola in Florida and the Tar River Basin in North Carolina (Stein et al., 2000). Used with the permission of the author.

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An ecosystem-based approach is used in this paper to characterize the imperiled living resources of the Southeast. This approach is based on established principles of conservation biology (Meffe et al., 1997, Soule and Orians, 2001) as well as the science information requirements identified in the Endangered Species Act (ESA): "to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved…" [ESA 1988, as amended, Section 2 (b)].

Identifying imperiled ecosystems requires identification of its components, most importantly the presence of threatened, endangered, and at-risk species (TER-S). For the purpose of this paper, TER-S include those taxa listed under ESA. However, broader definitions of TER-S should be considered in establishing priorities for research, monitoring or conservation action on an ecosystem basis. In North America the most widely used classification system for species and communities is the Heritage Conservation Status Ranks and is used by State and Federal agencies in establishing species and ecosystem priorities as well

as private organizations including The Nature Conservancy and NatureServe. Definitions for status ranks are summarized in Table 1 and a detailed discussion can be found in Stein et al (2000). Other classifications include the ICUN Red List, a worldwide conservation status listing and ranking system. The system divides threatened species into three categories: Critically Endangered (CR), Endangered (EN), and Vulnerable (VU). All three categories indicate a species or community at risk. Additional information on IUCN criteria and ranks can be found on the web at: http://www.iucnredlist.org/info/categories_criteria2001.

Finally, species or habitats identified as imperiled or listed as a priority species by a State Wildlife Action Plan (SWAP) are criteria that can be used to guide biodiversity conservation strategies. A summary of the aquatic components of SARP plans is published on the web at: http://www.fws.gov/fisheries. Additional information on SWAP Plans and the criteria used to identify priority species under individual SWAP plans can be found at the Teaming with Wildlife website, http://www.teaming.com/wildlife_state.htm .

Table 1. Heritage Conservation Rankings Definitions.

Rank	Definition
GX	Presumed extinct; not located despite searches
GH	Of historical occurrence; possibly extinct but some expectation of rediscovery
G1	Critically imperiled; typically 5 or fewer occurrences or 1,000 or fewer individuals
G2	Imperiled; typically 6 to 20 occurrences or 1,000 to 3,000 individuals
G3	Rare or uncommon but not imperiled; typically 21 to 100 occurrences or 3,000 to 10,000 individuals
G4	Uncommon but not rare; apparently secure, but with cause for some long-term concern; usually more than 100 occurrences or 10,000 individuals
G5	Common; demonstrably widespread, abundant, and secure

II. Defining the Resource – Area Addressed and Classification of Aquatic Habitats

A. Jurisdictional and Coarse-Scale Classification. For the purposes of this review of aquatic resources of the Southeast all or portions of fourteen States are included (VA, NC, SC, GA, FL, AL, MS, LA, TX, OK, MO, AR, TN and KY). All of these states are the member states of the Southeast Aquatic Resource Partnership with the exception of Virginia.

An essential resource for describing the watersheds for the United States is the State Hydrologic Unit Maps, (Seaber, et al., 1984). Most aquatic habitat classification systems utilize hydrologic unit maps or HUCs as a data layer. For example, most location and distribution databases for aquatic organisms use six digit (Accounting Units) or eight-digit (Cataloging Units) HUCs as a fundamental data layer.

Table 2. Jurisdictional and Ecosystem Boundaries for the Southeastern United States.[1]

State	Federal Regional Boundaries[3]	HUC Unit (3 Digits)	Bailey Ecosystems (Province)
Alabama	FWS: 4 EPA: 4 ACE: South Atlantic	South Atlantic Gulf (03) Tennessee (06)	**221** Eastern Broadleaf Forest (Oceanic) **222** Eastern Broadleaf Forest (Continental) **231** Southeastern Mixed Forest **232** Outer Coastal Plain Mixed Forest
Arkansas	FWS: 3 EPA: 6 ACE: Mississippi Valley, Southwestern	Arkansas-White –Red (11) Lower Mississippi (08)	**222** Eastern Broadleaf Forest (Continental) **M222** Ozark Broadleaf Forest-Meadow **231** Southeastern Mixed Forest **M231** Ouachita Mixed Forest-Meadow **234** Lower Mississippi Riverine Forest
Florida	FWS: 4 EPA: 4 ACE: South Atlantic	South Atlantic Gulf (03)	**232** Outer Coastal Plain Mixed Forest
Georgia	FWS: 4 EPA: 4 ACE: South Atlantic	South Atlantic Gulf (03) Tennessee (06)	**M221** Central Appalachian Broadleaf Forest **231** Southeastern Mixed Forest **232** Outer Coastal Plain Mixed Forest
Kentucky	FWS: 4 EPA: 4 ACE: North Atlantic, Mississippi Valley	Ohio (05) Tennessee (06)	**221** Eastern Broadleaf Forest (Oceanic) **M221** Central Appalachian Broadleaf Forest **222** Eastern Broadleaf Forest (Continental) **234** Lower Mississippi Riverine Forest
Mississippi	FWS: 4 EPA: 4 ACE: Mississippi Valley, South Atlantic	Lower Mississippi (08) South Atlantic Gulf (03) Tennessee (06)	**231** Southeastern Mixed Forest **232** Outer Coastal Plain Mixed Forest **234** Lower Mississippi Riverine Forest
Missouri	FWS: 3 EPA: 5 ACE: Northwest, Southwest, Mississippi Valley	Upper Mississippi (07) Lower Mississippi (08) Missouri (10) Arkansas-White-Red (11)	**222** Eastern Broadleaf Forest (Continental) **234** Lower Mississippi Riverine Forest **251** Prairie Parkland (Temperate)

North Carolina	FWS: 4 EPA: 4 ACE: South Atlantic, Great Lakes and Ohio River, North Atlantic	South Atlantic Gulf (03) Tennessee (06)	**M221** Central Appalachian Broadleaf Forest **232** Outer Coastal Plain Mixed Forest **231** Southeastern Mixed Forest
Oklahoma[2]	FWS: 2 EPA: 6 ACE: Southwest	Arkansas-White –Red (11)	**222** Eastern Broadleaf Forest (Continental) **M222** Ozark Broadleaf Forest-Meadow **231** Southeastern Mixed Forest **M231** Ouachita Mixed Forest-Meadow **251** Prairie Parkland (Temperate)
South Carolina	FWS: 4 EPA: 4 ACE: South Atlantic	South Atlantic Gulf (03)	**M221** Central Appalachian Broadleaf Forest **231** Southeastern Mixed Forest **232** Outer Coastal Plain Mixed Forest
Tennessee	FWS: EPA: ACE: Great Lakes and Ohio River, Mississippi Valley	Ohio (05) Tennessee (06) Lower Mississippi (08) South Atlantic Gulf (03)	**M221** Central Appalachian Broadleaf Forest **221** Eastern Broadleaf Forest (Oceanic) **222** Eastern Broadleaf Forest (Continental) **231** Southeastern Mixed Forest **234** Lower Mississippi Riverine Forest
Texas[2]	FWS: 2 EPA: 6 ACE: Southwest	Arkansas-White –Red (11) Texas Gulf (12)	**231** Southeastern Mixed Forest **232** Outer Coastal Plain Mixed Forest **255** Prairie Parkland (Subtropical)
Virginia	FWS: 5 EPA: 3 ACE: North Atlantic, South Atlantic, Great Lakes and Ohio River	Mid-Atlantic (02) South Atlantic Gulf (03)	**M221** Central Appalachian Broadleaf Forest **231** Southeastern Mixed Forest **232** Outer Coastal Plain Mixed Forest

[1]Ecoregions not within the Humid Temperate Domain as defined by Bailey (1995) are excluded.

[2] States which have lands excluded because they are not part of the Humid Temperate Domain.

[3] U.S. Fish and Wildlife Service, U.S. Environmental Protection Agency, U.S. Army Corps of Engineers.

B. Fine Scale Classification of Aquatic Ecosystems. Higgins et al.(1998) have developed an aquatic community classification system modeled in part after the Federal Geographic Data Committee (FGDC) standards for terrestrial plant communities. This classification system, which takes into account both biological and physical components of aquatic ecosystems, is the recommended standard for identifying areas for conservation action. Publications by Abell et al., (2000). Smith et al.,(2002), and Sowa et al. (2004, 2005) refine and apply this classification system both nationally and regionally. Classification of marine environments is addressed by another FGDC publication, *Marine Managed Areas: Best Practices*

for Boundary Making, available on the web at http://www.csc.noaa.gov/mbwg/htm/outreach.htm. The standards cited here are the most widely used for identifying conservation priorities and actions

III. Aquatic Ecosystems of the Southeast.

The southeastern United States includes a rich diversity rivers, streams, estuaries, and coastlines. While there are numerous small sandhill and limestone solution ponds, larger natural lakes are relatively scarce in the Southeast region. However, many and extensive reservoirs constructed for flood control, hydroelectric generation, recreation and other purposes dot the Southeast. Table 3 contains a summary of coastline and stream miles for southeastern states. Table 4 summarizes wetland acreage and wetland losses sustained in Southeastern states.

Table 3. Coastline Data and Stream Miles per State for the Southeastern United States.

State	General coastline in statute miles[1]	Tidal Shoreline in statute miles[1]	Stream Miles[2]
Alabama	53	607	77,274
Arkansas	--	--	87,617
Florida	Atlantic coast, 580, Gulf coast, 770	Atlantic coast 3,331, Gulf coast, 5095	51, 858
Georgia	100	2,344	70,150
Kentucky	--	--	49.104
Louisiana	397	7,721	66,294
Mississippi	44	359	84,003
Missouri	--	--	110,040
North Carolina	301	3,375	37.996[3]
Oklahoma	--	--	78,778
South Carolina	187	2,876	69,434
Tennessee	--	--	61,075
Texas	367	3,359	191,224
Virginia	112	3,315	50,415

[1] Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service.

[2] Information compiled by American Rivers from multiple sources –data reported in the chart maybe derived from maps or other sources at various scales and resolutions and thus may not provide an accurate basis for comparisons among states. Web site is:

http://www.americanrivers.org/site/DocServer/Stream_Miles_Table_FINAL__2_.pdf?docID=4081

[3] Data from North Carolina State University and North Carolina A&T University, 1997, **1997 Natural Resources Inventory of North Carolina on the web at:** http://www.ces.ncsu.edu/nreos/ncnatres/

A. Wetland Habitats. The Southeast leads the nation in wetlands acreage. Among the many attributes of wetland ecosystems that are of importance to TER-S in the Southeast include; preferred habitats for migratory bird species, nursery areas for fisheries, and essential habitats for some TER-S. Table 4 illustrates that the Southeast region has also sustained significant losses of wetland acreage and function.

Table 4. Wetland Areas For The Southeastern States With Historic Loss Information

				1780's		1980's		
STATE	**LAND**	**WATER**	**TOTAL**	**ESTIMATES**	**% S.A.**	**ESTIMATES**	**% S.A.**	**% LOST**
AL	32,544,640	485,120	33,029,760	7,567,600	22.90%	3,783,800	11.50%	-50%
AR	33,392,000	594,560	33,986,560	9,848,600	29.00%	2,763,600	8.10%	-72%
FL	34,647,040	2,831,360	37,478,400	20,325,013	54.20%	11,038,300	29.50%	-46%
GA	37,246,080	434,560	37,680,640	6,843,200	18.20%	5,298,200	14.10%	-23%
KY	25,504,640	348,160	25,852,800	1,566,000	6.10%	300,000	1.20%	-81%
LA	28,899,200	2,155,520	31,054,720	16,194,500	52.10%	8,784,200	28.30%	-46%
MS	30,309,120	229,120	30,538,240	9,872,000	32.30%	4,067,000	13.30%	-59%
MO	44,189,440	409,600	44,599,040	4,844,000	10.90%	643,000	1.40%	-87%
NC	31,283,200	2,371,840	33,655,040	11,089,500	33.00%	5,689,500	16.90%	-49%
OK	44,149,760	598,400	44,748,160	2,842,600	6.40%	949,700	2.10%	-67%
SC	19,379,200	496,000	19,875,200	6,414,000	32.30%	4,659,000	23.40%	-27%
TN	26,474,240	561,920	27,036,160	1,937,000	7.20%	787,000	2.90%	-59%
TX	168,300,800	2,796,160	171,096,960	15,999,700	9.40%	7,612,412	4.40%	-52%
VA	25,498,240	624,640	26,122,880	1,849,000	7.10%	1,074,613	4.10%	-42%

URL: http://www.npwrc.usgs.gov/resource/wetlands/wetloss/table_1.htm. Page Contact Information: npwrc@usgs.gov. Page Last Modified: August 3, 2006

The region has a wide variety of wetland types, several of which are rare and declining in the Southeast, including bogs, pocosin wetlands, limestone seeps or fens, freshwater tidal wetlands, mangrove swamps and coastal wetland forests. These aforementioned wetland types are habitats for unique and often endemic species of plants and animals. One such species, the ivory-billed woodpecker, is discussed below. Wetlands are also important habitats for organisms that migrate, including both fishes and birds. W. E. Odum (1984) provided data on the number and types of species that utilize a single wetland type, freshwater tidal wetlands. For the eastern U.S Odum included 280 species of birds and 102 species of amphibians and reptiles. Barrow et al. (2005) described the importance of coastal communities, including wetlands, to migratory birds. Bottomland hardwood wetlands are the primary habitat for bird species such as the prothonotary warbler (Harrison, 1984) and the recently re-discovered ivory-billed woodpecker (see insert below). While wetland and wetland functions are too broad a topic to discuss in the context of this overview (see Mitsch and Gosselink, 1986, for a detailed treatment of wetland science), wetland ecosystems illustrate the importance of addressing watersheds and landscapes holistically. The quantity, quality, type and location of wetlands within watersheds are critical to the overall health of watersheds and the species that depend on them.

Ghost of the Bottomlands – the Ivory-billed Woodpecker Re-discovered. On April 28th, 2005, an amazing discovery was announced at a news conference at the U. S. Department of the Interior. The ivory-billed woodpecker, unseen in the United States for 60 years, was identified using auditory and visual recording equipment in the Big Woods region of southeastern Arkansas. Historic records indicate that this rarest of all North American birds used large tracts of bottomland hardwood wetlands for habitat. Multiple Federal, State and other organizations have joined in the search to find and protect this elusive species. Intensive surveys have indicated that ivory-billed woodpeckers may still exist in as many as 11 southeastern States. Although the focus has been in the Lower Mississippi Valley, (see illustration), there is promising recent evidence for locations in Florida.

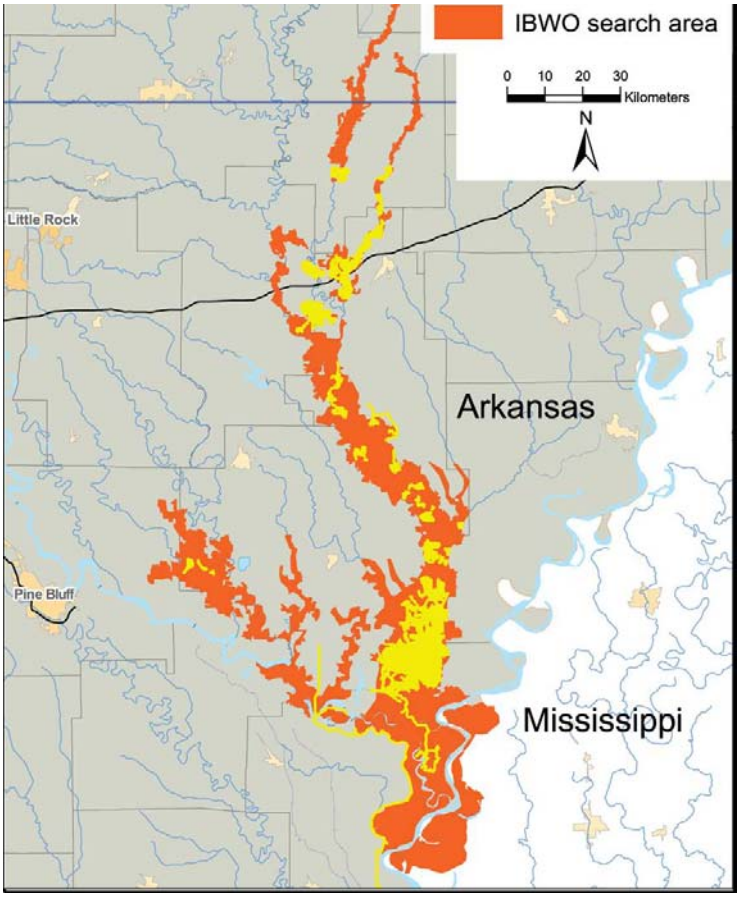


Figure 2. Current Search Area for the Ivory-billed Woodpecker in the Big Woods Region of Arkansas and Mississippi (with permission of the Cornell Laboratory of Ornithology).

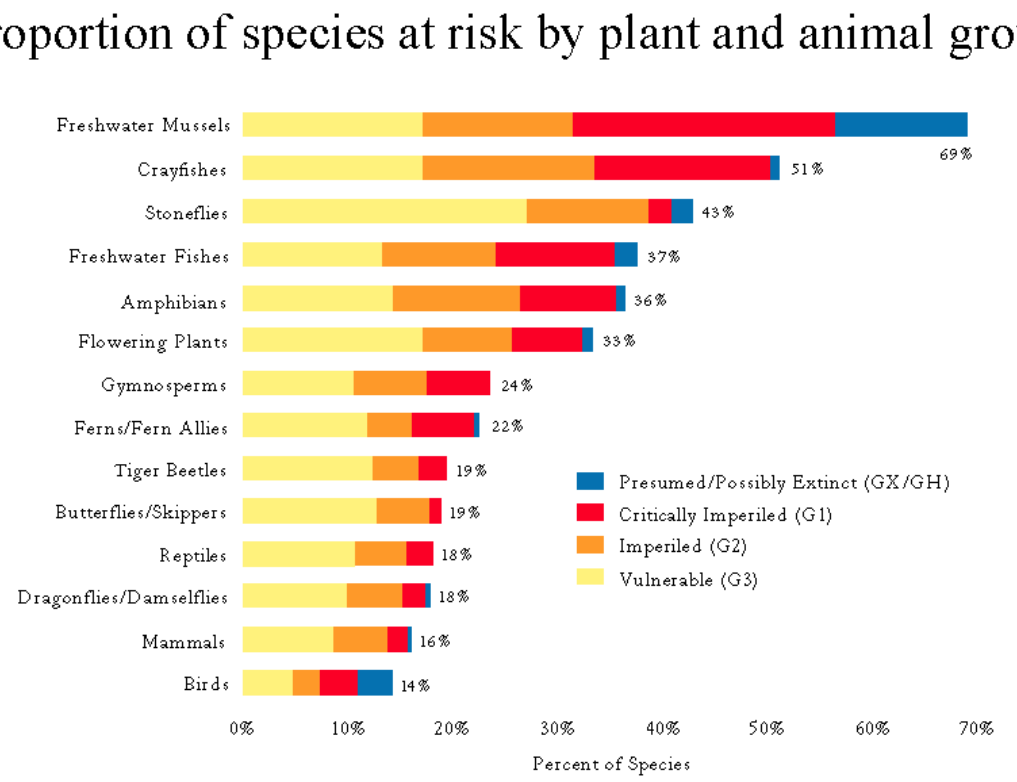
B. Rivers and Streams. Climate and the underlying geology of the Southeast makes this a region rich in lotic or flowing water systems, from the first order streams of the Appalachian Highlands to the Mississippi and Ohio Rivers, (two of the world's largest rivers). The well-known major landscape units of the southeast, (coastal plain, Piedmont and montane) shape the flow and function of these systems in a way that has created an extraordinary amount of habitat diversity. Of these major stream types, the coastal blackwater rivers and streams of the Atlantic coast are the least studied. This diversity of habitats found in southeastern rivers and streams created an environment for the evolution of the diverse flora and fauna that is the focus of this paper. Ishording and Fitzpatrick (1992) provide a detailed review of the types and status of southeastern streams and rivers.

C. Reservoirs. Approximately 144 major reservoirs have been built on the rivers of the Southeast and are distributed throughout the region. Of these reservoirs 59% are operated by the Army Corps of Engineers, 17% by the Tennessee Valley Authority and the remainder by State, local and private agencies. Reservoirs provide a variety of habitats because they include riverine and lacustrine zones and a transitional zone between the two, as well as spillways. The presence of lacustrine or lake-like conditions in reservoirs creates habitats that allow some aquatic species associated with pool and lake habitats to thrive. However, dam structures significantly impact and degrade riverine habitats, change temperature regimes within rivers and streams and block the passage of migratory fish and other species and from rapid changes in water levels associated with hydroelectric dams. A detailed discussion of reservoirs and their characteristics in the Southeast is addressed by Soballe et al. (1992).

D. Other Aquatic Habitats of the Southeast. Other aquatic habitats of importance in the Southeast include springs and cave/groundwaters, natural lakes, (principally Carolina Bays of the NC/SC coastal region and spring-fed lakes of North and Central Florida), backbays and lagoons, estuaries and near-marine environments. The ecological structure and function of these systems are addressed in Hackney, Adam and Martin (eds.) in *Biodiversity of the Southeastern United States: Aquatic Communities* (1992).

IV. Status of Aquatic Organisms and Watersheds in the SE

Figure 3 illustrates the status for the major terrestrial and aquatic species in freshwater aquatic systems in North America, based on 25 years of Natural Heritage data. The five most threatened taxa are freshwater species: freshwater mussels, crayfishes, stoneflies, freshwater fishes, and amphibians. The vulnerable status of aquatic fauna in the southeastern United States is well documented (Benz and Collins, eds. 1997; Adams and Martin eds. 1992). Most of the species known to be at risk are found in higher gradient streams in montane and Piedmont habitats. However, more intensive surveys conducted in low gradient and blackwater streams of the coastal plain have indicated that species richness, both for fish and macro-invertebrates, is comparable to richness found in higher gradient streams inland (Smock and Gilinsky 1992). Walsh and Jelks (2004) reviewed literature and website data available on the status of freshwater fishes in the Southeast and found that existing resources, including the Natural Heritage databases, have gaps in status and trends information for a significant number of fish species. Information on the species richness, status and threats to coastal streams and rivers is a significant gap in our knowledge of southeastern aquatic biodiversity. A state-by-state analysis and summary of the aquatic priority species, conservation areas by basin and a summary of issues and actions can be found on the web at: http://www.fws.gov/fisheries, and provides a basis for addressing conservation priorities by State and by watershed. Integration of State-based plans into a regional plan is a conservation need currently being addressed by the Southeast Aquatic Resource Partnership and other regional organizations. Federal agencies, including DoD, would benefit from an active partnership with these synthesis efforts to meet regional TER-S conservation goals.



Source: *Precious Heritage* (2000) © TNC, ABI

Figure 3. Proportion of species at risk by plant and animal group for North America **(**Stein et al. 2000, used by permission of the author).

V. Threats to Aquatic Biological Resources

The National Fish Habitat Initiative, (National Fish Habitat Science and Data Committee, 2006) published a draft report which outlines the primary threats to aquatic habitats. The authors identified 5 major categories of threat:

- Direct Habitat Modification
- Flow Alteration
- Invasives Species
- Pollution
- Climate Change

These five categories are a useful tool for characterizing threats in the Southeast.

Direct habitat modification

Coastal watersheds represent 13% of the nation's land surface area but they are home to more than half of the human population, and the urban sprawl that covered 14% of America's coastal watersheds in 1997 is predicted to increase to 25% by 2015 (Beach 2002). Humans modify aquatic habitats in many different ways; for example, wetlands are filled in for urban development or drained for agricultural use. It is estimated that 20,000 acres of sensitive coastal wetland are lost every year because of development (EPA 2000; Pew Oceans Commission 2003a). The nation's rivers have been extensively modified by dredging, impoundment, and dikes. In marine areas, bulk-heading and dredging for marinas and the associated increase in boating destroy shallow water seagrass beds and other shallow-water coastal habitats, and shoreline hardening for erosion control have affected coastal habitats. Similar effects to those in marine areas have been noted in inland lakes, impoundments and reservoirs.

Flow alternation

In the Southeast, as well as for most of the nation, the most rapid dam-building phase occurred between the 1950's and late 1970's. Since 1980the increases in national dam storage capacity have been relatively minor. Nonetheless, 75,000 large dams and a quarter of a million small dams remain nationwide. (National Research Council 1992). These dams cumulatively fragment the rivers of the United States, alter downstream flow patterns, eliminate or alter seasonal flooding cycles, alter water quality and temperature, reduce sediment supply to estuaries, prohibit movement of migratory fishes, and replace riverine biota that have adapted to swiftly flowing streams with lacustrine habitats and species (McAlister et al. 1997; Graf 1999; Abell et al. 2000; Harvey 2001). As a result, whole native faunas are in danger. However, Ahlstedt et al., (2007) noted that changes in minimum flows and aeration in dam management practices can result in significant gains in mussel densities and species richness.

Pollution

The primary pollution concern is nutrient enrichment as 60% of our nation's coastal rivers and estuaries are considered severely degraded from nutrient runoff (Bricker et al. 1999) and have contributed to the Gulf of Mexico's anoxic zone. The total amount of nitrogen released into coastal waters along the Atlantic seaboard and the Gulf of Mexico from anthropogenic sources has increased about fivefold since the pre-industrial era, and if current practices continue, it will increase 30% by 2030 (Howarth et al. 2000). Urban development has increased non-point source pollution; every year, 16.5 million gallons of oil run off America's streets into our waterways (Pew Oceans Commission 2003a). In addition point source discharges of contaminants such as polychlorinated biphenyls (PCBs) and heavy metals have contributed to broad scale impact on fish populations.

Invasive species

Since the first arrival of Europeans in the USA, the rate of known invasive aquatic species has increased exponentially. These invasive species often compete directly with other plants and animals by changing the energy flow in aquatic systems, as was seen in the Great Lakes with the invasion of alewives and sea lamprey from the Atlantic Coast, and by directly modifying habitat as demonstrated by zebra mussel infestations.

Climate change

In addition to these varied threats, climate change over the next century is expected to have profound effects on coastal and marine ecosystems. Sea-level rise, in combination with subsidence on the eastern

shore will gradually inundate highly productive coastal wetlands, estuaries, and mangrove forests (Pew Oceans Commission, 2003). The potential of stronger and more frequent hurricanes and other storm events that are predicted in climate change models will adversely affect coastal TER-S.

Disease

Introduction of new diseases (such as strains of H5N1 avian influenza) pose a threat to waterfowl, fish and other aquatic species. Reduction of habitat and the resulting concentration of migratory species increase the likelihood of significant disease outbreaks. Pollution and other stresses increase the susceptibility of aquatic wildlife populations to disease and parasites already in the environment.

VI. Priority Setting

Several comprehensive efforts to identify the priority aquatic resources of the Southeastern United States have already been published. Abell et al. (2000) published a continent-wide assessment, *Freshwater Ecoregions of North America*, which broadly identified freshwater ecoregions that support global biological diversity and examined the impacts to freshwater habitats from a range of sources, including flow alteration, habitat fragmentation, introduced species, and overall land use changes. The authors used a combination of measures of biodiversity, including species richness and endemism and threat, to determine priority areas for conservation. The majority of the watersheds of the Southeast were rated "Priority I", the highest priority, based on a combination of high biodiversity and high threat that characterizes the major rivers of the region.

Rivers of Life: Critical Watersheds for Protecting Biodiversity by Master et al. (1998) used a "hotspot" methodology, that is, using the location data collected by the Natural Heritage Network for vulnerable species of freshwater fish and mussels for which there were adequate data (307 species). Location data was assigned to the appropriate 8-digit HUC for each species. Using this information they identified priority watersheds using a rarity-weighed richness index. This methodology produced a set of priority watersheds which they depicted using GIS, (Figure 5). The highest priority watersheds identified in this publication were, with the exception of one watershed (the Verde River in Arizona), in the Southeast and included portions of the Green River, (KY), Clinch River (VA, TN), Conasauga River (TN, GA, NC), Altamaha (GA), Cahaba (AL), Kiamichi (OK) and Guadalupe (TX). Threats to these species were not part of analysis. The use of mussel species data, which generally have high diversity in higher gradient streams and are less diverse in coastal streams, may have favored montane and Piedmont watersheds over coastal watersheds in this analysis and therefore coastal streams may be underrepresented as priority watersheds. Furthermore, critical aquatic species that migrate (anadromous fishes) require access to large rivers and the oceans, and use by other fauna, (birds, mammals) were incorporated into this metric.

In *Priority Areas for Freshwater Conservation Action: A Biodiversity Assessment of the Southeastern United States*, Smith et al. (2002) built upon the work done by Master and others and uses a methodology that identifies "ecological drainage units" or EDUs that incorporate areas of high biodiversity and representative biodiversity and physical stream characteristics, including stream size and gradient, so as to develop a more complete portfolio of priority sites for conservation. Furthermore, they developed a conservation methodology that incorporated redundancy in selecting targets for conservation. Finally, by incorporating multiple segments of the river gradient they more effectively capture areas for conservation that range from headwater streams to the coast.

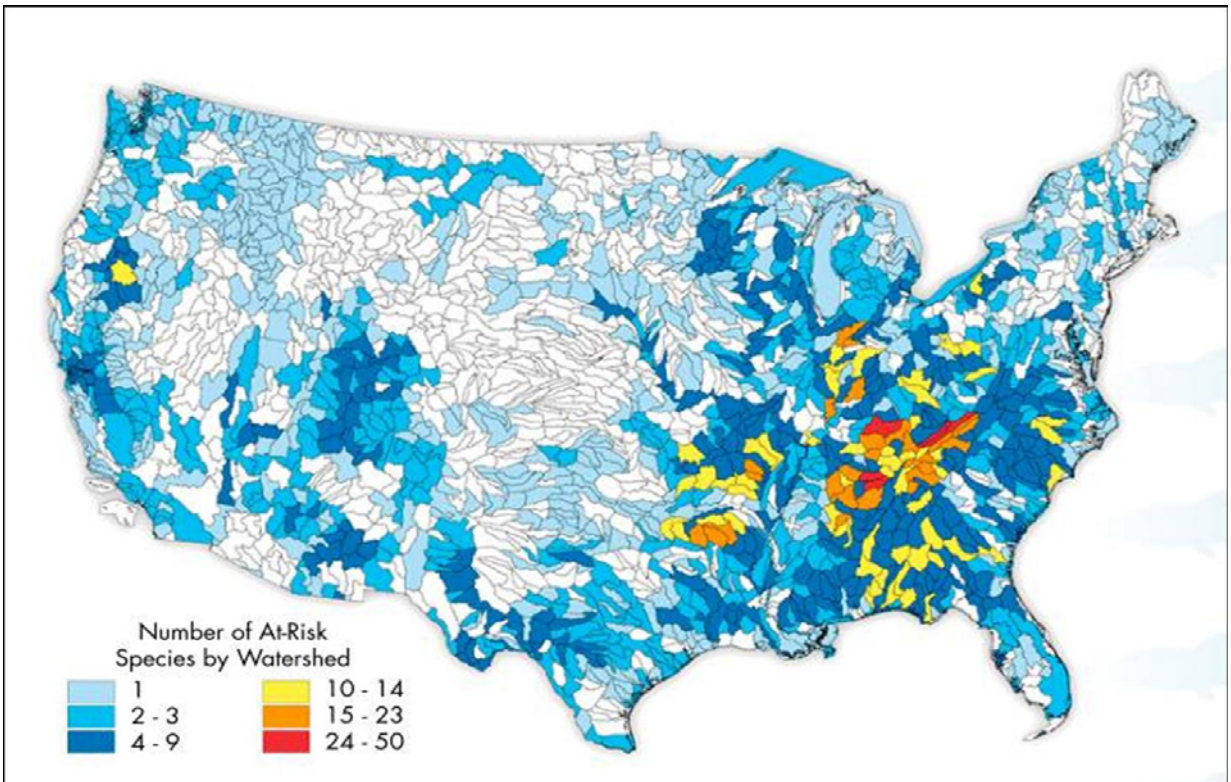


Figure 5. Hot Spots for At-Risk Fish and Mussel Species

Watersheds with 10 or more at-risk fish and mussel species are concentrated in the Southeast, reflecting the extraordinary species diversity of rivers and streams in this region.

Muir et al. (2007, in preparation) updates the distribution data for five freshwater taxa (fish, mussels, snails, crayfish and herptiles) using distribution data for the southeast from 1985 to date. Preliminary analysis generally show shrinking distributions for mussel and fish (the only data analyzed to date). Incorporated into their analysis is the use of priority species as identified in the State Wildlife Action Plans. Each state used different criteria to identify priority species for their State. However, by incorporating SWAP priority species into their analysis the authors hope to assist States in more effectively identifying overall conservation goals both within a State and across a region.

No methodology examined in this review attempted to rigorously characterize threat in the priority setting process, or "opportunity", that is, the practicality and available resources to conduct conservation action. This process is essentially a combination of scientific information and public policy/private action that does not lend itself to a rigorous priority setting process. Science can effectively identify TER-S resources and characterize the ecosystem structure, functions and services necessary to conserve them. Policy and political will are necessary to achieve conservation goals identified by science.

VII. Partnerships

Partnerships are essential in the management of aquatic ecosystems. Why? Watersheds integrate the ecological processes within their boundaries, and very few watershed of significant size are owned and/or managed by a single organization. This is particularly true in the Southeast where the Federal footprint is relatively small.

Partnerships in research, monitoring and land management to conserve TER-S are best approached using an adaptive management model that involves the cooperation of the principal sectors in conservation: Figure 6 illustrates the potential cooperators for partnerships fall in the four categories identified in the illustration.

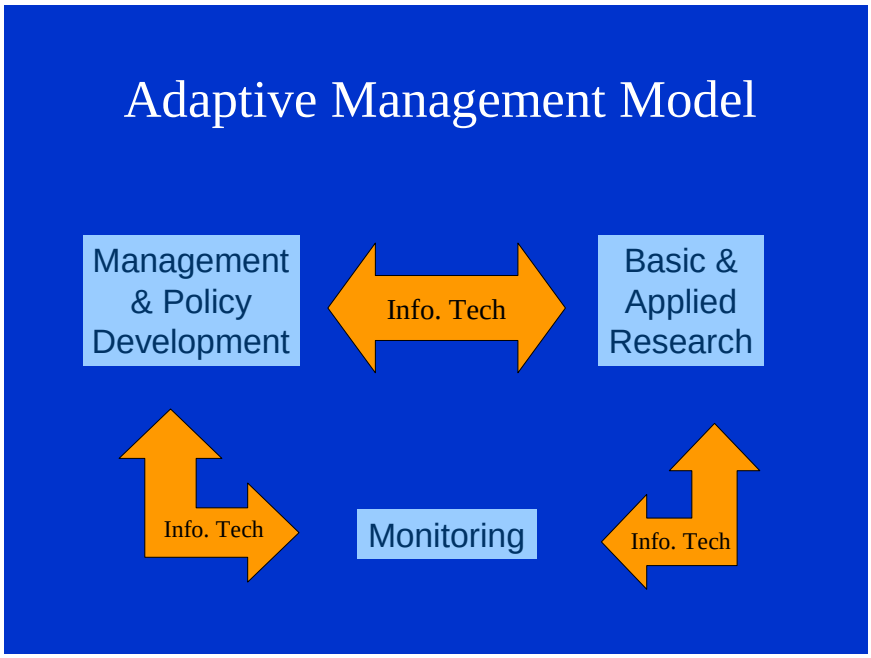


Figure 6. Major categories of potential partners in an adaptive management model. They include resource managers, (e.g., park superintendents, base commanders), policy-makers, (state agencies, multi-agency organizations) researchers, (federal research agencies, universities), Monitoring organizations, (states and others) and the information transfer community, (NBII, NatureServe, journals).

A. Resource Managers. Table 5 illustrates the major resource ownership papers in the southeast. (Note – TVA ownership is not included in the table.) Compared to the western United States, the southeast has an overall low percentage of Federal ownership. However, DoD has a significant portion of land ownership among federal agencies in the Southeast. The acreage ascribed to the U.S. Army of Engineers (ACE) in the table includes reservoirs and other waters. For that reason they are a particularly valuable partner in resource management. Similarly, the National Wildlife Refuge system includes many wetland and other aquatic resources.

The largest single Federal landholder in the Southeast is the Forest Service and is one of the few organizations that potentially can manage entire watersheds within their jurisdictional boundaries. A comprehensive assessment of the freshwater fauna and habitats of southern National Forest lands is found in McDougal et al. (2001). Imperiled species of fish, mussels, amphibians and other invertebrates are identified by HUC units. The key to identifying partnerships for individual partnerships is the juxtaposition of land/water ownership and regulation. Important from a watershed perspective is the location and management of strategically important resources and structures, (dams, wetland preserves, etc.). Finally, States and local jurisdictions play a central role, because management of aquatic resources largely is conducted by State and local governments. For example, the Clean Water Act is a Federal regulation that is an important element of the protection of imperiled aquatic species, but implementation

and enforcement is largely ceded to the States with the notable exception of wetlands protection under Section 404.

Table 5. Federal Ownership Patterns in the Southeastern United States

State	Federal Land (000's of acres)	% of State's Total Area	U.S. Ranking (% of Federal Land)	Military Bases	USACE	BLM FWS, NPS & USFS
AL	1,051,000	3.2	33	168,000	43,000	839,500
AR	3,938,000	11.8	17	518,000	93,000	3,297,000
FL	5, 068,000	14.7	15	683,000	53,000	4331,000
GA	2,276,000	6.1	29	556,000	336,000	1384,000
KY	1,369,000	5.4	32	229,000	351,000	788,000
LA	1,663,000	6.0	26	241,000	35,000	1,386,000
MS	1,959,000	6.5	25	28,000	387,000	1,551,000
MO	2,195,000	5.0	30	73,000	497,000	1,624,000
NC	2,460,000	7.9	23	329,000	87,000	2,044,000
OK	1,515,000	3.4	39	153,000	791,000	571,000
SC	1,043,000	5.4	28	100,000	149,000	794,000
TN	1,352,000	5.1	27	79,000	181,000	1,092,000
TX	4,280,000	2.6	37	1,484,000	945,000	2,991,000
VA	2,507,000	9.9	18	273,000	132,000	2,102,000
Total or AVER. %	32,679,000	5.11%	Average rank is 27.1 in a range of 1 to 50	4,914,000 (about 15% of all Federal land)	4,080,000 (about 12% of Federal land)	23,811,000 (about 72% of all Federal land)

Source: http://www.nrcm.org/documents/publiclandownership.pdf

1. Potential Land Management Partners -- Land Trusts. Land trusts are a growing force in protection of lands and water habitats for imperiled species. A recent census by the Land Trust Alliance, (Land Trust Alliance, 2005) reported that 37 million acres are being conserved through conservation easements and fee purchases. The amount of land and waters protected by land trust has doubled in the last five years and the number of trusts has increased by 32% to 1,667 over that same period. While the Southeast lags behind other regions in land trusts, over 950,000 acres in the region are currently protected.

Figure 7. Protected habitat in the Ochlockonee watershed, FL.

An example is the Tall Timbers Land Conservancy (TTLC) is the largest regional land trust in both Florida and Georgia with over 70,000 acres under conservation easement. The TTLC is active in both conservation and research, with its own research facility located in Tallahassee, Florida and with projects on TER-S such as red-cockaded woodpecker and at-risk habitats such as longleaf pine forests and coastal rivers including the as Ochlockonee River. Further information and contacts can be found at: http://www.talltimbers.org/.

B. Policy-Makers. The term "policy-maker" usually infers jurisdictional and/or regulatory decision-making capabilities, as exercised by Federal, State and local government. However, for the purpose of creating conservation partnerships, regional alliances of policy-making/decision-making are more effective. Ecosystems and watershed level planning and conservation actions are effective in addressing ecosystem functions and watershed level effects of disturbance. Governmental jurisdictions cross natural boundaries and are one of the challenges of managing on a landscape scale. It is important to engage private partnerships in conservation actions in the Southeast region since relatively little lands and waters are in public ownership in this region.

Examples of regional organizations that are strong candidates for partnerships with DoD and its collaborators include:

1. Southeastern Association of Fish and Wildlife Agencies. The Southeastern Association of Fish and Wildlife Agencies (SEAFWA) is an organization whose members are the state agencies with primary responsibility for management and protection of the fish and wildlife resources in 16 southeastern states. SEAFWA is the regional affiliate of the Association of Fish and Wildlife Agencies (AFWA). SEAFWA and AFWA provide a forum for addressing regional conservation issues and also a source of grants and other forms of support for conservation actions and research. For example, AFWA is leading a national effort to coordinate State Wildlife Action Plans. These plans address, on a state-by-state basis, priority species and habitats in both aquatic and terrestrial environments. Detailed information on State Wildlife Action Plans can be found at the Teaming with Wildlife website, http://www.wildlifeactionplans.org/. Contact information for SEAFWA on the web is: http://www.seafwa.org/contact.htm.

2. Southeast Aquatic Resources Partnership (SARP) – A Crossroad for Cooperation in the Southeast. SARP is a chartered organization of southeastern State and Federal agencies that is focused on cooperation to conserve and enhance freshwater and marine aquatic habitats of the southeast. Among its issue areas are imperiled fish and aquatic species recovery, aquatic habitat conservation and interjurisdictional fisheries. SARP has responsibility for developing the Southeast Region Aquatic Habitat Plan, the first regional component of the National Fish Habitat Initiative. As a 503(c) organization it has received over $700,000 in grants to implement aquatic habitat planning and habitat assessment in the Southeast. SARP is also conducting the regional coordination of State Wildlife Action Plans.

In cooperation with The Nature Conservancy, SARP has already developed detailed conservation plans for four watersheds: The Roanoke River, (NC-VA), Altamaha River (central and coastal GA), Pascagoula River (coastal MS) and Duck River (central TN). The Duck River, (pictured left) is home to 97 species of fish and 33 species of freshwater mussels (Master et al, 1998). SARP can be a key partner in decision making for imperiled species, development of conservation planning, and coordination with its own membership and partner organizations.

C. The Research Community.

Conservation research organizations that have a regional base are primarily Federal. Department/Agencies with significant and ongoing research activities the conservation of aquatic resources in the Southeast includes:

1. Department of the Interior: The U.S. Geological Survey is the principal research agency for DOI, however research and monitoring is conducted in cooperation with and by the Fish and Wildlife Service, National Park Service and other DOI agencies.

2. Department of Agriculture: The USDA Forest Service, Southern Region, conducts extensive research on freshwater ecosystems and management of freshwater systems. The Agricultural Research Service has a broad array of research on agriculture and effects of agricultural practices on aquatic ecosystems.

3. Department of Commerce. NOAA and the National Marine Fisheries Service have a significant research presence in the Southeast and are essential partners in marine, coastal, estuarine and watershed-based research and monitoring. Two fisheries commissions, the Atlantic States Marine Fisheries Commission and the Gulf States Marine Fisheries Commission, cover the southeastern region and have extensive research programs focused on commercial fisheries. The National Marine Sanctuaries Program has a research program directed at the preservation of imperiled marine species and habitats and four marine sanctuaries in the Southeast. Additional information on marine sanctuary research can be found on the web at http://sanctuaries.noaa.gov/science/welcome.html. Finally, NOAA and DOI share responsible for research, monitoring and other activities on marine mammals under the Marine Mammal Protection Act (MMPA) and on sea turtles under the Endangered Species Act. USGS has specific responsibility for West Indian manatees under the Act and a long-standing research program is being conducted by the USGS Florida Integrated Science Center.

4. U.S. Environmental Protection Agency. USEPA conducts aquatic research and monitoring principally associated with its responsibilities under the Clean Water Act. EPA, along with NOAA, USDA and USGS have an established research and monitoring plan entitled Coastal Water Action Plan: Coastal Research and Monitoring Strategy which can be located on the web at: http://www.epa.gov/owow/oceans/nccr/H2Ofin.pdf. In addition, EPA supports and coordinates the Gulf of Mexico Program, a regional partnership, cooperative conservation and research effort that includes 18 different Federal agencies, multiple state agencies as well as numerous public and private organizations. Finally, the National Estuaries Program includes a research component that helps unify a watershed approach at the interface of fresh and marine environments.

5. Army Corps of Engineers. The primary research center for the (U.S. Army Corps of Engineers (USACE) in the Southeast is the U.S. Army Engineer Research and Development Center (ERDC) Coastal and Hydraulics, Geotechnical and Structures, Environmental, and Information Technology Laboratories in Vicksburg, Mississippi. Among its research roles is addressing the Corps of Engineers civil works mission, as well as those for other federal agencies, state and municipal authorities. Technical areas addressed by the ERDC-Vicksburg include extensive research on wetlands, wetland mitigation, remediation and restoration; land planning, stewardship and management; threatened and endangered species; and cultural resources. The ERDC also houses expertise and resources regarding water resources such infrastructure, environmental assessment, flood control and storm damage reduction. The ERDC Web site is located at www.erdc.usace.army.mil.

6. Public/Private Research: Universities and non-government organizations such as The Nature Conservancy are involved in conservation biology research and monitoring activities in the Southeast. Examples of region-wide resources for aquatic research include:

- **The Fish and Wildlife Cooperative Research Units (CRUs).** The Fish and Wildlife Cooperative Research Program is a collaborative relationship between States, universities, the Federal government. There are forty state units in the program that are jointly supported by the US Geological Survey, host universities, State Natural Resource Agencies, Wildlife Management

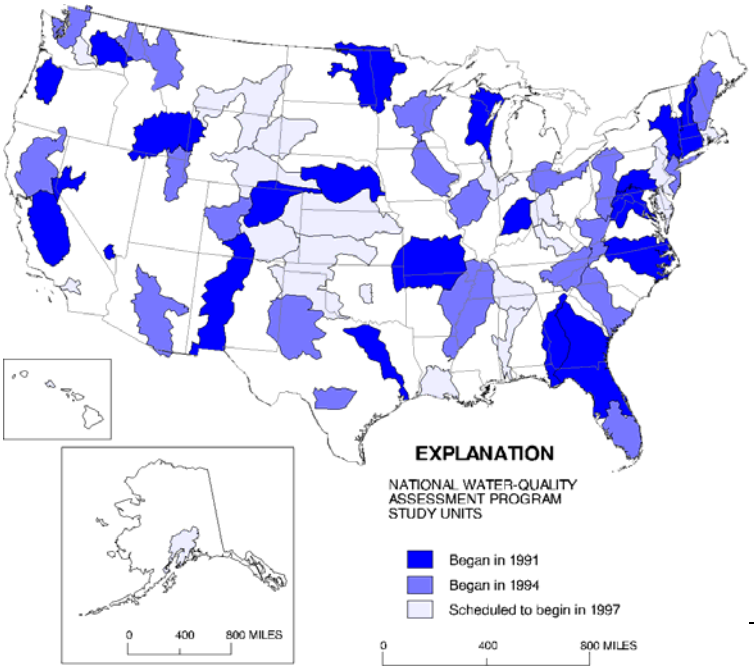
Institute, and the U.S. Fish and Wildlife Service. CRUs scientists have joint appointments with the land grant universities where they are located and with the federal government (USGS). There are CRU units in all the Southeastern states except Kentucky. For example, the Virginia Cooperative Fish and Wildlife Research Unit has a focus on the geographical ecology of freshwater fishes, conservation of aquatic ecosystems, use of biotic communities to assess environmental quality, biology and conservation of freshwater mussels and restoration and recovery of aquatic ecosystems. Contact information on resources available through individual Cooperative Research Units is available on the web at http://www.coopunits.org/cooptor/coopunits.html.

- **The Southeastern Universities Research Association (SURA)** is a consortium of over sixty universities across the Southeast. SURA is an umbrella organization for research in multiple disciplines, one of them being coastal science. SURA's coastal research program focus on coastal monitoring and may be a valuable source of oceanographic data to be applied to TER-S research and monitoring. Contact information is available at: http://www.sura.org/home/index.html.

D. Monitoring

The effectiveness of conservation activities for TER-S and habitats and the value of research to support conservation of imperiled resources require science-based monitoring using standard or comparable methods. Monitoring is the component of the adaptive management model that most frequently is the weak link. In many cases, monitoring is conducted on individual species, habitats or specific conservation projects, however this information is often not effectively shared. National and regional networks for monitoring are needed to meet conservation goals. National and Regional monitoring networks that include aquatic resources include:

1. The National Resources Monitoring Partnership. The Natural Resource Monitoring Partnership is a collaborative effort by the natural resource management community to improve monitoring efforts in order to support effective evaluation and decision-making. The focus of this partnership is sharing of standard methodologies for monitoring as a clearing house for monitoring data, rather than collection of monitoring data itself. Current participants include State, Federal, and Canadian natural resource management agencies, nongovernmental organizations, and academic institutions. Partners relevant to the Southeast include U.S. Geological Survey, Association of Fish & Wildlife Agencies. U.S. Forest Service, National Park Service, Florida Fish & Wildlife Conservation Commission, Arkansas Game & Fish Commission and U.S. Fish & Wildlife Service. Details are available on the web at: http://nrmp.nbii.gov/portal/server.pt.



2. National Water Quality Assessment Program.

The USGS implemented the National Water-Quality Assessment (NAWQA) Program in 1991 to develop long-term consistent and comparable information on streams, rivers, ground water, and aquatic systems in support of national, regional, State, and local information needs and decisions related to water-quality management and policy. The NAWQA program addresses questions about the conditions of the Nation's streams, rivers

and ground water, how these conditions have changed over time and ho natural features and processes as well as human activities affected these conditions. Information is collected regarding surface- and ground-water chemistry, hydrology, land use, stream habitat, and aquatic life in parts or all 50 States using a standard design and methods of sampling analysis. Large watersheds, called Study Units, were selected for NAQWA studies and sampled and analyzed in rotation, (see diagram above). The NAWQA Program includes 14 Study Units in the Southeast and each has a large data set on the physical and biological features within the unit's boundaries. This information is used to characterize the physical and ecological features that are important to TER-S and other aquatic life.

There are many other rich sources of information on aquatic resources in the Southeast. One of the principal resources for TER-S and their habitat needs is the Natural Heritage Database, which is managed through NatureServe. The Heritage Programs and NatureServe work together to collect and share information on the distribution, occurrence, status and trends of flora, fauna and biological communities and ecosystems.

E. Information Technology and Transfer.

Figure 6 above illustrates that the major components of adaptive management – monitoring, research and resource management/decision-making – are connected by information transfer. Scientific journals, professional organizations, libraries, museums, meetings and symposia have traditionally been the major means for transferring this information among these components and remain an essential element of communication among scientists and resource managers and users. However the electronic transfer of information via the world wide web has become the primary means for transferring information in the natural resource community. Examples of organizations that are resources for information transfer include the National Biological Information Infrastructure (NBII) and NatureServe.

- **The National Biological Information Infrastructure** (NBII) is a broad, collaborative program to provide increased access to data and information on the nation's biological resources. The NBII links biological databases, information products, and analytical tools maintained by NBII partners and other contributors in government agencies, academic institutions, non-government organizations, and private industry. NBII partners and collaborators also work on new standards, tools, and technologies that make it easier to find, integrate, and apply biological resources information. NBII has specific topic areas on Threatened and Endangered Species, Fish and Wildlife Focal Bird Species, River Restoration and the Southern Appalachians. NBII is not only a source of information, but an opportunity to exchange information as well. The portal to NBII is located at www.nbii.gov.
- **NatureServe.** NatureServe is an international network of natural heritage programs or conservation data centers that includes all the 50 States as well as other centers in other nations. NatureServe and its member organizations collect and manage detailed local information on plants, animals, and ecosystems and also have developed standard methods for collecting and serving information on biological resources. NatureServe has a database of information on the distribution, occurrence, habitat requirements, status and trends for thousands of species collected for over 30 years either directly by Heritage scientists or from verifiable sources such as museum collections. NatureServe uses a standardized software package to collect and update species information annually from Heritage Programs and this information is incorporated to a free online service called NatureServe Explorer. NatureServe information is the information resource most widely used to track the status of TER-S in the Southeast. NatureServe is a potentially important partner in successful conservation management in the Southeast. Access to NatureServe Explorer is located at http://www.natureserve.org/explorer/, or contact the Southeast Regional Coordinator for NatureServe, Milo Pyne, at milo_pyne@natureserve.org.

VIII. Conclusions

The Southeastern United States has the greatest freshwater aquatic biodiversity of any region in the nation. Many of these species are threatened and current trends indicate that threats from habitat loss, hydrological modifications, increased demands for water and the ecosystem services they provide and climate change will grow. An ecosystem/watershed approach that involves multiple partners from public and private organizations is needed to achieve conservation goals to protect these resources. Research and monitoring is an essential component of a conservation strategy to protect and restore aquatic biodiversity in the Southeast. Scientific research is the basis for identifying priority species, geographic locations and ecosystem services needed to conserve Southeast threatened, endangered and at-risk species.

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Importance of Connectivity at Multiple Scales in Times of Rapid Climate Change

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Abstract: Institutional programs that explicitly call for strategic analyses of environmental research and management are compelled to consider connectivity. There are many types of 'connectivity', of course, and several are now subsumed under the rubric of Ecosystem Management (e.g., interdisciplinary or trophic connectivity). As a nation of laws, most agencies accept obligations attendant to Threatened, Endangered and 'at-Risk' Species (TER-S) and '*the ecosystems that support them*'. But spatial connections within landscape systems (e.g., sandhills with embedded ephemeral ponds) and connections between and among adjacent ecosystem types (e.g., longleaf pine next to bottomland hardwood forests) are critical to many TER-S populations for primal Evolutionary/ecological reasons. Physical connectivity between military installations and other large conservation areas such as National Forests are increasingly called for as populations of TER-S are first fragmented and ultimately isolated in habitat ghettos that can not sustain them. This paper reviews principal scientific concepts of relevance to this topic and offers questions to distinguish between what is known and what is not. For purposes of organization we cover the specific topics of 1) Connectivity Conservation to Combat Fragmentation and Isolation; 2) Ecology in Relation to Size of Area; 3) Spatial Connections and Functional Ecological Connectivity; 4) Role of Temporal and Spatial Scales; 5) Patch (Habitat) Size and Quality Relative to Surroundings; and 6) Corridors of Life and Paths Across the Earth.

1. Connectivity Conservation to Combat Fragmentation and Isolation.

As the dire consequences of habitat and population fragmentation become increasingly well known there is also a new emphasis placed on *connectivity conservation*. Biogeographers and paleontologists have long established patterns and principles that derive from the breakup of former continents, reunion of continental connections because of plate tectonics or even the importance of the waxing and waning land bridges and coastal corridors due to sea level rise and fall. For at least 150 years propositions articulated by Wallace and Darwin have been reviewed and revised. Although this paper emphasizes the role of spatial connections and connectivity for addressing conservation and management of TER-S, the U.S.'s leadership of innovative conservation programming has been only partially tied to science in general or conservation science in particular. For example, two of the most sterling examples of empirical natural science (Wallace and Darwin on Biogeography and Evolution) date back to the 1850s. This is just how long U.S. leadership with federal conservation programming has existed. Yet, there has been virtually no commingling of the two pre-eminent movements? The fact that conservation is better rooted in politics and social science than natural science causes no small amount of consternation among hard-core natural scientists.

And so, in terms of the larger (and more pressing?) issues of regional biodiversity collapse as well as the advancement of conservation science we advocate a more top-down, geography and regional ecology approach. Saving species is a long established and undisputed tradition. But the establishment of a new generation of principles based in science and demonstration is now called for. Will not humanity as well as longer-term biodiversity conservation on earth better be served by linking species conservation with advancement of conservation science?

To the extent that a regional or landscape ecology approach is defendable within constraints of the law (governing TER-S), much greater clarity on two connectivity issues is called for:

- When and to what degree do physical connections across the landscape translate into functional connectivity for organisms of some or ALL species in question? How best can we document and apply the concept of biological or ecological legacy to tighten the linkage between physical connections of conservation units and functional connectivity for species?

- When and to what degree do physical connections across the landscape serve major ecological processes such as energy flow, nutrient cycles, pollination, predation or even modification of perturbations at the landscape scale (as opposed to movement of a few species)?

Related connectivity conservation issues demanding attention are:

- To what degree can an interconnected archipelago of smaller conservation areas substitute for large areas?

- To what degree do stepping stone 'islands' (e.g., migratory bird refuges) suffice for functional connectivity for resident species and/or ecology? Average mobility of resident TER-S is known from telemetry studies but probabilities of organisms transcend (or surviving in) disrupted landscapes is not established.

- Under what conditions can a non-connected archipelago of quality patches or conservation areas offset the requirements for large conservation areas and/or high-quality landscape matrix?

- To what degree can we cause regional planners (who traditionally focus on the built environment) to accept the need for interconnected native landscape in the context of sustainable development initiatives?

- To what degree can/will connectivity restoration and/or reclamation be accomplished?

2. ECOLOGY IN RELATION TO SIZE OF AREA

A strong positive relation exists between the size of habitat areas or regions of forest and the number of species they support. Although this relation is robust and it commonly applies to related variables such as population sizes, it clearly does not apply to all measures of diversity or the number of recognized TER-S resident in an area. Most importantly, a focus on the species-area relation does not address important ecosystem services or ecology and human societal functions that derive from, and must conform to, regional landscape configuration.

A primary element of the now well-established area-effects rule derives from the concept of drawing a 'sample' from a larger population, whether it be by natural geological process or by human endeavor. Importantly, known area relations for ecology greatly predate both conservation and the widely assailed Theory of Island Biogeography. Although many structural patterns and principles of area relations are known, only now are we documenting relations between area and fundamental ecological processes such as competition, predation, pollination, nutrient cycling etc. The extent to which our conservation programming for TER-S is hinged to ecological science is highly dependent upon accelerated research and demonstration aimed at relations between area and ecological process.

Even though no eminent conservation biologist would argue that a small patch or conservation area is superior to a larger one, the conditions under which a dispersed set of smaller areas can or should be

substituted for larger areas is debatable. For the more sedentary species (of very low mobility/vagility) the species genome and perhaps the species itself might best be conserved by strategically located small habitats. We do not know the degree to which connectivity adds to or subtracts from population persistence for species of low mobility such as the gopher tortoise. As detailed below, some organisms with very small body size (e.g., Monarch Butterfly) require vast areas of regional scale for life-cycle completion and species survival because of a heretofore unexplained evolutionary quirk in this time of receding glaciers.

The designation and prioritization of diversity 'hotspots' has held considerable sway in recent decades. Closer research reveals, however, that hotspots as defined by only a few taxa such as birds and mammals simply do not apply to the wide gamut of biodiversity ranging from micro-organisms and plants to wider-ranging species. Again, the size relations that pertain to the number of resident TER-S and/or the wider spectra of taxonomic diversity, and the broad sweep of ecological processes are not well known.

Almost by definition, weedy species, human commensals (e.g., rats and house mice) and invasive exotic species predominate in disturbed ecological communities. These common, often problematic, species also predominate on roadsides, in conjunction with dikes, dams, levees, industrial sites and even in the edges of conservation patches or fragments within our larger conservation areas. Habitat fragmentation is widely disclaimed as the pre-eminent threat to biodiversity conservation; a principal causal factor being negative edge effects around perimeters and/or areas subdivided by linear human infrastructure (e.g., roads or power lines). Weedy and/or invasive species show little regard for size of area as long as it is more or less fragmented. And so, unlike the robust species – area relation known across ecology and biogeography, weedy species not only violate the pattern, the pattern for them is almost the exact opposite. No other group of organisms is so favored by creation of small and/or highly-human-impacted conservation areas. Perhaps the single greatest criticism of traditional disciplines such as forestry and wildlife management as they pertain to biodiversity conservation hinges on their embrace of fragmentation and preferential management for common species at the expense of the rare. Admonitions that 21st century biodiversity conservation objectives should 'keep common species common' must be treated with great skepticism.

The Founder Effect is one of the most important biodiversity conservation principles to underlie the emergence of biodiversity conservation science. This principle hinges largely on the same 'sampling' phenomenon as described above for why species richness and population size generally increase along with the size of the conservation unit. Just as any sample of species drawn from a larger universe generally doesn't encompass the full gamut of species, neither does a 'sample' of individuals encompass the full diversity of individuals. Even more importantly, the genetic diversity contained within the organisms of the sample rarely encompasses the full gamut of genomic diversity represented by the species. The founder effect almost assures that any small population of a species will not capture the genetic diversity of the genome, and different subpopulations drawn from a species' range will have measurably different genetic compositions. This pattern is amplified for species (such as longleaf pine or red-cockaded woodpeckers) that had large regional distributions. Almost all of the contributors to genetic diversity (e.g., alleles, heterozygosity, etc.) increase as a function of population size, hence larger areas that support larger populations and encompass larger proportions of the genome are considered to be better for the conservation of biological diversity. We are not sufficiently knowledgeable about the magnitude of contribution or importance played by intermittent or infrequent outside additions to the genome of isolated subpopulations. Ecologists among us will want to clarify what this manifest structural pattern has to do with ecological function.

3. SPATIAL CONNECTIONS AND FUNCTIONAL ECOLOGICAL CONNECTIVITY

Regional and landscape-level ecological function of the Southeastern Coastal Plain (SECP) is tightly tied to ambient sea level. The relation between sea level and underlying ground water level in the highly karst topography is tight but not well mapped? It is but one causal mechanism. Major fluctuation of sea level is caused by the presence or lack of continental glaciers. During glacial peaks sea level has fallen over 300 feet below what it is today. The attendant drop in groundwater beneath the surface of the coastal plain greatly influenced occurrence and nature of 'perched' regional wetlands (e.g., Okefenokee and Okeechobee) and backwaters (e.g., Pontchartrain). It has greatly impacted xerophytic communities such as scrub and sandhills as well. At times of minimal ice coverage the Atlantic Ocean & Gulf of Mexico covered all of the coastal plain below the fall line. In other words, the coastal plain as we know it is simply the higher elevation fringe of continental shelf that is not presently covered by salt water.

In times of sea level low (only 18,000 years ago) both the east-west Gulf Coastal Corridor as well as the north-south Atlantic Coastal Corridor were wide and functional as conduits for species interchange. Did ecological processes move back and forth on these broad corridors as well? When sea level was low the Gulf of Mexico was only about 60% as large as at present and putative coastal cities such as Tampa and Cancun were neighbors. Effects of a more distant seawater heat sink meant predominant weather systems were quite different, perhaps even locations of jet streams were different. Not only were Pleistocene temperatures different, seasonality was amplified by presence of the glacier. Almost certainly, the future will be hotter, drier, and less seasonal. Natural reproduction, and even planting success, of longleaf pine will be more problematic (is it true that LLP has only fared well over its present range for 5 millennia?). Occurrence and distribution of natural lightning strikes were surely different and, along with altered surface and ground water conditions, the frequency and severity of fires would have created greatly different species distributions as well as operative ecological functions. Glaciation, sea level rise, opening and closing of the coastal corridors and altered climate and weather had very much to do with connectivity of ecosystems and processes across the landscape and the region. Almost nothing in the present, especially the human-impacted, distribution and ecology of species is reflective of the paleo-ecological history. Presently disjunct species and subspecies (e.g., Acacias, Great Plains grasses, burrowing owls, wood rats and scrub jays) were almost certainly more interconnected during those times. TER-S conservationists now suffer the challenges associated with these increasingly highly fragmented conditions.

Humans did not yet occupy the Southeastern Coastal Plain until 18,000 years ago, hence their influence on ecological structure and function was not yet operative. Just as the occurrence of fins, feathers and fur manifest the evolutionary history of vertebrates so too does the location of drainages, depressions (cypress domes, Carolina bays) sinks, springs and ephemeral ponds reflect our post-glacial ecological history. Ecology reflects what nature deals up with respect to surface hydrology, groundwater, weather and fire. Endemic species (e.g., Sand pine) and ecological communities (e.g., scrub) no doubt had significantly different distributional patterns and levels of connectivity. We can only surmise how, and to what degree, the spatially-explicit ecological processes, as opposed to species and community distributions, have been altered.

Since colonization of the SECP by humans 10,000 (some argue longer) years ago and occupation by Euro-man for almost a half-millennium no natural systems function remains the same. High-impact introductions such as diseases that devastated Amerindian populations had similar, if less dramatic, effects on plant and animal communities (e.g., rabies?). Free-ranging hogs no doubt affected longleaf pine regeneration just as it did apex predators such as wolves, panthers and alligators. But effects on the two guilds were opposite. But the fact that we can never restore nor return to natural ecological functions as occurred prior to Euro-man does not negate the notion that we should use native flora and fauna as our metric or standard against which we measure our conservation objectives and performance. The fact that

fires and floods 'roamed freely' across a larger and more intact landscape just as did wolves and bears is an important fact if not a tenable restoration objective (e.g. bear's role in plant distributions).

4. ROLE OF TEMPORAL AND SPATIAL SCALES

Ecologists and conservationists alike are admonished to 'focus on the relevant temporal and spatial scale'. With respect to TER-S this must be done on the basis of natural history and basic biological principles. Is it not obvious that life cycle time is the single best species-specific trait for assessing the relevant temporal scale? Is it not obvious that average levels of mobility (vagility) for individuals, when coupled with distributional range of the species or population (e.g., FL black bear), define the relevant spatial scales? A large and robust body of empirical fact interrelates the characteristics of size, cycle and movement. And, to the extent that a species-by-species approach to resident TER-S (mostly animals considered in list), ecology and conservation is called for then the following examples pertain.
To my knowledge, no one has yet compiled and plotted the data for TER-S of the Southeast that planners and policy administrators might find very useful. Very strong correlations exist between:

1) Average body size and longevity of individuals.

2) Home range size and average movement of individuals is correlated with body size; larger animals move farther and require more space to live than do species of smaller body size.

3) Average home range size increases with latitude such that average movement of individuals in south Florida will generally be less than their conspecifics occurring in VA.

4) The greater movement of individuals within a species (with latitude) means that species occurring at higher latitudes have greater species ranges than do tropical and subtropical species of similar ecologies.

5) Except for species that can depend upon almost-inert life stages (spores, or long-lived propagules) life cycles are faster for smaller species than for larger. For optimal habitat a tight inverse relation between latitude and altitude exists such that a species at higher altitude in low latitudes (e.g. over-wintering monarch butterflies) will occur at progressively lower altitudes as latitudes increases.

6) Within a given size class apex predators (large; strict carnivores) require much more space than do species of lower trophic guilds such as frugivores, granivores, or herbivores.

7) Cold blooded (exothermic) organisms generally move much less than do warm-blooded organisms of similar size and trophic level.

8) Hibernation is more common and more strongly expressed at higher latitudes (even within species such as black bear) than at lower latitudes or altitudes. This is an evolutionary alternative to seasonal migration and effectively shrinks the necessary annual home range size.

Although these generalities are all valid in-and-of-themselves, equally obvious exceptions occur. Both gopher tortoises and longleaf pine are medium sized but have small home ranges in spite of great longevity (relative to analogous species). And so, a cold-blooded (exothermic) herbivore with modest home range and dispersal characteristics (tortoise) has evolved an extraordinary longevity comparable to elephants in spite of its small size. Conversely, the FL panther, a quite large warm-blooded top carnivore with short interval to reproduction has the same 100-day gestation period and (under optimal conditions) can have the same short breeding interval as a small domestic lap cat! Whether assessing the role of

connectivity in the landscape or the dimensions of highway underpasses or greenways networks these guidelines pertain to the 'temporal-spatial' scale that is relevant to TER-S.

The temporal-spatial scales of ecological processes and/or disturbance events are arguably more important to advancement of conservation science. Old growth patches of prime habitat for a TER-S, for example, can (and will?) easily be extinguished by a singe disturbance event such as a wildfire, tornado strike or tropical storm ushering some synchronized combination of precipitation, flood and wind. Useful data compilations as well as graphical generalities pertaining to the relation between spatial scale and temporal frequency or return interval of disturbance events are published but I am not aware that a SE Region synthesis of critical events has been plotted against time and space dimensions as they pertain to different ecosystem types. Such a plot is increasingly called for as the probability of unforeseen, and increasingly unmanageable, disturbance events is apparently increasing at the same time that attention to national security is paramount. Although the likelihood of catastrophic events is perfectly predictable, the coordinates in time and space are not. If the era of accelerated climate change portends any salient thing it is surely the role of predictable dramatic, but not specifiable, disturbance events that easily can extinguish one or more TER-S populations (e.g., recent extirpation of migrant FL whooping cranes). Our challenge is exacerbated by sequestration of non-viable subpopulations in isolated ghettos as defined by ecology and history. Fire ecologists and managers appear to be in the forefront of this most important conservation science topic. The degree to which regional or landscape connections pertain to these issues is not clear.

5. PATCH (HABITAT) SIZE AND QUALITY RELATIVE TO SURROUNDINGS

Traditional biodiversity disciplines of fisheries, forestry, range and wildlife know very much about the effects of habitat quality as it affects production functions of their respective commodities. But most of this knowledge is based on reference to either pristine conditions (which they generally better) or more hardcore science disciplines such as animal science, agronomy or horticulture. If and when faced with a totally empty void (or universe) of species occurrence and/or proximity with natural system referents (as source pools) the knowledge base almost evaporates! Our present challenge strikes me as more akin to the second situation than to the first; existing military installations are increasingly isolated in voids of nature that are dominated by human development. For better or worse, our banks of empirical knowledge are almost totally drawn from traditional disciplines.

Habitat managers are often good at enhancing patches of habitat; not so good at assessing geographic and/or regional planning aspects of their endeavors. Restoration and reclamation disciplines are young and greatly undervalued. But for purposes here we must consider some sort of trade-off analysis between the merits of within-patch enhancement activities (management of habitat on installations) as opposed to those that are rarely under our control, if influence, that lie outside the installations and are likely much more important than we realize. At the risk of oversimplifying lets envision this as a trade-off analysis plotted on a two dimensional graph where 'outside-the-area' [matrix] effects define the X-axis and 'within-area effects' define the Y-axis. For very large areas (e.g., Eglin AFB?) evidence suggests a greater role for within-area effects for most species (not to include wolves, panthers, or perhaps even black bears). But now it gets tough, what to say about quite small and quite isolated areas such as McDill and/or Patrick AFB? One obvious retort is that managers must focus on the within-area issues simply because the surrounding matrix appears hopelessly lost and/or out of control. Usher in the landscape ecologists, regional planner and reclamation specialists because this is their day of reckoning!

My offering from 35 years observation in the rapid-growth Sunbelt region tempered by Florida's now equally-tenured conservation land (CL) acquisition programs suggests, at least, the following. Rarely will CL acquisition proposals succeed without at least tacit approval of 'growthers' and developers; why, because there is really big money to be made by owners and investors in development opportunities in the land and water matrix immediately surrounding the park or preserve. This, of course, is not unlike

Interstate and major Intrastate highway (and access ramp) sitings that provide public-paid access to choice private development opportunity. I envision that base-siting decisions are similarly influenced and provide a most wonderful opportunity for conservationists (e.g. transfer of USN flight training to Whiting Field, FL?). CL acquisitions are never enough (adequate size or configuration) for exactly the same reason that public buildings are almost always built to be inadequate for predicted growth. If my observation is correct, traditional paradigms for CL acquisition are guaranteed to fail with respect to broad-spectrum biodiversity and ecological-function conservation.

The pattern is this. Too little (or much too inadequate) land is purchased too late because obsolete, but dominant, models prevail in rank-and-file agencies as well as traditional professions and political-influence peddling groups. An important (?) CL isolate is defined geographically and legally by systems ordained by the likes of Thomas Jefferson based on a land tenure system guaranteed to ensure maximum fragmentation. Simple geometric statistics ordain that smaller areas are favored, not because conservation science dictates but because there is more prime and developable perimeter for per acre of purchase than is the case for large areas. It is not cynical to observe that sand-box CL purchases with public funds rewards NIMBY's. The obvious, if blatant, exception is linear river-front and ocean-front property where purchase of long stretches are argued for (as long as they are narrow) because development interests envision almost total access control to public-domain resources (marine turtles here?). Property Tax Assessors are elected officials and they are not naïve to how purchase of a public facility can so greatly increase the county's tax-base. And so, use modest public money to remove some land from tax roles in order to greatly enhance value of the surrounding taxable land base. It would be analytically instructive to compare assessed property value increases and totals in blocks where public funds were spent for CL acquisition and compare them to comparable growth and development devoid of embedded conservation lands.

With the help of forward-thinking developers, we spend your tax dollars to buy CL land that greatly increases the development value of surrounding matrix. Out-dated conservationists pat each other's backs over limited (if inadequate) success that is sure to cause sequestration and isolation of the CL acquisition. Thirty-five years after the CL acquisition we drive to or around these alleged biodiversity conservation (is)lands now in a matrix of upscale suburban development and lament that no viable populations of TER-S still remain because of shortsightedness and a vain hope that the within-area management so deeply ensconced in traditional disciplines will work. I greatly fear that it can not.

Science can only document the past and present. Can we trust it as the basis for predicting the future, even in instances of great moment such as asteroids, earthquakes, tsunamis, or global warming? Are most of us scientists our own worst enemies? Most all of the biodiversity conservation science I am aware of suggests that habitat matrix trends and conditions are very, and increasingly, important relative to whatever we can do within the areas. It seems this is certainly true for regional and landscape ecology functions such as hydrology, patch dynamics, disturbance regimes native community integrity and change and conservation of large, wide-ranging resident and/or migrant species.

Professionals in traditional disciplines are well trained and competent to keep common species common. But even this will challenge their abilities because of increasing limitations on traditional methods such as fuel load reduction, prescribed burning, hunting or reliance on traditional agriculture (e.g. Northern Bobwhite). New, or greatly transformed, disciplines committed to wide-spectrum biodiversity conservation science should be encouraged and embraced.

6. CORRIDORS OF LIFE AND PATHS ACROSS THE EARTH

As a phrase, 'corridors of life' has traditionally been used to portray evolutionary trajectory, it has played little if any role in prediction. This must now change as we embrace biodiversity conservation science and

connectivity conservation. For example, one important recent study concluded that "Using a large-scale replicated experiment, we showed that habitat patches connected by corridors retain more native plant species than do isolated patches, and that this difference increased over time, and that corridors do not promote invasion by exotic species." (Damschen et al. 2006, Science 133:1284-1286). In the new millennium, the corridors of life metaphor will translate quite literally to biodiversity conservation.

The phrase 'paths across the earth' has been invoked to portray and define movement and migration routes of animals (we know plants move, we do not know they 'migrate'). This phrase must now be customized to address 21st century challenges before us. Wildlife corridors for land-based species are routinely implemented now by progressive NGOs and some forward-thinking agencies. Although new and promising. this technology (including underpasses and overpasses) is most often a micro-scale and last-gasp salvage-type operation. This is partly because there is simply no single temporal-spatial scale that can meet all the challenges presently obvious. By this I mean eco-passages that are essential for amphibians are rarely relevant to larger mammals or birds. Corridors that are achievable for large carnivores have not been (heretofore) sensitive to spatially explicit horizontal ecological functions such as fires and floods. Statewide greenways networks offer the single best option for integrating conservation science into regional planning. But it must be accepted that these greenways (even ecological ones) are usually for people or else they will not be embraced by decision makers. Even the best of the greenway networks I'm aware of will be but modestly relevant to most TER-S. Over 15 years ago the following guidelines were published (Harris and Scheck 1991); I know of no similar or modified standards:

- When designed for movement of individual animals, when much is known about their behavior and when the corridor is to function in terms of weeks or months then width dimensions can be measured in meters.
- When the movement of a species is being considered, when much is known about its biology and when the corridor is expected to function in terms of years then the corridor width can be measured in tens-of- meters (10-100).
- When the movement of entire assemblages of species is being considered and/or when little is known of the biology of the species involved and/or the faunal dispersal corridor is expected to function over decades then the appropriate width must be measured in kilometers (> 1000m).

The issue of biological (or ecological) legacy strikes me as a single great void in our southeast region science and application. Surely, the 19th century massive tonnages of large-dimension lightwood logs (resin soaked dead wood) littering the landscape played major ecological roles just as evolution of the resin itself still does. This has not been studied. But for purposes here let's consider linear scent and sight or related structural legacies coursing the landscape. Linear tree fall gaps pursuant to domino felling are obvious even to humans. A good tracking hound can detect and follow a scent trail left scores of hours before and even detect which direction the subject (prey?) item was moving. We know virtually nothing about the conservation applications of such linear biological legacies. With some exception (e.g. Red-cockaded woodpeckers?) it is dispersal of juvenile males that facilitate population expansion and colonization of new areas. This is not because they can reproduce upon colonization, clearly they can not. But from a population viability standpoint this cohort is genetically least valuable, and most expendable. Yet, how and why does the dispersal of juvenile males provide value to the stay-at-home reproductive females if not by linear biological legacy? We could easily research, demonstrate and extend this knowledge by experiment with highly olfactory creatures such as black bears on the central FL ridge south of Avon Park. Do not birds achieve similar dispersal results by use of auditory and visual displays as opposed to olfactory? Ecologists are invited to suggest how ecological functions (other than seed dispersal or pollination) 'moves' across the landscape.

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