Land Corridors in the Southeast USA: Connectivity to Protect Biodiversity and Ecosystem Services


Thomas S. Hoctor
University of Florida
GeoPlan Center
Gainesville, FL 32611

William L. Allen III
The Conservation Fund, Director of Strategic Conservation
410 Market Street
Suite 360
Chapel Hill, NC 27516
Phone: (919) 967-2223 ext 124
Email: wallen@conservationfund.org
http://www.conservationfund.org/strategic_conservation

Margaret H. Carr
University of Florida
GeoPlan Center
Gainesville, FL 32611

Paul D. Zwick
University of Florida
GeoPlan Center
Gainesville, FL 32611

Ellen Huntley
The Conservation Trust for Florida, Inc.
P.O. Box 134
Micanopy, FL 32667

Daniel J. Smith
University of Central Florida
Department of Biology
4000 Central Florida Blvd.
Orlando, FL 32816-2368

David S. Maehr
University of Kentucky
Department of Forestry
205 Cooper Bldg.
Lexington, KY 40546-0073

Ramesh Buch
Alachua County Environmental Protection Department
201 SE 2 Avenue
Suite 20
Gainesville, FL 32601

Richard Hilsenbeck
The Florida Chapter of The Nature Conservancy
625 North Adams Street
Tallahassee, FL 32301
INTRODUCTION

Protection of biodiversity and ecosystem services is increasingly considered an essential component of national, regional, state, and local planning. Research is expanding and being refined on issues such as habitat fragmentation and ecosystem integrity, and this is heightening awareness of the links between human activities and ecosystem function. Regional conservation planning is an essential approach for addressing these issues to promote sustainable and healthy natural and human communities. Large-scale research and planning is needed to determine how landscape patterns and processes control ecosystem function and to minimize land use conflict (Harris 1984; Noss and Cooperrider 1994; Forman 1995; Turner et al. 1995; Harris et al. 1996b; Soulé and Terborgh 1999; Poiani et al. 2000; Groves 2003; Hoctor 2003). One term used to promote this approach is “green infrastructure” described as networks of natural lands, working landscapes and other open spaces that conserve ecosystem values and functions and provide associated benefits to human populations (Benedict and McMahon 2006).

In this article, "land corridors" are discussed as an integral element of regional conservation planning. Land corridors most commonly refer to landscape linkages or conservation corridors that are designed to combat impacts of habitat fragmentation (Wilcox and Murphy 1985; Harris and Scheck 1991; Noss 1993; Bennett 1999; Anderson and Jenkins 2006). Landscape linkages and conservation corridors, when designed and managed properly, facilitate connectivity, which maintains listed and other focal species populations (Lambeck 1997) and ecosystem services (Costanza et al. 1997; Daily 1997). Interconnected systems of conservation lands are often called “ecological networks” (Hoctor et al. 2000; Noss 2003; Jongman and Pungetti 2004; Clevenger and Wierzchowski 2006). Data, tools, and planning products for designing ecological networks are increasing and will significantly enhance efforts to achieve sustainable landscapes. Various regional conservation projects in the southeastern United States focused on protecting and restoring landscape connectivity are discussed in this article.

Other corridors include built linear infrastructure for maintaining transportation and energy networks such as roads, rail lines, electrical transmission lines, and natural gas or other pipelines. Linear infrastructure development is a critical consideration for the protection of regional landscapes for biodiversity and ecosystem services. Ecological impacts of roads are well documented, and strategies for minimizing these impacts such as wildlife crossing structures are an essential part of conservation planning (Trombulak and Frissell 2000; Forman et al. 2003; Clevenger and Wierzchowski 2006). Other linear infrastructure such as transmission lines and pipelines can also negatively impact focal species and ecosystems (Hall et al. 1994). The burgeoning human population in the southeastern United States, and associated need for transportation and energy infrastructure improvements, will increase potential conflicts with ecological networks. One important trend in planning is the development of Geographic Information System (GIS) data and tools for designing transportation and energy infrastructure that avoids, minimizes, and mitigates environmental impacts.

Policies are evolving to facilitate more effective regional conservation strategies. For example, state and local governments are spending more money to acquire ecologically-sensitive lands in the face of continuing development, sprawl, and rising land prices. Recent changes in federal tax laws related to conservation easements should promote more protection of privately owned and managed lands that make very significant contributions to conservation. Growth management policies in states such as Florida are changing to address impacts of sprawl development. Global climate change is spurring new initiatives, such as carbon neutral policies, that will result in additional resources for protecting conservation lands. These and other relevant policies and programs that can facilitate regional conservation planning to protect land corridors will also be discussed.
CONSERVATION CORRIDOR AND CONNECTIVITY DEVELOPMENTS

Discussion of the implications of island biogeography theory for ecosystem conservation began in the 1970s and led to the development of conservation biology as a discipline in the 1980s (MacArthur and Wilson 1967; Wilson and Willis 1975; Soulé 1985). Island biogeography developed several predictions from empirical data about species diversity on islands affected by island size and distance from mainland sources. The theory had implications for species on continents because the rapid loss of habitat was resulting in habitat islands within a “sea” of development. Though the analogy is not perfect, the discussion about the relevance of island biogeography served as an important catalyst for increasing awareness of habitat loss and the need for more research to develop effective conservation strategies (Harris 1984; Shafer 1990; Freemuth 1991; Noss and Cooperrider 1994; Hoctor 2003). Sullivan and Shaffer (1975, p. 13) described the issue well:

If a chance process of reserve selection continues, it may produce a network . . . in which all but a few species adapted to urban life become extinct. . . . The challenge remains to integrate the existing distribution of national parks and wilderness areas with a plan that will ensure the functional integrity of the world’s ecosystems while land use for human purposes increases.

Conservation biology has expanded research on habitat fragmentation and other human impacts on biodiversity. The impacts of fragmentation and ecosystem degradation have been documented in detail and efforts are progressing to develop conservation strategies to address these impacts. There are two developments in this research that are most relevant to land corridors. First, the need to work at regional scales is made clear by the scale of habitat fragmentation and human modification of the environment combined with the requirements to successfully protect viable populations of focal species and functioning ecosystems. Second, research increasingly identifies conservation corridors and connectivity as a critical part of regional strategies for maintaining biodiversity and healthy ecosystems.

The Need for Regional Approaches for Effective Conservation

Harris (1984) and Noss (1983) discussed the need for regional scale conservation to counter habitat fragmentation and ecosystem degradation. Since then, conservation biology research has reinforced these early calls for regional approaches, and various conservation strategies and initiatives are based on these principles (Harris 1984; Noss and Cooperrider 1994; Forman 1995; Turner et al. 1995; Harris et al. 1996b; Soulé and Terborgh 1999; Poiani et al. 2000; Groves 2003; Hoctor 2003; Noss 2003; Benedict and McMahon 2006). The development of landscape ecology has reinforced these conclusions by clarifying the link between spatial patterns and ecological processes (Forman 1995). Landscape ecology stresses the importance of spatial context for controlling ecosystem processes (Harris 1984; Harris et al. 1996a), and that natural resource conservation and land use planning must consider the effects of actions within their largest spatial and temporal perspectives (Forman 1987). Regional conservation planning attempts to address these issues by conducting research and planning at sufficiently large spatial scales to account for the interactions of competing land uses. Such large-scale planning facilitates effective protection and restoration of landscapes that will conserve biological diversity and ecosystem services (Noss and Cooperrider 1994; Harris et al. 1996b; Costanza et al. 1997; Daily 1997; Daily 2000; Groves 2003; Hoctor 2003; Benedict and McMahon 2006).

For example, landscape and regional approaches are essential for managing and restoring longleaf pine (Pinus palustris) ecosystems, which are critical for biodiversity in the southeastern United States. Hoctor et al. (2006) discussed the importance of connectivity between
uplands and wetlands within longleaf pine landscapes. Furthermore, many species within longleaf pine landscapes require functional connections between different natural communities to meet their life history needs including fox squirrel (Sciurus niger), eastern indigo snake (Drymarchon corais couperi), black bear (Ursus americanus), and various ephemeral pond breeding amphibians (Weigl et al. 1989; Moler 1992; Dodd and Cade 1998; Cox and Kautz 2000; Kautz and Cox 2001; Maehr et al. 2001; Hoctor et al. 2006). A regional-scale strategy that integrates the principles and techniques of landscape ecology, conservation biology, and restoration ecology is required to restore the diversity, ecosystem function, and evolutionary significance of longleaf pine ecosystems (Hoctor et al. 2006).

**Connectivity Research Developments**

Other emerging trends for regional conservation are the green infrastructure and ecosystem services concepts. Green infrastructure emphasizes the importance of networks of natural and semi-natural lands (such as silviculture and agriculture) for providing both ecosystem services and maintaining biodiversity (Benedict and McMahon 2006). Research by Chan et al. (2006) indicates areas important for biodiversity conservation may serve as a good surrogate for identifying areas most important for protecting ecosystem services. Green infrastructure promotes the critical concept that ecosystem function, biodiversity, and the health of human communities are inextricably linked (Benedict and McMahon 2006). Together, the green infrastructure and ecosystem service concepts help communicate the importance of protecting intact natural systems and rural lands.

Noss (1992, p. 17) expressed the importance of connectivity and the protection of functionally connected reserve networks: “Connectivity is in many respects the opposite of fragmentation. A reserve system with high connectivity is one where individual reserves are functionally united into a whole that is greater than the sum of its parts.” This principle emphasizes that functionally connected conservation lands are more likely to protect species populations and ecosystem processes than a set of isolated protected areas (Noss and Harris 1986; Harris et al. 1996a; Harris et al. 1996b; Keitt et al. 1997; Noss and Daly 2006). In some landscapes and regions it may still be possible to manage the larger landscape matrix (e.g., the dominant land uses) to be compatible with protecting connectivity for various focal species and ecosystem processes. However, in most regions the level of land conversion and habitat fragmentation necessitates consideration of explicit protected corridors to facilitate connectivity (Harris et al. 1996b; Noss and Daly 2006).

A conservation corridor can be defined as any explicit spatial area designed, protected, or managed to maintain connectivity for focal species or ecological processes (Harris and Scheck 1991; Noss 1993; Bennett 1999; Hoctor 2003; Anderson and Jenkins 2006; Noss and Daly 2006). Landscape linkages are large conservation corridors containing significant areas of habitat while also facilitating connectivity between conservation areas (Harris and Scheck 1991; Noss and Daly 2006).

Corridor research is complicated by the difficulty of conducting experiments at relevant landscape and regional scales (Beier and Noss 1998). However, recent experimental research and empirical evidence bolsters the function of conservation corridors (Dunning et al. 1995; Beier and Noss 1998; Bennett 1999; Haddad et al. 2003; Damschen et al. 2006; Noss and Daly 2006). Examples include research at the Savannah River Ecology Laboratory in South Carolina and black bear in Florida.

A team of researchers from several universities have developed landscape scale, corridor experiments at the Savannah River Ecology Laboratory. Their results strongly support the role of corridors for maintaining biodiversity and facilitating functional ecological processes. Haddad et al. (2003) documented increased movement between connected habitat patches compared to isolated patches for various animal and plant species.
Damschen et al. (2006) found that habitat patches connected by corridors maintained higher native plant diversity than isolated patches, that the difference increased over time, and that corridors do not promote exotic species. Levey et al. (2005) determined that corridors facilitated seed dispersal by birds. Haddad (1999; 2000) found that, for butterflies, corridors increased dispersal frequency and distance compared to isolated patches. Haddad and Baum (1999) found that butterflies reached higher densities in patches connected by corridors versus isolated patches, which could increase pollination of butterfly-dependent plant species. Townsend and Levey (2005) also documented significantly higher pollination by bees and wasps in connected patches than in isolated patches.

Wide-ranging species are frequently the focus of connectivity and corridor research, since these species require large areas to support viable populations. Effective conservation of such species requires regional scale planning, and conservation corridors are an important consideration for maintaining functional connectivity between populations (Noss et al. 1996; Harris et al. 1996b). Empirical studies of corridor use by wide-ranging species are also complicated by scale (Beier and Noss 1998), but various studies demonstrate corridor use. Maehr (1990; 1997) showed that the Florida panther (*Puma concolor coryi*) used a riparian corridor connecting larger conservation lands in southwest Florida. Beier (1995; 1996) demonstrated corridor use by cougars (*Puma concolor*) in southern California. More recently, Dixon et al. (2006) demonstrated Florida black bear (*Ursus americanus floridanus*) dispersal between Ocala National Forest and the Okefenokee National Forest/Okefenokee Wildlife Refuge complex and the potential significance of this dispersal for maintaining genetic diversity.

Black bear and Florida panther (*Puma concolor coryi*) are the two most likely focal species in the Southeast that require large, intact regional landscapes. There are still several populations of black bear in North Carolina, South Carolina, Georgia, Florida, and Alabama on large protected and industrial forest lands in the coastal plain and in the Appalachians (Maehr 1984; Wooding et al. 1994; Figure 1). The only Florida panther population occurs in southwest Florida though dispersal of subadult males has occurred into central Florida (Maehr et al. 2002). The Florida panther recovery plan requires the establishment of two additional, sustainable populations within its historic range. Thatcher et al. (2003) completed a GIS habitat feasibility analysis for the Florida panther within the historic range and found potentially suitable sites in north Florida, Georgia, Alabama, Arkansas, and Louisiana.

**FIGURE 1** Approximate black bear (*Ursus americanus*) population locations (Maehr 1984; Wooding et al. 1994) in the southeastern United States on top of the United States Environmental Protection Agency Region 4 Southeastern Ecological Framework.
In conclusion, conservation scientists agree that protecting or restoring functional connectivity is an essential issue for conserving biodiversity and functional ecosystems. Crooks and Sanjayan (2006, p. 15) suggest that the key question now is:

What is the most effective pattern of habitats in landscapes to ensure ecological connectivity for species, communities, and ecological processes? . . . Overall, much of the current discussion regarding the advantages and disadvantages of connectivity seems to be less about the pros and cons of corridors as a specific conservation tool, than about the challenges associated with purchasing, designing, constructing, restoring, maintaining, and protecting natural levels of connectivity.

LANDSCAPE AND CONSERVATION CORRIDOR PROJECTS IN THE SOUTHEAST

Various projects in the southeastern United States seek to protect conservation corridors and regional ecological networks. Many of these include Department of Defense installations as critical components. This section will briefly describe several projects in this region.

Florida Ecological Greenways Network

The Florida Ecological Greenways Network (FEGN) is part of the Florida Greenways Program administered by the Florida Department of Environmental Protection Office of Greenways and Trails (Figure 2). It is the product of over twenty years of discussion and analysis for identifying and protecting an ecological reserve network in Florida (Harris 1985; Noss 1987; Harris and Atkins 1991). Governor Lawton Chiles appointed the Florida Greenways Commission in 1991 based on

![FIGURE 2 The Florida Ecological Greenways Network identified by the University of Florida and administered by the Florida Department of Environmental Protection Office of Greenways and Trails.](image)
recommendations from 1000 Friends of Florida to explore the utility of a statewide greenways system that included both a recreational and an ecological component. The Florida Greenways Commission (1994) recommended the development of a state-adopted program that protected a system of trails and a functionally connected network of conservation lands protecting Florida’s natural and rural landscapes. In 1995, staff at the University of Florida was contracted to develop a GIS decision support and delineation process to identify the best opportunities for an ecological network and a recreational network (Hoctor et al. 2000). The FEGN represents the ecological component of the state greenways system and was developed using a GIS-based regional landscape analysis to delineate the best opportunities to protect large, connected landscapes across the state (Hoctor et al. 2000; Hoctor 2003).

The implementation plan for the Florida Greenways Program identifies Critical Linkages within the FEGN based on ecological significance and threats from development (Hoctor et al. 2005). The Florida Ecological Greenways Network is now in its implementation phase, though updates to the base boundaries and priorities will occur periodically as land use and other GIS data are updated. The prioritized FEGN is now used to inform Florida’s conservation land acquisition program, Florida Forever, regarding the location of the most important conservation corridors in the state. Several new Florida Forever projects have been added specifically to protect critical gaps in the FEGN. The FEGN's Critical Linkages are the primary focus of landscape protection initiatives pursued by Florida government and various partners (Figure 3). All of the most active projects to protect the FEGN include important linkages and buffers for various

FIGURE 3  The prioritized Florida Ecological Greenways Network including the highest priorities, named Critical Linkages.
military installations including: Eglin Air Force Base, Camp Blanding Military Site, Avon Park Air Force Range, and Whiting Field Naval Air Station, and the state of Florida and Department of Defense are working together to protect parts of the FEGN that also have an important role for military training and readiness. The three most important projects are described briefly here.

**Ocala to Osceola / Okefenokee Corridor Project (O2O)**

O2O is one of the highest priority Critical Linkages in the FEGN and incorporates the Florida black bear corridor identified by Dixon et al. (2006). This project will protect a network of interconnected conservation lands from the Ocala National Forest north of Orlando to the Okefenokee National Wildlife Refuge in southeast Georgia, and will span approximately 200 miles and over 1.5 million acres of protected lands (Figure 4). It is one of the most important north-south corridors in the eastern United States. Furthermore, protection of O2O will also protect the Camp Blanding Military Site from urban and suburban encroachment associated with the nearby Jacksonville metropolitan area. Partners working on this project include The Nature Conservancy, The Conservation Trust for Florida, Florida Department of Environmental Protection, Florida Army National Guard, and Department of Defense. Progress to date includes completion of the Pinhook Swamp landscape linkage between Okefenokee National Wildlife Refuge and Okefenokee National Forest through many years of hard work by Larry Harris (1985), The Nature Conservancy, the State of Florida, the U.S. Forest Service, and many other partners.

**FIGURE 4** The Ocala to Osceola/Okefenokee Corridor Project (O2O). Project partners include The Conservation Trust for Florida (CTF), Florida Department of Environmental Protection Office of Greenways and Trails, University of Florida, The Nature Conservancy, Defenders of Wildlife, Florida National Guard, Department of Defense, U.S. Forest Service, St. Johns Water Management District, and Suwannee River Water Management District.
Northwest Florida Greenway

The Northwest Florida Greenway is a cooperative project started in 2003 between The Nature Conservancy, State of Florida government, the Department of Defense, and other partners to protect a regional 100-mile conservation corridor and buffer between the Apalachicola National Forest and Eglin Air Force Base. The project goal is to preserve connected habitat despite rapid population growth and to maintain an important flight path for five U.S. Air Force and Navy installations in the area that supports important testing and training missions (U.S. Department of Defense 2006; Figure 5).

These partners are working to accomplish the following objectives (U.S. Department of Defense 2006):

- Protect one of the nation’s six most biologically diverse regions;
- Protect an area that is host to five Air Force and Navy installations;

FIGURE 5 The Northwest Florida Greenways project pursued in partnership by the Florida Chapter of The Nature Conservancy, Florida state government, Department of Defense, and other partners.
• Prevent uncontrolled incompatible development that could hinder realistic military training;

• Prevent habitat fragmentation that could threaten biodiversity, and threatened and endangered species and;

• Strengthen the regional economy by sustaining the mission capabilities of the military in the region and enhancing recreation and tourism.

**Big Cypress National Preserve to Ocala National Forest Landscape Linkage Project**

This is a critical regional landscape for ensuring a functional ecological network from south to north Florida (Figure 6). In addition, this landscape includes vast ranch lands with an agricultural tradition that are compatible with biodiversity and ecological connectivity in this region. These ranches are threatened by development spreading south from Orlando and inland from both coasts. Focal species requiring large intact landscapes that will greatly benefit from this effort include the Florida black bear, Florida panther, Audubon's caracara (*Polyborus plancus auduboni*), and Florida sandhill crane (*Grus canandensis pratensis*). Avon Park Air Force Range and associated conservation lands are a critical part of the corridor and protection of lands around the Range will help minimize future development impacts. In addition, it is a likely destination for natural population re-establishment by black bears that disperse from central Highlands County, which is the key landscape linkage between the Big Cypress region in southwest Florida and points north (Maehr et al. 2004).
Southeastern Ecological Framework

The U.S. Environmental Protection Agency (EPA) Southeastern Ecological Framework (SEF) is a cooperative effort between EPA Region 4 and the University of Florida that identified priority conservation areas across an eight state region including North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Tennessee, and Kentucky (Figure 7). The framework encourages federal and state cooperation and facilitates coordination to effectively protect and restore landscapes (Carr et al. 2002). The GIS process to identify the SEF incorporated various data on conservation lands, important wildlife habitat, large wetland basins, intact riparian buffers, large forested areas, and intact coastal lands needed to maintain biodiversity, water quality, air quality, flood control, and storm protection.

The SEF is a spatial database of important ecological areas useful for many purposes such as: 1) the development of mitigation banks and sites that provide connectivity to larger intact wetland systems, 2) buffering protected wildlife or natural areas such as wildlife refuges, national parks, state and local parks and private wilderness areas, 3) planning future road right-of-ways to minimize impacts on existing natural areas, 4) watershed protection, 5) prioritization for areas in conservation through wetland reserve or conservation reserve programs, 6) identifying areas for reforestation of riparian zones, 7) integration of local greenspace protection with the larger regional picture, and 8) reserve design and planning for biodiversity conservation.

Many of these potential applications of the SEF are being integrated into regional scale planning efforts. The Southeast Regional Partnership for Planning and Sustainability (SERPPAS – http://www.serppas.org), a multi-state, multi-agency partnership, is utilizing the SEF as a key organizing framework for regional sustainability issues that cross federal, state, and local geographic and civic borders. Specifically, SERPPAS and its related complementary efforts are attempting to identify and protect a network of lands that maintain and enhance ecological values, support working forest and farm landscapes, and maintain military readiness. A pilot effort in eastern North Carolina is implementing the SERPPAS vision through a Strategic Lands Inventory that is developing decision support tools that identify opportunities to achieve multiple benefits related to green infrastructure, gray infrastructure, ecosystem services, and compatible land use.

FIGURE 7 The United States Environmental Protection Agency Region 4 Southeastern Ecological Framework delineated by the University of Florida.
TRENDS IN LAND USE AND ROAD AND UTILITY CORRIDORS

Rapid human population growth throughout much of the southeastern United States is a major threat to protection of large, intact landscapes and conservation corridors. Human dependence on automobile transportation typically creates great pressure to increase road infrastructure (e.g., new roads and widened roads) as population increases. Roads are a major threat to conservation corridors because of isolation and roadkill impacts to many species (Trombulak and Frissell 2000; Forman et al. 2003), and reducing these impacts is a major challenge for protecting and restoring ecosystem connectivity (Hoctor 2003; Clevenger and Wierzchowski 2006). Human population growth also creates increased energy demand which results in greater need for energy delivery through linear infrastructure, such as electrical transmission lines and gas pipelines. Linear energy infrastructure can impact areas important for listed species, wetlands, and existing conservation lands.

Population Growth and Sprawl in the Southeast

The conversion rate of pristine and agricultural land to urban use in the Southeast is alarming. Recent analyses and studies of urban growth patterns in Florida indicate the conversion of undeveloped land for urban use is tracking population increases. That is, as population doubles, the area in urban land use also doubles (Carr and Zwick 2007). In some areas of Florida it appears per capita land consumption is actually declining, but considered for the state as a whole it appears to be roughly tracking population growth (Kolankiewicz and Beck 2000). The factor then driving sprawl in Florida is population growth, and it is not predicted to abate any time soon (Zwick and Carr 2006). Indications are that the sources of sprawl for the rest of the Southeast are somewhat different from Florida. In some areas it appears per capita land consumption is on the rise, and this coupled with population increase, is driving the conversion of rural lands to urban lands (Kolankiewicz and Beck 2000). Again, however, predictions for continued population increases in the entire Southeast suggest that the demand for new urban land will continue.

Pressure for New Road Infrastructure: The Florida Example

Florida’s existing highway system fragments and otherwise impacts conservation lands and other areas of ecological significance, and the Florida Department of Transportation has adopted a Florida Intrastate Highway System plan that will increase ecological impacts. A major component of the plan is widening most east-west state highways from two lanes to four or six lanes. In 2002, Florida adopted legislation reducing the requirements to justify new toll roads and broadening the powers of the Florida Turnpike Authority. Most recently, the Florida Department of Transportation unveiled a set of proposed new highway study areas across the state, named Future Corridors. Many of these projects could severely impact biodiversity and ecosystem service conservation (Hoctor 2003).

Now that good information about lands important for conservation exists, alterations should be possible to avoid ecological impacts while meeting transportation needs. Furthermore, an integrated statewide assessment of transportation projects and green infrastructure would significantly enhance efforts to avoid, minimize, and mitigate impacts. System-wide planning should also ensure that sufficient funding is available for ecological mitigation including many more wildlife crossing structures across highways.
Transportation Infrastructure Issues in the Southeast and United States

Road impacts are a primary issue in efforts to protect ecological connectivity represented by the Southeastern Ecological Framework (SEF). Although there are some significant roadless areas that were identified and incorporated into the SEF, the Southeast is covered by a dense road system. Approximately 150,000 kilometers of roads cross the SEF and 79% of the SEF is within 1 kilometer of a road (Carr et al. 2002). Also, 70% of the SEF has a road density greater than 1 mile per square mile, which is considered to be an important threshold for the potential to support species sensitive to road impacts including black bear and other wide-ranging species (Thiel 1985; Pelton 1986; Van Dyke et al. 1986; Mech et al. 1988; Noss 1992; Noss and Cooperrider 1994; Carr et al. 2002). There is a need to retrofit the existing road system to minimize habitat fragmentation and other ecological impacts associated with roads if ecological connectivity and integrity are to be restored. Federal agencies and state governments should work together to use existing funding sources and develop new ones to support planning and retrofitting that will increase the compatibility of transportation infrastructure with ecological connectivity (Smith 1999; Carr et al. 2002; Hoctor 2003; Clevenger and Wierzchowski 2006). Given the current increasing number of WVCs is likely a function of new highway construction and increased traffic volumes and speeds relative to wildlife population distribution and abundance (Messmer and West 2000; Putman et al. 2004; Huijser et al. 2007). Efforts to retrofit transportation infrastructure to reduce WVCs are discussed below in this article.

Wildlife vehicle collisions (WVCs) are also an increasingly important transportation and conservation issue. Since 1980 the total annual WVCs are increasing by about 6,800 per year. The availability of consistent and detailed wildlife vehicle collision (WVC) data are limited.

However, based on the reported crashes for large animals, WVCs have some specific attributes. WVCs are more commonly or typically:

- during early morning and late evening hours
- within spring and fall months
- lower severity crashes
- evenly distributed among younger and medium aged drivers
- in locations with high wildlife populations
- with deer
- in sections of roadway near forested cover and drainages
- on dry straight roadways

The current increasing number of WVCs is likely a function of new highway construction and increased traffic volumes and speeds relative to wildlife population distribution and abundance (Messmer and West 2000; Putman et al. 2004; Huijser et al. 2007). Efforts to retrofit transportation infrastructure to reduce WVCs are discussed below in this article.

Trends in Utility Corridor Development

Human population growth translates into increased energy needs and increased infrastructure to supply that energy. One important example of these trends is the growing need for electrical transmission lines. An article in Transmission & Distribution World in February 2005 details the development of new transmission line siting tools in Georgia (http://tdworld.com/mag/power_gisbased_linesiting_methodology). Georgia's population in the 1990s grew by 26% while the energy demand grew by 46%, which resulted in the need for more transmission line corridors. However, suitable land for transmission line corridors is increasingly difficult to locate due to conflicts with both expanding developed land and stronger requirements to avoid impacts to environmentally sensitive features including wetlands and listed species habitat. In a recent report the Georgia
Transmission Corporation and Electric Power Research Institute (2006, p.1-1) discussed the growing dilemma:

In fast-growing states like Georgia, demand for electricity is outpacing rapid population growth, placing pressure on electric utilities to build more electric transmission power lines. In 2004, for instance, Georgia’s utilities built more than 100 new miles of transmission lines and Georgia Transmission Corporation is currently investing more than $100 million annually in construction. With more construction comes more public scrutiny on a range of issues, including the decisions made when determining locations for new electric transmission lines.

AVAILABLE DATA AND TOOLS FOR REGIONAL CONSERVATION AND CORRIDOR PLANNING

Advances in conservation science have resulted in the development of increasingly sophisticated data and planning tools relevant for identifying conservation corridors and other areas of ecological significance at local to regional scales. This section will briefly discuss some of the data, tools, and planning products relevant to regional conservation planning and protection of connectivity in the Southeast and other regions.

TNC Ecoregional Plans

The Nature Conservancy has developed conservation plans for every ecoregion in the United States and many other ecoregions globally. Ecoregional planning identifies all areas necessary to conserve viable populations of all focal species, all natural communities, and functional or restorable landscapes within each ecoregion (Groves et al. 2002; Groves 2003). Methods for developing ecoregional plans vary based on available data, analytical capabilities, and evolving guidelines. Data and tools used include GIS land cover and land use data, locations of focal species and natural communities, species habitat modeling and population viability assessments, and ecological and landscape integrity GIS indices. Resulting maps show the location of sites needed to effectively conserve biodiversity in each ecoregion. Therefore, these plans are an important consideration for all regional conservation and corridor planning projects.

Federal Gap Analysis

The federal Gap Analysis project identifies biodiversity hotspots that are not protected, or are under-protected, in existing systems of conservation lands. This has been accomplished by developing potential habitat maps for all vertebrates (and sometimes selected invertebrates) and then combining these maps to determine areas of high species richness (Scott et al. 1993). The Gap Analysis program started state-by-state in the 1990s. However, multi-state regional Gap Analysis recently began for the southwestern, northwestern, and southeastern United States using improved land cover data and more sophisticated habitat modeling (See http://gapanalysis.nbii.gov/portal/server.pt). The Southeastern Gap Analysis project is creating detailed land cover data for the region as a base for species habitat modeling. The land cover classification and habitat modeling is being done in seven mapping zones in Virginia, Kentucky, North Carolina, Tennessee, South Carolina, Georgia, Alabama, Mississippi, and Florida. The Gap Analysis Conference in September 2007 in Asheville, North Carolina featured the Southeast Gap Analysis project (http://www.basic.ncsu.edu/segap/). Though habitat modeling developed through Gap Analysis can be coarser than habitat analysis done at smaller scales for specific project areas, Gap Analysis data can help identify potential focal species habitat and potential conservation corridors in regional conservation planning study areas.
Other EPA Regional Data

Like the EPA Southeastern Ecological Framework in EPA Region 4, other EPA Regions have completed, or are working on, regional assessments of “critical ecosystems”. Hoctor et al. (2004a) detailed EPA regional ecosystem assessments and made recommendations for future enhancements. Other EPA regional critical ecosystem assessment examples include the Region 5 Critical Ecosystems Assessment Model (CrEAM) and the Region 6 GIS Screening Tool (GISST). Therefore, EPA data are another potential source of information for regional conservation and corridor planning.

State Wildlife Action Plans

State Wildlife Action Plans were required by the federal government for states to receive federal funds through the State Wildlife Grants program (http://www.wildlifeactionplans.org/). They outline strategies for conserving wildlife in each state. Plans vary in scope and methods, but all plans must provide key elements such as: information on the distribution and abundance of wildlife species; descriptions of locations and relative condition of key habitats and community types; descriptions of problems which may adversely affect key species or their habitats; priority research and surveys; and descriptions of conservation actions and monitoring. Other plan elements include coordinating with federal, state and local agencies and incorporating public participation. Priority species and areas for conservation within state wildlife plans may be important targets for protection of conservation corridors, with the additional benefit of a built in mechanism for receiving federal funds to achieve protection. In Florida, the next proposed step of the State Wildlife Action Plan is a “Conservation Blueprint,” which would use the best available GIS data and other information in regional planning and mapping workshops. Regional maps would add detail to state priorities and help guide wildlife conservation action at multiple scales. One proposed element of these plans is the identification of regional and local corridors for conserving focal species and ecosystems.

Reserve Design Software: Spexan/Marxan

Spexan and the most recent iteration, Marxan, is a reserve design program developed in Australia that uses an iterative algorithm to identify the most efficient set of sites for achieving specified conservation goals (Ball 2000; Ball and Possingham 2000). This software is typically used to make sure that all elements of biodiversity (or other natural resource features) are adequately represented in existing and proposed conservation lands. It is increasingly used to address conservation goals for both biodiversity and ecosystem services (Ardron et al. 2002; Kelley et al. 2002; Noss et al. 2002; Leslie et al. 2003; Oetting and Knight 2003; Chan et al. 2006). However, one of the primary weaknesses of these algorithms is an inability to incorporate spatial and viability considerations such as the importance of connectivity or location of corridors (Briers 2002; Cabeza 2003; Hoctor et al. 2004a; Noss and Daly 2006). Nonetheless, Spexan/Marxan is an objective means for assessing biodiversity representation in regional conservation plans, and it can be combined with efforts to assess viability and delineate spatial design, including corridors and buffers, necessary to protect viable ecological networks.

Least Cost Path Analysis

Least Cost Path Analysis (LCP) is a raster-based optimization function that seeks the best route between a source and a destination. It has been applied to various projects to identify the best potential corridors for various focal species based on the biology and behavior of the species and related factors such as land use and road densities (Hoctor 2003; Larkin et al. 2004; Beier et al. 2006; Carroll 2006; Kautz et al. 2006; Theobold 2006). Although LCP has limitations such as questions about species movement behavior in real landscapes versus...
the LCP's cumulative path optimization, LCP is a potentially useful tool for identifying corridor options between conservation lands (Hoctor 2003; Carroll 2006; Theobold 2006). The expanding use of GPS technology in tracking radio-collared study animals will likely provide the foundation for testing and refining LCP modeling for landscape-scale conservation planning in the future.

**Spatially Explicit Population Models**

Spatially Explicit Population Models (SEPMs) can assess the significance of connectivity options to maintain viable populations of focal species. Although there are several SEPM software options, including VORTEX and RAMAS GIS (Lacy 1993; Akçakaya et al. 2004), PATCH software has been most recently used to identify important corridors and other priority conservation actions for various wide-ranging species (Carroll et al. 2001; Carroll et al. 2002; Carroll et al. 2003; Carroll et al. 2004; Carroll 2006; Noss and Daly 2006). SEPMs are data and time intensive but are an important tool for addressing population viability in the design of ecological networks.

**NatureServe Vista**

Vista is software created by NatureServe, the association of state and other natural heritage programs, which packages focal species and natural community occurrence data in a decision support process (http://www.natureserve.org/prodServices/vista/overview.jsp). It can be used to evaluate different protection and development scenarios to determine impacts on focal species and natural communities. Natural heritage data are critical for regional conservation planning, and this software can serve as a means for incorporating these data in corridor and ecological network projects.

**Green Infrastructure: Linking Landscapes and Communities Book**

Benedict and McMahon (2006) describe the significance of green infrastructure and the process and options for identifying and protecting it. Benedict and McMahon (2006, p. 1) define green infrastructure as, “an interconnected network of natural areas and other open spaces that conserves natural ecosystem values and functions, sustains clean air and water, and provides a wide array of benefits to people and wildlife.” Green infrastructure is a conceptual advance in environmental planning because it explicitly links the integrity of natural systems with the health and well being of human communities. Benedict and McMahon (2006) emphasize the importance of ecosystem services and their linkage with protecting biodiversity. The book also covers land protection tools, ecological network implementation strategies, and efforts to build support for green infrastructure.

**Smart Land-Use Analysis: The LUCIS Model Land Use Identification Strategy**

Margaret Carr and Paul Zwick, from the University of Florida, recently completed a book on using ESRI's ArcGIS software to analyze regional scale land use and assess potential trade-offs regarding different development and conservation strategies. Their methods take full advantage of the geographic analysis capabilities of ArcGIS to determine regional suitabilities for urban/suburban development, agriculture, and conservation of biodiversity and ecosystem services. After developing these suitability maps, they recommend a conflict analysis strategy to determine which areas important for agriculture or conservation may be most threatened by development. From their conflict analysis it is possible to develop alternative future land use scenarios to test different land use policies. These methods include the use of population projections, variable gross urban densities, mass transit alternatives and conservation.
schemes to fully explore the implications of future growth and minimize the impacts on biodiversity and ecosystem services (Carr and Zwick 2007).

Developments in Growth, Transportation, and Utility Corridor Planning

Human population growth, accelerated land use conversion, and increasing demand for expanded transportation and energy infrastructure are critical trends that heavily influence opportunities to protect conservation corridors and ecological networks. Planning tools and initiatives that closely integrate development and conservation planning at regional scales are essential for understanding potential trade-offs and to develop planning strategies that will avoid and minimize ecological impacts and maximize protection of critical ecosystems. In this section we discuss several examples of developing planning tools to assess and minimize the impacts of conversion to urban and suburban land use, transportation projects, and energy utility corridors.

Growth Projection Modeling

Growth projection modeling identifies the areas most likely to be converted to development. Such modeling can be used to support the analysis of alternative futures (or scenarios) to demonstrate how different densities and patterns of growth can minimize the impacts on natural resources. In cooperation with 1000 Friends of Florida, a growth management advocacy group, Zwick and Carr (2006) have developed a statewide example of spatial growth projections for Florida (Figure 8). They are now conducting more detailed regional analyses that are proposed to be completed for every Florida region. These regional models will look more specifically at different development and conservation scenarios while working with local governments and stakeholders.
Florida Department of Transportation Efficient Transportation Decision Making

In response to the "Environmental Streamlining" legislation passed by Congress as part of the Transportation Equity Act for the 21st Century, the Florida Department of Transportation (FDOT) has been working with partners to develop and implement a more efficient transportation planning and environmental review process (http://etdmpub.fla-etat.org/est/). These efforts led to the development of the Efficient Transportation Decision Making (ETDM) process. It is intended to improve transportation decision-making in a way that protects human and natural environments. The approach includes active participation of federal, state, and local agencies, and the public early in the planning process. Agencies can identify avoidance and mitigation opportunities and prescribe technical studies to be accomplished by FDOT if the project proceeds. The Environmental Screening Tool (EST) provides an essential foundation to the ETDM. The EST is an internet-accessible application that provides tools to input and update information about transportation projects, perform standardized analyses, gather and report comments about potential project effects, and provide information to the public. This significant improvement in transportation impact assessment should vastly improve efforts to minimize the impact of new transportation infrastructure important ecological areas, and could serve as a model for other states.

EPRI-GTC Overhead Electric Transmission Line Siting Methodology

In response to increasing energy demand coupled with heightened public scrutiny, the Georgia Transmission Corporation (GTC) developed a new transmission line corridor selection methodology in cooperation with the Electric Power Research Institute (EPRI) and a panel of GIS, scientific, and planning experts from universities and other entities (Electric Power Research Institute and Georgia Transmission Corporation 2006). The project team developed a new GIS Siting Model with a more objective, quantifiable, and consistent methodology that minimizes environmental and social impacts while also meeting engineering requirements. The model is also more transparent than past methods and therefore better suited for public review.

Trends in Wildlife Crossing Technology to Mitigate Impacts of Transportation Infrastructure

The Western Transportation Institute, Road Ecology Program is currently conducting a National Wildlife Vehicle Collision Study for the Federal Highway Administration. This study addresses issues associated with wildlife vehicle collisions (WVCs). Included in this study is a summary of methods designed to reduce WVCs and increase habitat connectivity and permeability of roads for wildlife. These methods are divided into four major categories, 1) mitigation efforts that attempt to influence driver behavior, 2) mitigation efforts that seek to influence animal behavior or population size with no or minimal structures on or over the road or in the right-of-way, 3) mitigation efforts that seek to physically separate animals from the roadway, and 4) mitigation measures that seek to provide crossing opportunities for wildlife (Huijser et al. 2007).

Crossing opportunities for wildlife include: safe crossing opportunities such as gaps in fences and wildlife underpasses and overpasses, escape opportunities from the right-of-way such as jump-outs or escape ramps and one-way gates, mitigation for fence ends such as boulders between fences and roadways, animal detection systems, and gaps caused by access roads such as gates and cattle or wildlife guards (Huijser et al. 2007). The number of wildlife crossing structures continues to increase and is extremely important for mitigating the impacts of roads on connectivity (Forman et al. 2003; Clevenger Wierzchowski 2006).
Comprehensive Mitigation Planning for Transportation Infrastructure

The Conservation Fund, in partnership with Maryland Department of Natural Resources and the U.S. Fish and Wildlife Service, is working with the Maryland State Highway Administration on a green infrastructure approach to identifying stewardship and compensatory mitigation opportunities for the construction of the US Highway 301 bypass around Waldorf, Maryland. Priority projects to restore streams, purchase conservation easements, and other strategies will be determined through an intensive GIS, field study, and work group process that builds on and updates Maryland’s statewide green infrastructure assessment (Weber and Wolf 2000) and utilizes optimization techniques to maximize conservation benefits. Similar approaches could be utilized in the Southeast by refining the SEF for local scale use.

There is a clear need to retrofit the existing road system to minimize habitat fragmentation and other ecological impacts if ecological connectivity and integrity are to be restored (Carr et al. 2002; Forman et al. 2003; Clevenger and Wierzchowski 2006). The Florida Department of Transportation has made significant progress to address existing impacts and to avoid future conflicts (Foster and Humphrey 1992; Roof and Wooding 1996; Smith 1999). However, the Florida Department of Transportation’s planned budget for road infrastructure improvements between 2001-2020 is $108 billion (Hoctor 2003). If just 5% of that budget were devoted to environmental mitigation, it would be sufficient to build many new wildlife crossing structures and protect large areas of habitat to mitigate transportation impacts on biodiversity. Across the Southeast, transportation agencies need to work closely with the appropriate government agencies and NGOs to integrate wildlife crossing structures and other forms of mitigation into transportation planning.

Co-location of Linear Development and Conservation Corridors

Co-location of transportation and utility infrastructure is an obvious potential means for minimizing environmental impacts. However, it may also be possible to co-locate linear development and conservation corridors in cases where other opportunities to protect or restore ecological connectivity are not feasible. Though not common, there are some examples of such co-location. One example from Australia is the maintenance or restoration of forest corridors along roadways for various focal species in lands largely converted to agriculture or other human uses (Straker 1998). In addition, if sufficiently wide and strategically located, utility corridors could help provide connectivity for some focal species between conservation areas (Hall et al. 1994).

Policy Development to Facilitate Protection of Conservation Corridors

Policy is changing in several ways in an attempt to keep pace with human population growth, land use conversion, and increasing land prices. One trend in the Southeast and the United States as a whole is expanding land acquisition programs (including conservation easements) at the local, state, and federal levels. A strong majority of Americans support greenspace protection. Conservation easements were debated recently in Congress and the result is better provisions that make easements more attractive for private landowners. Other incentives for protecting additional lands include a growing market for carbon credits and carbon-neutral policies, which can result in significant forest restoration and protection. Growth management planning is an essential part of efforts to effectively manage rapid population growth to reduce sprawl, public infrastructure costs, and environmental impacts. Florida has a long history of growth management and recent updates such as the Rural Lands Stewardship Areas program embody efforts to improve growth management to protect large, intact
landscapes. Florida state government has also instituted the Century Commission for a Sustainable Florida, which is reviewing relevant trends and data to develop recommendations to help achieve a sustainable future.

**Expanding Conservation Land Acquisition Programs**

Conservation land acquisition and protection programs are increasingly popular in the United States at the local, regional, and state levels. Voters are frequently approving financing measures to fund land conservation programs. The Trust for Public Land maintains a website called LandVote that tracks these measures and funding levels across the nation (http://www.tpl.org/tier3_cdl.cfm?content_item_id=15266&folder_id=2607). Most of the states and various municipalities and counties in the southeastern United States have passed land conservation acquisition funding measures (Figure 9, page 39). Since 1988, $44 billion dollars of conservation acquisition funds have been approved nationwide by voters in local, regional, and state initiatives.

Rising land prices are an important concern for conservation land acquisition programs. In Florida, state government has spent approximately $300 million per year on conservation lands since 1990 through the Preservation 2000 and Florida Forever land acquisition programs. Florida local governments have raised an additional $9.8 billion for open space protection since 1988 (TPL LandVote 2007). However, the average sale price of lands bought for conservation has increased from $1,500 to $3,500 per acre since 1990, and, therefore, these state and local programs have lost 2/3 of their buying power in the last 17 years. Land prices are also increasing at a faster rate in urbanizing counties (Ramesh Buch, personal communication). In response, a coalition of conservation organizations is working on a campaign to increase funding to at least $600 million and up to $1 billion per year through 2020. The goal of this Florida Forever successor program campaign is to protect at least 2 million more acres in addition to the approximately 2.3 million acres that have been protected since 1990 (The Florida Chapter of The Nature Conservancy 2006).

The Environmental Law Institute (2006) examined the effectiveness of 28 state open space conservation programs for protecting biodiversity. An important issue faced by state programs is balancing the pressing need to acquire land as quickly and efficiently as possible with the need to be strategic in acquiring land that maximizes protection of biodiversity and ecosystem functions. State Wildlife Action Plans provide a science-based blueprint to prioritize conservation actions (ELI 2006). State open space conservation programs also need to seek opportunities for leveraging conservation dollars by building partnerships with other organizations and programs with similar missions. ELI (2006, p. 2) concluded:

The 28 programs included in ELI’s study together contribute an annual average of more than $700 million in 21 states to land protection for the purpose of biodiversity and wildlife conservation. Clearly, states are investing in the conservation of open space to protect wildlife habitat and biodiversity. If they are equipped with sufficient information and resources, they can be well-positioned to make calculated land protection decisions and to maximize the conservation benefits that result from each dollar spent.

At the federal level the Department of Defense has become the most important source of conservation land acquisition dollars through DOD’s Range Enhancement and Protection Initiative (REPI) as well as the Army Compatible Use Buffer (ACUB) Program. DOD acquisition funding now exceeds that of the federal share of Land and Water Conservation Fund (LWCF). The LWCF program provides matching grants to state and local governments for the acquisition of public
FIGURE 9 Potential future urban development in 2060 in a growth projection model conducted by Paul Zwick and Margaret Carr from the University of Florida for 1000 Friends of Florida. The brick red represents all potential urban, suburban, commercial, and industrial lands in 2060. It is important to note that this scenario assumes no additional conservation land protection beyond the existing conservation lands shown in green (from 1000 Friends of Florida 2006 and Zwick and Carr 2006).
conservation lands. Though the LWCF funding was improving in the recent past (it peaked at almost $1 billion in 2001), it has again fallen precipitously ($346 million in 2006) (Vincent 2006). More importantly, the LWCF falls significantly short of providing the financial support needed based on the demand for land conservation and escalating conversion to suburban and urban land uses.

**Conservation Easements**

The federal rules for conservation easements were changed in 2006 to increase the financial incentives for private landowners, and the hope is that the 2008 US Farm Bill that proposes to extend these incentives will be passed. The incentives are:

- A conservation agreement donor to deduct up to 50% of their adjusted gross income in any year;
- Qualifying farmers and ranchers to deduct up to 100% of their adjusted gross income; and
- Donors to take deductions for their contribution over as many as 16 years (Conservation Trust for Florida; also see the Land Trust Alliance web site for more information: http://www.lta.org/publicpolicy/tax_incentives_qa.htm)

Conservation easements are an extremely valuable tool for conservation land protection because they require less money than fee-simple acquisition, the land remains on tax rolls, and the owner provides most or all of the land management. The primary obstacles for easements are: 1) resistance to use of public funds to protect private lands that are typically not accessible to the public; and 2) monitoring requirements can be complicated, time consuming, and difficult to enforce.

**Conservation Tax Credit Programs**

Some southeastern states employ Conservation Tax Credit programs that are designed to support protection of important conservation areas. North Carolina has a tax credit program that allows individuals and corporations to receive income tax credits when real property is donated to a qualified entity for conservation purposes (http://www.enr.state.nc.us/conservationtaxcredit/). In 2006, Georgia passed a similar conservation tax credit program for donations of real property for conservation purposes. Qualified donations include either fee simple donations or conservation easements (http://www.gadnr.org/documents/conservation_tax_credit.html). Though these measures provide important incentives for protecting conservation lands, they are not strategic in terms of directing more resources to the highest priority areas (Will Allen, personal communication).

**Federally-listed Species Habitat Conservation and Management Programs**

The U.S. Fish and Wildlife Service has a number of programs to provide private landowners options and incentives to protect and manage federally listed species habitat. Programs include conservation banking, Candidate Conservation Agreements, the Private Stewardship Program, Safe Harbor Agreements, and Habitat Conservation Plans (http://www.fws.gov/endangered/landowner/index.html). Although these programs have various deficiencies (Noss et al. 1997), they do provide some flexibility and additional resources to maintain and restore functional habitat for federally listed species on private lands.

**Private Landowner Habitat and Forest Management Programs**

Private landowners may voluntarily participate in state and federal administered programs that foster conservation. These programs help landowners protect...
wetlands and wildlife habitat and foster farm and forest productivity. The programs in turn provide incentive payments and technical assistance to landowners (Demers et al. 2003). The programs described here and others may be researched at the Environmental Protection Agency (EPA) online Catalog of Federal Funding Sources for Watershed Protection (www.epa.gov/watershedfunding).

The Natural Resources Conservation Service (NRCS), part of the United States Department of Agriculture (USDA), offers programs to assist landowners with conservation goals. The Wetlands Reserve Program (WRP) is another USDA/NRCS voluntary program designed to restore and protect wetlands on private property. Private landowners may qualify for financial incentives to enhance wetlands in turn for retiring marginal agricultural land. WRP offers three options of permanent easements, 30-year easements and restoration cost-share agreements of a minimum of 10-year period. Under the Wildlife Habitat Incentives Program (WHIP), NRCS provides landowners with up to 75 percent costshare funds to develop habitat for upland and wetland wildlife, endangered species, fisheries, and other wildlife. Landowners work with NRCS to develop a 5 to 10-year wildlife habitat development plan in consultation with the local conservation district. The plan describes the landowner’s goals for improving wildlife habitat, includes a list of practices and a schedule for installing them, and details the steps necessary to maintain the habitat for the life of the agreement. The plan may or may not be part of a larger conservation plan that addresses other resource needs, such as water quality and soil erosion. WHIP is a voluntary program that encourages creation of high quality wildlife habitats that support wildlife populations of National, State, Tribal, and local significance. Through WHIP, the Natural Resources Conservation Service (NRCS) provides technical and financial assistance to landowners and others to develop upland, wetland, riparian, and aquatic habitat areas on their property. The Grassland Reserve Program is a third USDA/NRCS voluntary program that works similarly to the WRP and WHIP to protect grasslands on private property.

The United States Fish and Wildlife Service (USFWS), part of the Department of Interior (DOI), offers technical and financial assistance for a wide variety of partners to restore wildlife habitat on private lands. USFWS provides habitat-planning guidance and cost-share assistance on projects enrolled in the USDA Wetland Reserve Program and other conservation programs.

The Farm and Ranch Lands Protection Program (FRPP) is a voluntary program that helps farmers and ranchers keep their land in agriculture. It is managed by the U.S. Department of Agriculture’s (USDA) Natural Resources Conservation Service (NRCS). The program provides matching funds to state, tribal, or local governments and non-governmental organizations with existing farm and ranch land protection programs to purchase conservation easements. FRPP is reauthorized in the Farm Security and Rural Investment Act of 2002 (USDA 2007).

The Forest Legacy Program has protected 1,145,586 acres as of February 2006 (http://www.fs.fed.us/spf/coop/programs/loa/flip_projects.shtml). A program of the USDA Division of Forestry, the Forest Legacy Program provides an alternative to selling timberland for development. It provides assistance in private, voluntary conservation using grants to enrolled states to purchase conservation easements or fee simple acquisition on environmentally important forest lands that are threatened with conversion to non-forest uses. Conservation easements are given higher priority than fee-simple acquisition, and the purchase of development or full fee rights can be accomplished with up to 75% federal funds and at least 25% coming from private, state or local sources. Forest Legacy has funded 242 projects that protect a total of 1,567,224 acres nationally.
Carbon Sequestration and Carbon Neutral Programs

Global climate change is spurring various initiatives that could have a significant impact on land conservation. Carbon sequestration is the process of long-term carbon storage to reduce atmospheric carbon dioxide levels and potentially reduce the severity of global climate change. Already, the evolving carbon emissions credit market is resulting in the restoration and protection of southeastern forest lands to provide carbon sequestration. For example, in Louisiana, the Entergy corporation is working with various partners to meet their carbon sequestration commitment while also restoring listed species habitat (http://www.fws.gov/southeast/news/2005/r05-041.html). With $15.7 million, Entergy has acquired approximately 11,000 acres and reforested over 8,000 acres around the Tensas River National Wildlife Refuge to restore habitat and create corridors for the federally listed Louisiana black bear (Ursus americanus luteolus).

Entergy is also working with the Conservation Fund and the U.S. Fish and Wildlife Service to protect and reforest land to create the new Red River National Wildlife Refuge in Louisiana (http://www.conservationfund.org/node/414). The Conservation Fund is also working with many other private and public partners on two other carbon sequestration initiatives to protect and restore forest land: the Obion Creek Wildlife Management Area in Kentucky and the PowerTree Carbon Company, which is a partnership seeking to reforest lands in the lower Mississippi Alluvial Valley. Overall, The Conservation Fund and partners have already restored 20,000 acres and planted more than 6 million trees (http://www.conservationfund.org/node/546).

Another emerging initiative is Carbon Neutral programs (See http://www.conservationfund.org/gozero). As part of a large group of universities developing carbon neutral programs, the University of Florida is discussing using either donated or purchased lands that have other important conservation values as carbon sequestration banks (http://www.napa.ufl.edu/2003news/carbonneutral.htm). The expansion of carbon neutral programs could provide very significant funding for land conservation. Therefore, an important goal is to create partnerships between organizations pursuing carbon neutrality and those identifying and protecting strategic conservation lands.

Growth Management

Growth management is an essential complement to land acquisition and easement programs. A variety of incentives and disincentives can be used to avoid sprawl and direct growth away from areas with the highest conservation and environmental values including conservation corridors.

Although Florida has a long history of growth management efforts through various laws and programs starting in the 1970s, growth management remains a problematic issue with less than significant impacts made on the pace or pattern of development (Nicolas and Steiner 2000; Hoctor 2003). Collectively, all of the future land use plans adopted by local governments (including counties and cities) would allow anywhere from 50 to 90 million people, which is approximately 3 to 6 times larger than the current population (Nicolas and Steiner 2000; Hoctor 2003). Effective growth management should direct development away from environmentally sensitive areas whenever possible (Soulé 1991). The protection of areas important for biodiversity, fiber production, and agriculture should be key components of comprehensive plans. In addition, good comprehensive plans would limit sprawl, which would give land acquisition efforts more time to protect critical areas for conservation. Finally, good planning is needed to buffer protected conservation lands, where intensive development is separated from reserves by rural lands including silviculture, agriculture, and other uses more compatible with conservation objectives (Harris 1984; Noss and Harris 1986; Soulé 1991; Hoctor 2003). Prescribed fire management is also a critical issue throughout the southeastern coastal plain and growth management should ensure that development
is located and designed to minimize interference with prescribed burns (Harris et al. 1996a; Gordon et al. 1997; Macie and Hermansen 2002; Maehr and Larkin 2004).

Florida government continues to modify growth management to seek improved performance. A recent addition to Florida law is the Rural Lands Stewardship Areas program (RLSA). The program goal is to use a Transfer of Development Rights (TDR) concept to promote the protection of large, rural landscapes. Development credits are determined by the value of land being protected in sending areas and are then transferred to receiving areas where development occurs. Rules currently require that a minimum of 10,000 acres be available to plan the sending and receiving process, which can either be in a single land ownership or composed of multiple ownerships. RLSA agreements then must be incorporated into amended county comprehensive plans. Although the RLSA program is promising, it is relatively new, and early indications are that the program could facilitate large-scale development in rural landscapes where development otherwise might not occur for many years, if ever. Potential beneficial changes to the law would include the requirement of receiving areas to be located within or near current urban areas in order to reduce sprawl and fragmentation effects upon rural landscapes. For an operating example of the RLSA program see this Collier County website: http://209.247.187.111/Index.aspx?page=1515.

Florida Century Commission: Planning for Sustainability

The Century Commission for a Sustainable Florida was created by the Florida Legislature in 2005 and will:

- envision Florida’s future by looking out 25 and 50 years,
- make recommendations to the Governor and Legislature regarding how they should address the impacts of population growth, and
- establish a place where the “best community-building ideas” can be studied and shared for the benefit of all Floridians.

The Century Commission is working on various initiatives to accomplish its mission (http://www.centurycommission.org/home.asp). One of the first initiatives is the development of the Critical Lands/Waters Identification Project (CLIP). The goal for CLIP is to identify areas of statewide priority for protecting biodiversity and ecosystem services using the best available GIS data and tools. CLIP is still under development but will likely become an important decision support tool for guiding the development of recommendations for the Century Commission and future conservation land acquisition and growth management decisions. Proposed next steps include comparing CLIP to development projects and proposed transportation projects to determine how to maximize compatibility and policy priorities for guiding Florida’s future growth. CLIP will also be combined with the Florida Fish and Wildlife Conservation Commission’s Conservation Blueprint initiative to coordinate and integrate their similar goals and maximize synergy.

CONCLUSIONS: OPPORTUNITIES AND CHALLENGES FOR PROTECTING CONSERVATION CORRIDORS IN THE SOUTHEAST

Probably the most important, obvious trend emerging regarding land corridors is the importance of regional scale, integrated planning. There are many processes and land uses occurring in regional landscapes that are impacting biodiversity, ecological integrity, and sustainability. In support, scientific research over the last three decades shows that the process linkages between various ecosystems and land uses are strong, and that effectively conserving biodiversity requires working at large spatial scales. However, impacts to ecosystem services and biodiversity are occurring at all scales from local to global. To be effective, conservation planning
strategies must successfully integrate planning at multiple scales AND link the importance of conservation to all other elements of planning including economic, transportation, energy, national security, etc. The need to protect conservation corridors for biodiversity and ecosystem services must be linked to the need for environmentally sound economic development and human health (Grifo and Rosenthal 1997). It will be very important for ecological decision making to be placed in a “multiple benefits” planning framework to provide economic incentives for ecological system and service protection. For example, The Conservation Fund is working with multiple partners in the Southeast to protect biodiversity and ecosystem services using an integrated planning process that considers:

- Economic / “Gray Infrastructure”,
- Conservation / “Green Infrastructure”,
- Ecological Services,
- Energy, and
- National Security / Compatible Land Use

The green infrastructure concept is therefore extremely relevant. It is a planning framework that links protection of biodiversity and conservation corridors with protection of lands that provide ecosystem services and other related benefits to human communities (Benedict and McMahon 2006). The connection between protection of biodiversity, ecosystem services, and human values will be essential in continued efforts to protect conservation corridors in the Southeast.

One of the most important challenges for such an approach is the successful collaboration and effective integration of planning at multiple scales (Hoctor et al. 2004b). One of the most important obstacles to regional conservation planning in the United States is a strong bias towards local land use decision-making. Research has made clear that regional-scale planning is required to understand how ecosystems and ecological processes fit together and to develop effective strategies for conserving biodiversity and ecosystem processes that remain viable and functional. Reconciling the predominance of local planning and the need to include the public, private land owners, and all stakeholders with the imperative for regional-scale analysis and planning is an essential issue facing conservation planning. Policy analysis that informs practitioners on the best methods for ensuring successful collaboration across jurisdictional levels including local, regional, state, and federal, while effectively including the public and stakeholders is a key research need. One requirement is to firmly establish the necessity of ecosystem sustainability for maintaining healthy ecosystems and human communities at all scales of planning and decision-making (Meffe and Carroll 1997; Hoctor et al. 2004b).

The opportunities for protecting conservation corridors are many. Science continues to expand our knowledge about ecosystem processes and the importance and characteristics of functional connectivity. Geographic Information Systems has led to the development of many existing plans and data that can be very useful to regional conservation projects. There are also a variety of sophisticated and increasingly easy to use analytical and decision support tools for conducting planning at all scales. Public policy also continues to evolve to more thoroughly incorporate ecological sustainability into planning. The public increasingly supports the protection of greenspace, and, overall, budgets for protecting conservation lands are expanding. Conservation easement policy has recently changed to make them more financially attractive to private landowners, and various incentive and subsidy programs exist to restore and manage wetlands, forests, and other habitats on private lands. Growth management has not been very effective but continues to evolve to address human population growth and sprawl. Finally, institutions are responding to the threat of climate change in ways that will significantly enhance available resources for restoring ecosystems and ecological connectivity.
An important challenge is the difference between planning for protecting conservation corridors versus more traditional conservation land protection. In the past, governments and private organizations had the flexibility to work with various willing landowners across regions to protect lands important for biodiversity and natural resources. However, protecting connectivity frequently results in significant spatial constraints where there are many less options because there are only a few opportunities to restore or protect functional corridors. In Florida, a relevant issue is increased development pressure along major roads within conservation corridor projects, which has led to discussion about whether such lands should be protected first so that they do not become obstacles before the rest of the project can be completed. Though it makes sense to prefer to work with large private landowners to increase efficiency and reduce costs (Morrison and Reynolds 2006), conservation corridors may require working with many small private landowners to protect connectivity. Therefore, cooperation with local governments and local land trusts, and the use of various conservation tools and incentives such as easements and habitat management programs, must be fully explored. Protecting conservation corridors will also require full consideration of trade-offs regarding various options for protecting connectivity in terms of spatial locations, land use and land management policies, and the various economic alternatives for protecting land (Morrison and Reynolds 2006).

Rapid human population growth combined with global climate change is by far the biggest challenge facing conservation corridors protection. The pace of habitat loss and fragmentation requires that planners work quickly without complete information about location of priority ecological areas and policy options, and some options for protecting connectivity may disappear before we have time to safeguard them. Rapid human population growth also drives up land prices, which is straining land conservation acquisition budgets, and buying power has been decreasing. Governments and various non-governmental organizations need to work together to inform the public about this crisis to generate an effective increase in land conservation budgets from federal to local levels. The impacts of global climate change on biodiversity and ecosystem function is greatly exacerbated by the high levels of habitat fragmentation in most regions. Climate change is occurring rapidly in an evolutionary context, and species have much less opportunity to functionally respond because of diminished landscape connectivity and habitat gradients (Lovejoy and Hannah 2004). Therefore, the final question is, “Can conservation planning effectively keep up in a rapidly changing world?” One answer is that regional conservation planning that is well integrated with other planning scales and emphasizes the interconnectedness and interdependence of nature and human communities has the best chance of doing so.

ACKNOWLEDGEMENTS

The authors want to thank the U.S. Department of Defense for funding the development of this article as part of the SERPPAS effort.
LITERATURE CITED


