Babcock Ranch




Steering Committee Final Report
January 2011

BABCOCK RANCH

Table of Contents

Steering Committee Charge

In July of 2006, as part of a settlement with the Sierra Club, Clarke Keller and Gail Giles, Kitson & Partners established a Steering Committee made up of local and statewide parties to better understand future growth patterns for the areas surrounding the Babcock Ranch Preserve and to develop strategies to protect, enhance and re-establish wildlife corridors. The primary charge was to use the available resources (people, money and previously completed studies) to study and create recommendations for future land use and wildlife corridors, including coordinated action steps for implementation. Through a public workshop style format, the Steering Committee has gathered science-based information, discussed available tools and strategies, and developed consensus on what to do next.

The goal of the Steering Committee was to conduct a land use study to assist with understanding current and future growth patterns, anticipated conservation objectives, potential development activities, and the protection of the Caloosahatchee River and to conduct a regional wildlife corridor study to assist with understanding existing and potential corridors. Early on, the Steering Committee established a philosophy that would guide the Steering Committee and its members to work collaboratively and develop consensus recommendations that can hopefully be used by policy makers, landowners, citizens and other interested parties, for better land use planning and protecting wildlife corridors connecting to and surrounding the Babcock Ranch Preserve and the City of Babcock Ranch. It should be understood that the Steering Committee has no regulatory or other authority, and accordingly, the ability to positively influence policy and implementation rests upon the strength of the ideas and the broad-based membership of the Steering Committee.

The members of the Steering Committee represented multiple viewpoints and positions, which ultimately helped to develop the best possible recommendations. Due to the many different perspectives and the ability to discuss difficult policy issues in a productive and respectful manner, the Steering Committee members were deemed the “unlikely coalition.”

Meetings

The Steering Committee held sixteen meetings between January of 2007 and August of 2010, with broad representation from many diverse interests, including state and local government, environmental organizations, landowners, consultants and interested citizens. The meetings were held on January 28, 2007, February 20, 2007, March 20, 2007, April 23, 2007, May 30, 2007, August 8, 2007, September 27, 2007, April 8, 2008, May 21, 2008, July 9, 2008, November 5, 2008, March 25, 2009, June 12, 2009, September 29, 2009, February 26, 2010 and August 25, 2010. The participants and affiliations are set forth in Appendix 1 (please note that not all participants attended all meetings).

Overview

The following report is a summary of the major topics of discussions that took place during the course of the Steering Committee meetings. Many additional resources and studies are referenced and discussed throughout this Final Report. Also included in the Appendix is the complete Babcock Ranch Regional Connectivity Study report, dated February 22, 2010, by Reed Noss and Tom Hoctor. The goal of this Final Report is to highlight the major topics and points of discussion and will not include all of the information discussed during the meetings. If anyone is interested in the more detailed discussions that took place, please request a copy of the Steering Committee summaries that were completed for each meeting. The major topics of discussion are listed and detailed below.

Land Use

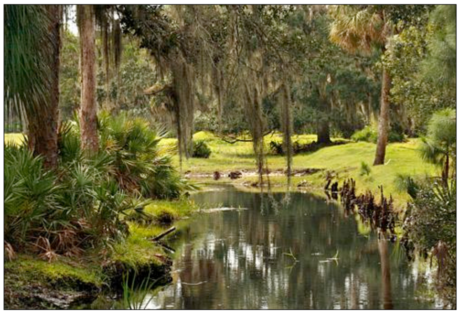
One of the Steering Committee's main goals was to focus on land use from a regional perspective. Due to the large size of the Babcock Ranch Preserve and its connection with the Fred C. Babcock-Cecil M. Webb Wildlife Management Area, many land use issues arose during the course of the Steering Committee meetings. While land use and wildlife corridors are ultimately interrelated, for this Final Report they have been separated in order to discuss the individual merits of each.

In order to have a complete discussion on land use in the region, the Steering Committee started by consulting GIS databases and reviewed and discussed existing studies to fill in any information gaps that may exist. These coordinated databases should be used for future work, and need to be updated over time as better data becomes available.

The Steering Committee generally agreed that public acquisition of property by itself is not going to accomplish the overall goal of protecting and preserving wildlife corridors. The Steering Committee felt that local governments could do a better job dealing with land use if they were able to foster involvement in a non-adversarial manner and educate landowners, citizens, advocacy groups and others within the community. Currently, there is not enough public outreach and involvement for planning in advance of specific development applications to actively make better land use decisions. The Steering Committee also felt that the paradigm needs to change from thinking of "no growth" to "smart growth with environmental protection" when considering how to evaluate land use decisions. This is especially important when trying to plan for climate change and potential sea level rise. Proper land use planning needs to happen now to protect key core areas and habitat linkages, including migratory corridors for wildlife.

Major Issues Affecting Land Use

One of the major areas of discussion, and ultimately one of major concern for the Steering Committee, was how to manage platted lots that have not yet been developed. Many of the counties in the region surrounding Babcock Ranch have platted lots that have yet to be developed. As part of the GIS information the Steering Committee reviewed, it was learned that some critical natural systems lie within areas that have already been platted but have not yet been developed.



Many of the platted lots have small parcels with many owners holding title. Some counties in the region have been investigating how to best deal with their undeveloped platted lots but have yet to create any policy to actively address this issue. A great opportunity currently exists to protect natural systems that surround the Babcock Ranch Preserve due to the current lull in the economy.

Caloosahatchee River

The Caloosahatchee River was a major topic of discussion. There is increased awareness of its importance to recreation, water quantity for surrounding areas and the water quality and the effects of the interconnected bodies of water upon each other. Our charge was to look specifically at how land use decisions and wildlife orders could impact the Caloosahatchee River, rather than detailed discussion about the Caloosahatchee River itself. The Steering Committee agreed that it is critical to provide better access to the Caloosahatchee River. Currently, the general public's ability to connect or recreate with the river is limited. It was agreed that additional public access could be granted to the Caloosahatchee River, while integrating additional educational components. The Steering Committee suggested that water quality projects currently taking place and those that will take place embrace the opportunity to create public awareness by way of passive recreation. Included in the suggestions were the creation of additional hiking trails, boardwalks, canoe and kayak access and interpretative kiosks. The idea would be that, if properly planned, more than one public policy objective could be addressed or highlighted with the same project.

The SFWMD C-43 Reservoir project is primarily focused on creating additional water storage. As suggested by the Steering Committee, this project could potentially integrate passive recreation to help increase public awareness and education. In addition, the Steering Committee felt that this project should also include a water quality improvement component.

Wildlife Corridor Planning

Connectivity in planning and implementing wildlife corridors is critical, as fragmented habitat causes many problems, including problems with genetic diversity. The wildlife corridors applicable to the Babcock Ranch Preserve should account for Florida Black Bears, Florida Panther, Red Cockaded Woodpeckers and Fox Squirrels. These focal species were selected because they are good indicators of how other species may be affected by loss of habitat and corridors.

Wildlife corridors can be located based upon existing vegetation, field observations, existing data occurrence points, and computer modeling. Population modeling to address births and deaths, along with dispersal patterns, is also important in determining their location. There is merit to locating wildlife corridors along rivers. It is important to maintain or restore natural connections where possible; however, it is equally as important not to try to make connections that should not be made (for instance, in situations where a bottleneck or dead end could be created).

Functional connectivity deals with the needs of a particular species, as some species need different types and sizes of corridors. For instance, a gopher frog may move from an upland site to ponds during spring for breeding, but typically will not move a very long distance. For other species, longer distances are needed in varying widths, depending upon the adjacent land uses (e.g., the Florida Panther has a much larger range). There is also a need for connections between metapopulations so that genetic diversity is furthered (Florida Black Bear is an example). Either way, the key for creating or maintaining corridors is to circumvent barriers to movement.

For more information and greater analysis please review the Hoctor/Noss report located in the Appendix. The report goes into great detail on corridors and their importance to species movement in the region. In addition, the report covers the needs of the Florida Panther, Black Bear and Sherman Fox Squirrel.

Wildlife Crossings

A critical area of concern is the fragmentation of wildlife habitat and danger to animals from roads. The Steering Committee discussed the importance of limiting corridor fragmentation by better land use planning and the use of wildlife crossings in appropriate locations. The Steering Committee discussed the use of wildlife crossings for the areas surrounding Babcock Ranch, as well as the region. It is important to understand that wildlife crossings are not a "one size fits all" solution. Different species often require different sized crossings. It is important that any wildlife crossings and underpasses have appropriate fencing to direct both prey and predators to the crossings to minimize road kill. As to small mammals, turtles and snakes, the crossings can be much smaller, although barriers to movement such as curbs need to be minimized. Alternative types of curbs or openings in curbs should be located in conjunction with road crossings for these species. The Steering Committee referenced Florida Fish and Wildlife Conservation Commission (FWCC) information on wildlife crossings during discussions.

Mark Schulz of the Environmental Management Office, Florida Department of Transportation (FDOT), District 1, provided an overview of FDOT guidelines for wildlife crossings to the Steering Committee. Florida is a recognized national leader in building wildlife crossings, starting with the crossings on the expansion of Alligator Alley. Mr. Schulz's presentation covered an overview of the guidelines, the requirements for consideration including need, location and type, design considerations, and the process for getting involved. FDOT recommended getting involved early in the process at the planning/PD&E Phase, as by the time FDOT reaches the design and construction stage, it is very difficult to make changes in the plans. The current cost of a standard Florida Panther wildlife crossing, including fencing is approximately $4 million (this is an average cost, which will vary based on specific design and location). FDOT does not have funds to do retrofits on existing roads, so typically crossings are done as roads are widened.

One of the most important considerations is permanent protection on both sides of the road, either through public acquisition for conservation purposes or a conservation easement, so that the corridor will have certainty. Several studies on wildlife movement, such as the Least Cost Pathways analysis for Florida Panthers, University of Florida work on Black Bear movements, and work by Reed Noss and Marty Main in Collier County can be helpful in determining where wildlife crossings should be placed. Modeling for Least Cost Pathways works only if accurate habitat and habitat quality information is used. FWCC is working on an initial screening tool and an expanded least cost pathway for all of District 1, which is expected to cover both the Florida Panther and the Florida Black Bear.

Currently there are no plans for wildlife crossings for the expansion of I-75 between the two portions of the Fred C. Babcock–Cecil M. Webb Wildlife Management Area. The PD&E Study for that section has been completed. FWCC recommended to FDOT that wildlife crossings should be included in that section. The PD&E Study for SR 82 does include a wildlife crossing and FDOT is beginning to work on designing construction plans for that section. Although there is advance notice to state agencies of FDOT projects, there is currently no coordinated procedure for advance notice of County Road projects. It is important that people who are interested in wildlife movements and wildlife crossings stay informed as transportation projects are planned, and then input be given as early in the process as possible.

The Steering Committee also discussed the potential for specific studies to be done regarding potential locations for wildlife crossings on the roads surrounding Babcock Ranch. Analysis with respect to SR 31 is being done as part of the state and federal permitting for the City of Babcock Ranch, which will be responsible for two wildlife underpasses on SR 31 as that roadway is widened.

One of the most important strategies is to permanently protect corridors with road crossings before further fragmentation of ownership and land use takes place. These road crossings need to be properly sized for the species expected to use them, as panthers and bears need a larger crossing than snakes and turtles. Road kill data can be used to locate the best places for crossings. Also, the type of vegetation on both sides of the road is important: native species tend to encourage movement whereas some exotic species tend to discourage movement.

Least Cost Pathways (LCP)

A major topic of discussion for the Steering Committee was the use of Geographic Information System (GIS) databases to determine the LCP for corridor protection. By definition, an LCP is the path, among possibly many, between two points which has the lowest traversal cost, where cost is a function of time, distance, or other user-defined factors. Understanding LCPs for wildlife corridors is important in order to focus efforts on the protection of the most important wildlife corridors.

Essentially, a computer program evaluates the habitat between two points and determines which habitat a panther or other local species is most likely to use in getting from point A to point B. Most of the analysis done on LCPs has been done primarily south of the Caloosahatchee River, but more could be done north of the Caloosahatchee River. When considering the LCPs, care must be taken to include concerns of landowners.

The LCP analysis for the Florida Panther is based upon assigning a value to various habitat types. For instance, pine flatwoods are easy to cross for a panther, so they would be given a score of 0 to 1. An open pasture of 200 acres is harder to cross, so it would be given a score of 4 to 5. A Wal-Mart parking lot would be very hard to cross, so it would be given a score of 10. The LCP analysis will assist in planning for corridors, to allow movement between Everglades National Park, Big Cypress National Preserve and the Florida Panther National Wildlife Refuge and other areas to the north, and connect various metapopulations of panthers. The modeling efforts to date correlate reasonably well with the telemetry data.

Over the course of the Steering Committee meetings, Tom Hoctor and Reed Noss worked on creating a LCP study that demonstrates the existing corridors that could potentially be used by panthers, bears and Sherman Fox Squirrels. The following is an executive summary of

Tom Hoctor's and Reed Noss's work on the Wildlife Corridor Study. The complete Wildlife Corridor Study can be found in the appendix of this report.

This study assesses opportunities for facilitating regional ecological connectivity between Babcock Ranch and surrounding lands of high ecological value to assist the Babcock Ranch Steering Committee with its work. We reviewed existing reports and spatial data and conducted new analyses using currently available land-use data and spatial models, as well as data from new studies. These data are of sufficient resolution for state and regional scale conservation planning and can be particularly useful for such applications, however, the data are not appropriate for use in high accuracy mapping applications such as property parcel boundaries, local government comprehensive plans, zoning, DRI, site plans, environmental resource or other agency permitting, wetland delineations, or other uses requiring more specific and ground survey quality data. The analysis, maps and data in this report were developed for state and regional conservation planning purposes and are not intended, nor sufficient, to be the basis for local government comprehensive plans, environmental resource or agency permitting decisions. They are however relevant for informing decision making as to areas needing more attention and potentially more detailed study.

Issues related to facilitating connectivity, including road crossings and potential corridor bottlenecks were also assessed, as was the need for additional research and analyses. The study area for this research included the lands immediately surrounding Babcock Ranch, nested within a larger landscape that extends, for least cost path analysis, northward to Tampa Bay, east to the Kissimmee River Valley, and south to Big Cypress; for long-term connectivity considerations, a still larger study area is appropriate, north to the Green Swamp and south to the Everglades. Additional analysis and coordination is also needed to determine how best to establish better connectivity, using a broad range of potential tools and working with private and public landowners on implementation strategies.
We begin this report with a review of some functions of ecological connectivity.

Connectivity is determined by the intersection of a species' life history characteristics, including its behavior, and the structure of the landscape. For a particular corridor or greenway to provide functional connectivity, we have to know a considerable amount about the species that we hope will benefit from the corridor, as well as about the habitat structure and landscape context of the corridor.

There are many potential functions of connectivity. Besides their value in providing dwelling and breeding habitat for some species, corridors potentially facilitate: (1) movement of animals within home ranges; (2) seasonal migrations or wanderings of animals; and (3) dispersal of juveniles or adults of animal or plant species, which in turn provides for colonization or recolonization of suitable habitat patches and for movement of individuals among populations over a larger area. Large-bodied animals, in particular, have large home ranges, for example on the order of 416.5 km2 for male Florida panthers. We review evidence that the current habitats of three focal species that we consider in this study – Florida panther, Florida black bear, and Sherman's fox squirrel – are becoming fragmented, and that these species would benefit from protection and restoration of functional habitat corridors. Dispersal and colonization of new habitats by many species will be of critical importance for adaptation to climate change, including escape from rising sea level, which we believe is an urgent issue in Florida.

Information used in this study include data on existing conservation lands; Florida Forever projects; the Florida Ecological Greenways Network; Water Management District 2004-2006 FLUCCS Land Use data; Strategic Habitat Conservation Areas for Florida panther and Florida black bear from the Florida Fish and Wildlife Conservation Commission (FWC); data on Florida black bear range, locations, and roadkills from FWC; Highlands-Glades Florida black bear range and telemetry data from University of Kentucky; Florida black bear habitat priority areas delineated by T. Hoctor; data on Florida panther locations and mortality from FWC; U.S. Fish and Wildlife Service (FWS) Panther Subteam Habitat Conservation Zones; Florida panther Habitat Protection Priority Areas; National Hydrography Flowline data; Conservation Lands and Waters Identification Program (CLIP) landscape integrity data; Florida Natural Areas Inventory (2008) Babcock Ranch Ecological Inventories; Johnson Engineering roadkill data and other information from reports; GIS data prepared by Johnson Engineering for the Babcock Ranch Steering Committee; Babcock Ranch Primary Internal Transportation Plan, Primary Greenway Plan, and Preserve Recreation Master Plan; and the primary literature (scientific journal articles, etc.).

The methods of this study included: (1) A review of existing literature, databases, and other information; (2) development and refinement of habitat models for 3 focal species – Florida panther, Florida black bear, and Sherman's fox squirrel; (3) ground-truthing of habitat models and assessment of habitat quality for focal species within Babcock Ranch; (4) collection of roadkill data and observations on roads surrounding Babcock Ranch; (5) identification of regional-scale habitat corridors (high, moderate, and low connectivity options) using least-cost path analysis, visual interpretation of habitat and conservation area patterns, and other methods; and (6) comparison of results to future scenarios, including alternative future development scenarios (e.g., Florida 2060) and sea-level rise scenarios.

Regarding the habitat models for the three focal species, the Florida black bear habitat model was based on 4 variables: land cover type, patch size, distance from primary habitat patches, and connectivity to large habitat patches. Florida panther habitat was identified using all forest cover patches 5 acres or larger and secondary habitat within 200 meters; Fox squirrel habitat was identified using 4 variables: land cover type, patch size, distance from primary habitat patches, and landscape large enough to support potentially viable populations. For the least cost path (LCP) analysis, LCP was defined as the best potential route between a source and destination based on a cost surface. The least costly route is essentially the path of least resistance, where resistance is defined by unsuitable or low-security habitat for the species in question. We created 6 different cost surfaces for each focal species. Cost surfaces variations included: habitat for focal species reclassified into a cost surface; habitat plus major roads; habitat, major roads, and edge effects; habitat, major roads, edge effects, and sea-level rise; habitat plus CLIP Landscape Integrity layer; and influence of roads, edge effects, and sea-level rise. The destinations included for the LCPs leading outward from Babcock Ranch were Big Cypress National Preserve, Okaloacoochee Slough State Forest, Fisheating Creek Wildlife Management Area, Bright Hour Watershed, the Myakka complex of conservation lands (Myakka), and the Avon Park Air Force Range. Therefore, with 6 cost surfaces and 6 destinations, there were 36 LCP results for each focal species.

We integrated results from these analyses into three conservation options: low, moderate, and high connectivity options. We used the following datasets to create the three connectivity options: The low connectivity option included existing conservation lands; the Caloosahatchee Ecoscape Florida Forever Project; one set of LCP results buffered by 1 mile between Babcock Ranch and the six selected destinations. The moderate connectivity option included existing conservation lands; Florida Forever Projects; two panther and two bear cost surface buffered LCP results buffered by 1 mile; all Critical Linkages within the Florida Ecological Greenways Network; all primary and secondary black bear habitat within primary range identified by FWC, all bear population habitat conservation recommendations delineated by T. Hoctor, or the new FWC bear SHCAs; all panther habitat within the USFWS Panther Subteam Primary and Dispersal Zones, or the older FWC Habitat Protection Plan areas, or the new FWC SHCAs; and the Integrated Habitat Network (given a value of 2 whereas all other areas within the option were given a value of

1). The high connectivity option included existing conservation lands; Florida Forever Projects; two panther and two bear cost surface buffered LCP results buffered by 1 mile; all areas within the Florida Ecological Greenways Network; all potential bear (primary and secondary), panther, and fox squirrel habitat (primary and secondary); all regional and local riparian corridors; and the Integrated Habitat Network (given a value of 2 whereas all other areas within the option were given a value of 1).

The LCPs clearly demonstrate potential options to connect Babcock Ranch to other large conservation areas in the study region. LCP results for the Florida Panther and Florida Black Bear are similar in most cases. Although the fox squirrel LCPs showed some deviation for several destinations, the overall pattern of potential connectivity for fox squirrels is similar to that for panthers and bears; hence, we suggest that fox squirrel connectivity may be suitably addressed at the regional scale by the best options for panthers and bears. In addition, local to landscape-scale connectivity may be more important for fox squirrels within this region due to the fragmented habitat base and lower dispersal capabilities. Further research on fox squirrels in the region could include identification of core habitat areas and the opportunities to restore or maximize connectivity at the local to landscape scales through habitat management, restoration, and protection.

Our analysis of LCP overlap provided an objective method for evaluation of best potential corridors between Babcock Ranch and other large regional conservation areas. However, selection of best corridor options also requires a more subjective expert analysis of factors potentially critical to population persistence, including the number and location of road crossings, presence of bottlenecks/proximity to areas of intensive development, length of corridors, consistency with existing guiding features in the landscape such as riparian corridors, etc. Before developing the connectivity options, we conducted these additional visual assessments of LCP results to select the best potential corridor options. From this assessment, we determined that LCPs based on two separate cost surfaces for both panthers and bears were most applicable to developing the various conservation scenarios.

The three connectivity options fall along a gradient of political and economic feasibility. The low connectivity option primarily represents the minimum feasible or most constrained effort to functionally connect Babcock Ranch with other larger existing conservation lands in the region. The moderate connectivity option is intended to represent a primary option for protecting and restoring functional connectivity across the region. The high connectivity option represents almost all existing areas that contribute, or could contribute, to protection of a functionally connected ecological network in the study area. All options would require addition of lands to Florida's conservation area network. For example, approximately 1.7

million acres of private land is included in the moderate connectivity option, with approximately 500,000 of those acres within proposed Florida Forever projects, as well as 400,000 acres of wetlands.

Assuming that all potential habitat is suitable habitat and that individual animals can move freely through the corridor network, which is actually unlikely, we made crude estimates of potential population sizes for the three focal species under the three connectivity options. To partially correct for biases, we provided population estimates based on the unrealistic assumption that all potential habitat is suitable and compared these with estimates based on an arbitrary but more realistic assumption that only 75% (for panthers and bears) or 50% (for fox squirrels) of the potential habitat in each connectivity option is suitable.

Applying the moderate connectivity option, the 75% suitable habitat assumption, and population densities obtained from a study in Ocala National Forest, for example, the study region could support 1582 to 2331 bears. Under the same option and 75% suitable habitat assumption, and using population densities calculated by Maehr et al. (1991), the study region could support 65 to 89 panthers. And under the same option, a 50% suitable habitat assumption, and density estimates from two studies of fox squirrels, the study region could support 4,609 to 13,829 fox squirrels. Nevertheless, these revised estimates are still highly optimistic, especially so for the fox squirrel, for which so little of the potential habitat is suitable today due to inappropriate management for the fox squirrel. Especially for habitat specialist species such as the fox squirrel, protection of large habitat blocks and connections among blocks is not enough to assure persistence. Ecological management to maintain suitable habitat – both within Babcock Ranch and within other existing and potential conservation areas within the study region – is essential to assure population viability. The fox squirrel, in particular, requires an open understory, as maintained historically by frequent growing-season fire in pinelands.

In summary, we found that options for maintaining connectivity for three focal species – Florida panther, Florida black bear, and Sherman's fox squirrel – between Babcock Ranch and other existing and potential conservation areas within the regional landscape are still relatively abundant and intact. Nevertheless, several problematic corridor bottlenecks are present already in the region and will constrain animal movement unless remedied by increased land protection and mitigation of impacts from roads and development.

Moreover, unless potential conservation areas (e.g., Florida Forever projects) are protected soon, connectivity for our focal species and many other animals will be significantly diminished, especially if human population growth and development continue in the study region and if road impacts (increased traffic volume, road widening, etc.) are not reduced by properly located and designed wildlife crossings and associated barrier fencing. Impacts from sea-level rise, although predicted to be relatively minor in the immediate vicinity of Babcock Ranch, are likely to be severe in the southern and western portions of our study area and in the Lower Peace and Myakka River areas, where some of our identified LCPs will be severed by rising waters. Moreover, even inland areas substantially above 3 meters in elevation will be at high risk as displaced people flee the coasts over the coming decades. This likely phenomenon underscores the need to protect key core areas and landscape linkages soon.

Further work is needed to evaluate available tools to plan and seek to implement any of these connectivity options. Future Florida Forever or other acquisition programs, landowner incentives, private conservation efforts, innovative planning strategies, and other tools will be needed to actually accomplish the creation of a connectivity strategy.

Educational Resources

During the course of the Steering Committee meetings, a number of GIS databases and studies were assembled and reviewed prior to creating recommendations. It is important to note that current GIS databases reviewed were coarse and not recommended for detailed "parcel by parcel" planning. However, the GIS databases did give the Steering Committee an overview of the major natural systems, developed areas and transportation networks needed to guide the Committee's recommendations.

Lengthy discussions took place about the areas and natural systems that lie north and northwest of the Babcock Preserve. By looking at the GIS information, the Steering Committee was able to review the areas that were most important from a wildlife perspective. The Steering Committee discovered that there are a number of natural systems intact that benefit the Caloosahatchee River and that the lands to the north and south of Babcock Ranch should be focused on from a wildlife perspective.

GIS can be extremely valuable, especially in helping create effective policy. For example, when the Steering Committee reviewed GIS information, lengthy discussions took place about how to better maximize the Babcock Ranch purchase from a connectivity perspective.

The Steering Committee was able to see that a number of natural systems are currently intact surrounding the Babcock Ranch purchase by looking at maps without ownership lines. When ownership lines were viewed, it became obvious that many of the natural systems still intact were in places that had previously been platted for development. By using GIS the Steering Committee was better able to focus its recommendations and policy decisions for local governments on how to deal with undeveloped platted lots.
For planning purposes, the GIS information allowed the Steering Committee to identify the most important areas needing protection from development. The use of GIS, along with proper agency coordination, could help focus resources on the most important properties that need protection while helping better direct where development goes to minimize environmental impacts.

Landowner Incentive Programs

Currently missing from the toolbox is a set of incentives for rural property owners and counties to protect land from development. There is a need for state incentives for restoring and maintaining habitat for listed species and other wildlife. Large portions of the state's wildlife habitat acreage are in private ownership, and much of this land is currently used for low intensity ranching and forestry. Modification of estate and other taxes as an incentive to leave land in native range is urgently needed, as is the need to create additional conservation incentives for private owners. FWCC is starting to take a proactive approach to conservation planning, rather than relying upon project by project permitting review. The strategy is to go to the counties and work with them on their comprehensive plans, particularly their Evaluation and Appraisal Reports, to identify important conservation areas and potential approaches to protecting ecosystems. This will also include information on and suggestions for management for both public and private lands. FWCC is also seeking to engage landowners in proactive conservation planning and management.

The Steering Committee discussed the FWCC's Cooperative Conservation Blueprint (CCB) and its relationship to the Century Commission's Critical Lands and Waters Identification Project (CLIP) and how these efforts could assist the communities surrounding Babcock Ranch with future conservation planning. FWCC created the CCB to build agreement between government and private interests to use common priorities as the basis for statewide land-use decisions. The major focus of the CCB is to create a toolbox of incentives that can be used by landowners statewide.

The CCB will consist of the following elements:

1. a fully unified set of Geographic Information System (GIS) data layers of priority statewide natural land and water resource areas, working landscapes and development areas,
2. an online application to make the GIS data layer(s) available to all Floridians, and

3. a package of recommended landowner incentives needed to apply the integrated land-use, natural resource and habitat conservation strategies statewide.

The purpose of the blueprint is to help conserve vital working landscapes and natural resources while maintaining a sustainable economy and conserving Florida's farms and ranches. A public/private partnership will create, publish on-line, and maintain a centralized GIS application of common priorities. The blueprint will help to guide future land-use planning decisions and recommend market-based incentives that encourage conservation.

The CCB is needed for several reasons:

1. to help envision Florida by looking 25 and 50 years into the future,
2. to address the impacts of population growth and minimize the conversion of natural, rural and agricultural lands,
3. to lead a coordinated effort that integrates environmental, social and economic factors to enhance the quality of life for future generations of Floridians, and
4. to make the process of developing habitat conservation priorities transparent to everyone.

Government agencies and broad-based public user and interest groups will collaborate to develop the blueprint. A steering committee comprised of public and private interests provides oversight and direction for the effort. A team manages and guides the process. Contractors and technical experts produce the integrated GIS data layers of priorities and the GIS tools, apply the process and facilitate meetings.

The key to successful use and implementation of incentives is to have consistent, science-based data, and to provide incentives and innovative tools for landowners and government to implement better conservation planning (and better communities as a result). FWCC has prioritized stakeholder involvement. As a result, FWCC has been able to bring together multiple agencies and interests to help them develop their incentives.

In addition to the CCB, FWCC is currently working on the implementation of the federal safe harbor provisions of the Endangered Species Act, with more interest in the northern parts of the state.

Current Incentive or Easement Programs

Conservation easements are another tool not being utilized as much as they could be. One reason may be the permanent nature of most conservation easements, as a number of agricultural owners might be willing to restrict their uses for a period of time, say 10 – 15 years, but not willing to restrict them forever.

Also discussed was the Florida Ranchlands Environmental Services Project (FRESP) which is a public-private partnership involving the World Wildlife Fund, the Florida Department of Agriculture, state and federal agencies, and willing landowners. Under this program, rather than buying land with public funds, ranchers are paid to store water and for water quality improvements. This program is ready to move from its pilot phase into broader implementation. The Steering Committee discussed the need to make it financially rewarding for landowners to store water in the wet season rather than discharging excess water, and to have a number of different tools that can be employed for this purpose. Conservation acquisition programs

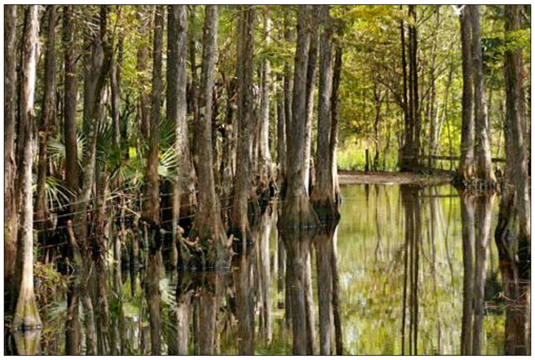
Since the State's acquisition of 73,000 acres of the Babcock Ranch Preserve, there have been additional land acquisitions. This section highlights some of the most pertinent local and regional acquisitions of significance.

The South Florida Water Management District (SFWMD) has been actively involved in a number of acquisitions during the past 4 years. The Imperial River Basin Restoration is almost completed, with $28,000,000 having been spent on a project with an original budget of $14,000,000. There are several remaining parcels that are needed, including one large parcel, and the SFWMD is considering the possible sale of certain lands not necessary for the environmental restoration that they had previously purchased. The cost to complete the Imperial River Basin Restoration will be more than double what was budgeted for the program.

The Northern Everglades Watershed Protection Plan is underway. The goal of this program is to clean the water in the basin, with a specific strategy of removing nutrients including nitrogen and phosphorus, and managing the correct amount of flow for the estuaries. Under the plan, the state will commit $100,000,000 per year and the SFWMD will commit $100,000,000 per year. All of the land has been acquired for the proposed C-43 reservoir and design and permitting have been completed. Construction is awaiting federal funds. The district is working on a design for the water quality project for the 1,770 acre Boma tract to the east of Port Labelle along the south side of the Caloosahatchee River (the focus will be to remove nitrogen from the water). The district is also continuing work in the Four Corners area, with a focus on an existing 3,500 acre citrus grove and a potential restoration plan. The most widely discussed acquisition has been the potential purchase of the U.S. Sugar lands. The purchase of a reduced number of acres, as a result of financial considerations, was approved and completed in October of 2010.

Local Government Acquisition

Since July of 2006, Lee County has continued its efforts to acquire environmentally sensitive properties. Lee County's acquisition program, the "Conservation 20/20 Program," made great strides and was able to protect a few key pieces of property since 2006. The Conservation 20/20 Program was established in 1997 and is based upon ½ a mil of ad valorem taxes, with 90% of the funds for acquisition and 10% of the funds for management. Since inception, the Conservation 20/20 Program has purchased 107 parcels totaling 23,821 acres. An additional 218 acres are currently under contract, and 190 acres under negotiation. The largest acquisition was 5,620 acres of the Babcock Ranch Preserve in July 2006 for a total of $41.5 million. Also in the vicinity, the 243 acre Daniels Preserve at Spanish Creek was purchased for $3.9 million in 2005 and the 1,727 acre Telegraph Creek Preserve (formerly known as the Argo Ranch) immediately south of the City of Babcock Ranch for $23.9 million in 2008.



Lee County is currently reviewing 29 willing seller applications that total 7,165 acres with a total asking price of $261,164,600 with an anticipated 2011 budget of only $27 million. Among these nominations are a 451 acre site that is approved for the development of 238 homesites and called the "Broadlands." This site is located directly south of the Telegraph Creek Preserve and borders the northern bank of a substantial segment of Telegraph Creek. Another nomination of 149 acres (known as the Amazing Grace parcel) is located immediately to the east of Babcock Ranch and would provide an eastern public access point to the Lee County portion of the Babcock Ranch Preserve.

The Conservation 20/20 Program has been very successful and popular, evidenced by Lee County's decision in 2010 to fully fund the program, even with budget cuts in other areas. Due to the slumping economy, the Conservation 20/20 Program is inundated with nominations of quality properties at bargain prices. There will probably never again be such an opportunity to buy key environmental parcels. Unfortunately, program funds are based on a percentage of property values, so funds are greatly diminished from previous years. Furthermore, there is no certainty that the program will continue to be funded as the program is only renewed annually during the budget process.

Charlotte County has been very successful with their Environmentally Sensitive Lands acquisition program as well, having acquired a number of key parcels throughout the county. The Environmentally Sensitive Lands committee is currently working on management plans for the properties that have already been acquired. The program has had some funding issues as the county did not receive the originally anticipated amount of $77 million. The county is searching for grants to reimburse them for the money that has already been spent to acquire lands. Despite the funding issues, the Environmentally Sensitive Lands committee has done a commendable job. Including the Babcock Ranch Preserve, Charlotte County is now second in the region for amount of lands protected, behind Collier County.

City of Babcock Ranch

From the very beginning it was Kitson & Partners' goal to build the most environmentally sensitive community possible to complement the protection of the Babcock Ranch Preserve. Over time, many aspects of the original Babcock Ranch Community's plan and design have changed but these changes were made with a great deal of input and the environment in mind. The Steering Committee has provided great insight and recommendations for the City of Babcock Ranch.

The goal of Kitson & Partners is for the City of Babcock Ranch to become a living laboratory, where innovative companies and universities can implement new technologies. Kitson & Partners is working in partnership with FPL to construct the country's largest solar photovoltaic facility, 75 MW, on approximately 400 acres of sod farms along the north side of the entrance road to Babcock Wilderness Adventures. Kitson & Partners and FPL will also be working together on roof top solar facilities for homes, businesses and civic buildings, and the use of smart grid technology throughout the City of Babcock Ranch.

Recommendations

The following recommendations represent the consensus of the Steering Committee, as generated from discussions during Steering Committee meetings, and form the basis for additional work in the region.

1. **The work of the Steering Committee should continue in the region.** This unlikely coalition has been successful in bringing together different viewpoints and perspectives and this group should continue to meet in some fashion. Based upon the work to date, it appears that this group of diverse interests represented on the Steering Committee could be a vehicle for a civil discussion about conservation and land use planning for the region as well as shaping future policy decisions. The consensus is that the work of the Steering Committee could be part of a proactive regional strategy to work on conservation and land use issues. Part of this work should focus on implementation of these recommendations as this broad and diverse group of interests should have credibility with policy makers.

Quarterly meetings are suggested. It is recommended that future efforts include Hardee County and Collier County.

2. **Reach out to Florida Gulf Coast University (FGCU) as a potential "permanent home" for this group.** With its focus on environmental studies, FGCU would seem to be an ideal platform for this effort, and once the FGCU ecological research center is established in the City of Babcock Ranch, the effort could be located there. It is important that the GIS database, including the additional GIS work done by Tom Hoctor and Reed Noss, be part of an ongoing effort to assemble and update such information. In the interim, perhaps FWCC can "house" the GIS database as part of the CCB pilot mentioned below. Steering committee members will want to coordinate with FGCU and other educational institutions for both technical and scientific support. It is also important that future residents of Babcock Ranch and visitors are aware of this coordinated effort.

3. **For continuing work, partner with Florida Fish and Wildlife Conservation Commission with respect to their Cooperative Conservation Blueprint.** As mentioned above, the FWC is continuing with its work on the CCB and part of this effort includes pilot projects to focus their efforts on more detailed conservation planning and implementation of potential incentives ideas. Southwest Florida, the Heartland Region and the Kissimmee River Basin have been identified as pilot project areas. This could prove to be an excellent opportunity to combine the efforts of the Steering Committee and the FWC in developing a strategy to protect corridors identified in the Wildlife Corridor Study completed by Tom Hoctor and Reed Noss. FWCC will be moving forward with the Southwest Florida Pilot Project and using the work of the Steering Committee as an integral component of that effort.

4. **Reach out to the United States Fish & Wildlife Service and Florida Department of Community Affairs.** USFWS will play an integral role in the future of conservation in Southwest Florida, and it is important that they be made aware of the work of the Babcock Ranch Steering Committee. USFWS is also embarking upon a somewhat similar program, the Landscape Conservation Cooperative for Peninsular Florida, which will be based in large part upon the work of the Cooperative Conservation Blueprint. This is an important effort for the region and the state. The Florida Department of Community Affairs is the lead state agency on land use planning, platted lands strategies, and local comprehensive planning, and it is important that it be involved as a partner in future work to implement the recommendations of the Babcock Ranch Steering Committee.

5. **Promote Babcock Ranch as a model for an alternative to conventional single-use sprawl.** With its preserve areas, connectivity and the wildlife corridors, mixed-use design, solar energy and smart grid focus, the City of Babcock Ranch is a positive precedent for future conservation and development alternatives. It is important to have successful alternatives. Other aspects to promote include, but are not limited to, use of native

landscaping, fertilizer restrictions, recruitment of green industry to Southwest Florida, alternative transportation, restoration activities and preserve areas with public access.

6. **Steering Committee members should be active in current efforts to update local comprehensive plans and encourage use of strategies discussed in this report.** Educational and outreach efforts are very important, particularly at a grassroots level, if there is to be any change from the status quo disjointed planning process. The concept of increased density and intensity on certain lands with lower environmental value, with good design, so that important natural areas can be conserved and managed permanently without any development should be further evaluated and used in appropriate locations. Where appropriate, development credits should be transferred to existing urban areas. Current planning densities of one unit per acre and even lower densities will still result in large areas of development, with fragmented habitat. To achieve a different result, comprehensive plans will need to be amended. Steering Committee members should continue to provide input to these efforts, with a particular emphasis on connecting and protecting critical wildlife corridors. Through coordinated efforts, Steering Committee members can have a positive impact on conservation planning in the region.

7. **Incentives should be developed that give real economic value to landowners for private conservation of important natural areas.** As a complement to public acquisition of lands and conservation easements, an easy to understand set of incentives needs to be developed so that landowners will agree to permanently protect important natural areas, including working landscapes such as farms and ranches. These could include property tax and other tax incentives, payments for ecosystem services, transfer of development rights, extended permits for water and water management, and other incentives that could be developed relating to land use, transportation concurrency, ecotourism, etc. The program of incentives should encourage protection of a connected system of wildlife corridors throughout the region before additional fragmentation of habitat takes place. All potential incentives should be very carefully evaluated so that all potential impacts and benefits are understood, as well as the appropriate use of any potential incentives.

8. **Payment for Ecosystem Services programs should be developed.** The Florida Ranchlands Environmental Services Project (FRESP) is a public-private partnership involving the World Wildlife Fund, SFWMD, Florida Department of Agriculture and Consumer Services (FDACS), state and federal agencies, and willing landowners, currently in a pilot stage to evaluate the public and private values of such a program. Where additional water storage infrastructure is needed for regional water supply, ranchers could be paid to store water and for specified water quality improvements on their land, while still being able to conduct compatible agricultural operations. The concept is to provide a cost-effective alternative to large public works projects. In the near future, the pilot project could be ready to move into a broader implementation phase. In general, if the program can be developed that would make it financially rewarding for landowners to store water in the

wet season rather than discharging excess water, such a program could be a less expensive way to accomplish multiple objectives. Multipurpose projects should be encouraged, particularly those that have a positive impact on water quality and wildlife habitat. Again, all of these potential ecosystem services should be very carefully evaluated so that all potential impacts and benefits are understood, as well as the appropriate use of these programs.

9. Conservation easements should be encouraged as an alternative to fee simple acquisition. Conservation easements need to be utilized more often. If they are conservation easements purchased with public funds, the funds go farther because a less than fee acquisition is less expensive. If they are conservation easements as a result of a permitting decision, such as one resulting from an environmental resource permit from the SFWMD, public funds are not used for the acquisition. Either way, the private landowner would retain ownership and maintenance responsibilities. Permanent conservation easements are more desirable from a conservation perspective, so that the land can be permanently protected. In certain limited circumstances, a less than permanent conservation easement (or agricultural easement) can be preferable to no protection from conservation perspective and acceptable to the land owner. Such an approach could be beneficial as it would provide a "time out" from development pressures. While this approach brings about additional concerns, the Steering Committee recognized potential issues such as the effect of temporary conservation easement on future uses and how to appropriately value temporary easements.

10. To achieve conservation objectives, there need to be more incentives. The existing regulatory system allows for conservation easements as part of the permitting process. If it can be financially beneficial to the owner, as well as to the public, conservation beyond that required for permitting would be a more desirable result. The region needs to better understand how the economy and the environment are linked. The Steering Committee recognizes the value of integrating the environment with the economy as opposed to separating the environment with the economy. In addition to regulations, additional incentives should be carefully evaluated so that all potential impacts and benefits are understood, and if appropriate, they should be implemented.

11. Better communication and coordination between state and federal agencies, counties, environmental organizations and land owners is needed. One of the most important discussions taking place throughout the Steering Committee meetings related to this topic. As different perspectives are discussed and explored, common ground is identified, and mutual objectives can be formulated. The involvement of state and federal agencies, along with county representatives, is a model that should be continued. It is believed that increased participation and awareness will result in a better future condition.

12. **Land swaps and other program for platted lots should be developed.** As discussed, the region has a tremendous number of platted lots that are still undeveloped (many without any roads or other infrastructure) and these lands contain valuable natural systems that could be contained within protected wildlife corridors. The surrounding counties could offer a program in which the owners of the platted lots could swap their undeveloped lots for lots that already have or are planned to have public infrastructure. Land swaps could also be used to connect to and enhance previously purchased public conservation lands, by consolidating ownership and uses. Initial focus areas should include Lehigh Acres.

13. **The region should focus on creating green jobs and green industry.** As a complement to the wildlife corridor and land use strategies, a green industry focus should be employed. The region is uniquely positioned as an area where the environment and the economy are inextricably linked. In order to be economically sustainable, the region needs to utilize its strengths and recruit industries such as hurricane window production, solar assembly/manufacturing and other green collar jobs.

14. **Consensus is better than confrontation.** In many situations, working together to achieve common objectives will achieve better results than the alternative. Although there are exceptions, if people can focus their energies on the many areas where there is mutual agreement, they will accomplish more than if they focus their energies on the few areas where there is disagreement. The ability to have open dialogue in a framework conducive to such discussions is critical.

Appendix 1 - List of Individuals Participating in Steering Committee Meetings

Jim Beever
Southwest Florida Regional Planning Council

Ellie Boyd
Responsible Growth Management Coalition

Brian Branceforte
Florida Fish & Wildlife Conservation Commission

Ruth Bromberg
Sierra Club- Greater Charlotte Harbor

Bill Byle
Charlotte County

Mary Bryant
The Nature Conservancy

Iris Casanova
American Prime

Sarah Catala
Hendry County

Vince Cautero
Hendry County

David Ceilley
Florida Gulf Coast University

Al Cheatham
Charlotte Harbor Environmental Center

Erica Chutkan
Kitson Babcock

Brad Cornell
Collier Audubon

Cris Costello
Sierra Club

Ernie Cox
Family Lands Remembered

Marti Daltry
Sierra Field Representative, Ft. Myers

Wayne Daltry
Lee County- Smart Growth

Tom Danahy
Kitson Babcock

Dan Delisi
Delisi Fitzgerald

Andy Dodd
Peninsula Property

Terrey Dolan
Lykes Land Investments

Thomas Eason
Defenders of Wildlife

Elizabeth Fleming
South Florida Water Management District

Tom Flood
Collier Enterprises

Ed Flowers
Fla. Deptarment of Agriculture, Division of Forestry

Gail Giles
Sierra Club, Greater Charlotte Harbor

Brian Goguen
Barron Collier

Luis Gonzalez
Florida Fish & Wildlife Conservation Commission

Suzy Hackett
Charlotte County Code Enforcement

Tammy Hall
Lee County

Bill Hammond
Kitson Babcock

Cathy Harrelson
Defenders of Wildlife

Ken Heatherington
SWFRPC

Larry Hilton

Tom Hoctor
Geoplan/University of Florida

Paul Holmes
Eco-Voice of SW Florida

Frank Jackalone
Sierra Club

Jerry Jackson
Florida Gulf Coast University

Tom Jones
Barron Collier

Alan Keller
Collier County Audubon

Clarke Keller

Mike Kemmerer
Florida Fish & Wildlife Conservation Commission

Darrell Land
Florida Fish & Wildlife Conservation Commission

Johnny Limbaugh
State of Florida Department of Transportation

Mike Lohr
Johnson Engineering

Paul Lohr
Johnson Engineering

Kim Love
Cooperative Conservation Blueprint

Andrew McElwaine
Conservancy of SWFL

Peg McPherson
Everglades Foundation

Laurie Macdonald
Defenders of Wildlife

Marty Main
University of Florida

Paul Mann
Miller Legg

Tom Moore
Charlotte County

Mark Morton
Lykes

Bob Mulhere
RWA

John Murray

Gary Nelson
Kitson Babcock

Reed, F. Noss, PhD
University of Central Florida

Myra J.W. Noss
University of Central Florida

Paul O'Connor
Lee County

Mary Oakley
University of Florida (Cooperative Conservation Blueprint Initiative)

Tony Palermo
Lee County

Ellen Peterson
Sierra Club- Calusa Chapter

Sue Reske
Sierra Club-Greater Charlotte Harbor

H.M. Ridgely III
Evans Properties, Inc.

Rosanna Rivero
Everglades Foundation

Church Roberts
Johnson Engineering

Mike Rosen
Collier Enterprises

Shane Rye
Family Lands Remembered

Pete Quasius
Collier Audubon

Gordon Romeis
Florida Deptartment of Environmental Protection

Donald Schrotenboer
Alico

Mark Schulz
Florida Department of Transportation

Matthew Schwartz
Sierra Wild Lands Committee

Chris Scott
RWA

Jie Shao
Charlotte County

Christine Small
Endeavours Together, LLC

Chris Stahl
Florida Deptartment of Environmental Protection

Donna Storter Long
Glades County

Lee Taylor
Florida Fish & Wildlife Conservation Commission

Lynda Thompson
Lee County Conservation 20/20 Program

Douglas Tucker

Patrick Vanasse
RWA

Carl Veaux
Sierra Club, Pentian Steering

Michael Wallander

Joe Walsh

Bill Wilcox
Edison College; Babcock Ranch, Inc.

Kendra Willett
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Inga Williams
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Babcock Ranch Regional Connectivity Study

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February 22, 2010

Executive Summary

This study assesses opportunities for facilitating regional ecological connectivity between Babcock Ranch and surrounding lands of high ecological value to assist the Babcock Ranch Steering Committee with its work. We reviewed existing reports and spatial data and conducted new analyses using currently available land-use data and spatial models, as well as data from new studies. These data are of sufficient resolution for state and regional scale conservation planning and can be particularly useful for such applications, however, the data are not appropriate for use in high accuracy mapping applications such as property parcel boundaries, local government comprehensive plans, zoning, DRI, site plans, environmental resource or other agency permitting, wetland delineations, or other uses requiring more specific and ground survey quality data. The analysis, maps and data in this report were developed for state and regional conservation planning purposes and are not intended, nor sufficient, to be the basis for local government comprehensive plans, environmental resource or agency permitting decisions. They are however relevant for informing decision making as to areas needing more attention and potentially more detailed study.

Issues related to facilitating connectivity, including road crossings and potential corridor bottlenecks were also assessed, as was the need for additional research and analyses. The study area for this research included the lands immediately surrounding Babcock Ranch, nested within a larger landscape that extends, for least cost path analysis, northward to Tampa Bay, east to the Kissimmee River Valley, and south to Big Cypress; for long-term connectivity considerations, a still larger study area is appropriate, north to the Green Swamp and south to the Everglades. Additional analysis and coordination is also needed to determine how best to establish better connectivity, using a broad range of potential tools and working with private and public landowners on implementation strategies.

We begin this report with a review of some functions of ecological connectivity. Connectivity is determined by the intersection of a species' life history characteristics, including its behavior, and the structure of the landscape. For a particular corridor or greenway to provide functional connectivity, we have to know a considerable amount about the species that we hope will benefit from the corridor, as well as about the habitat structure and landscape context of the corridor.

There are many potential functions of connectivity. Besides their value in providing dwelling and breeding habitat for some species, corridors potentially facilitate: (1) movement of animals within home ranges; (2) seasonal migrations or wanderings of animals; and (3) dispersal of juveniles or adults of animal or plant species, which in turn provides for colonization or recolonization of suitable habitat patches and for movement of individuals among populations over a larger area. Large-bodied animals, in particular, have large home ranges, for example on the order of 416.5 km2 for male Florida panthers. We review evidence that the current habitats of three focal species that we consider in this study – Florida panther, Florida black bear, and Sherman's fox squirrel – are becoming fragmented, and that these species would benefit from protection and restoration of functional habitat corridors. Dispersal and colonization of new habitats by many species will be of critical importance for adaptation to climate change, including escape from rising sea level, which we believe is an urgent issue in Florida.

Information used in this study include data on existing conservation lands; Florida Forever projects; the Florida Ecological Greenways Network; Water Management District 2004-2006 FLUCCS Land Use data; Strategic Habitat Conservation Areas for Florida panther and Florida black bear from the Florida Fish and Wildlife Conservation Commission (FWC); data on Florida black bear range, locations, and roadkills from FWC; Highlands-Glades Florida black bear range and telemetry data from University of Kentucky; Florida black bear habitat priority areas delineated by T. Hoctor; data on Florida panther locations and mortality from FWC; U.S. Fish and Wildlife Service (FWS) Panther Subteam Habitat Conservation Zones; Florida panther Habitat Protection Priority Areas; National Hydrography Flowline data; Conservation Lands and Waters Identification Program (CLIP) landscape integrity data; Florida Natural Areas Inventory (2008) Babcock Ranch Ecological Inventories; Johnson Engineering roadkill data and other information from reports; GIS data prepared by Johnson Engineering for the Babcock Ranch Steering Committee; Babcock Ranch Primary Internal Transportation Plan, Primary Greenway Plan, and Preserve Recreation Master Plan; and the primary literature (scientific journal articles, etc.).

The methods of this study included: (1) A review of existing literature, databases, and other information; (2) development and refinement of habitat models for 3 focal species – Florida panther, Florida black bear, and Sherman's fox squirrel; (3) ground-truthing of habitat models and assessment of habitat quality for focal species within Babcock Ranch; (4) collection of roadkill data and observations on roads surrounding Babcock Ranch; (5) identification of regional-scale habitat corridors (high, moderate, and low connectivity options) using least-cost path analysis, visual interpretation of habitat and conservation area patterns, and other methods; and (6) comparison of results to future scenarios, including alternative future development scenarios (e.g., Florida 2060) and sea-level rise scenarios.

Regarding the habitat models for the three focal species, the Florida black bear habitat model was based on 4 variables: land cover type, patch size, distance from primary habitat patches, and connectivity to large habitat patches. Florida panther habitat was identified using all forest cover patches 5 acres or larger and secondary habitat within 200 meters; Fox squirrel habitat was identified using 4 variables: land cover type, patch size, distance from primary habitat patches, and landscape large enough to support potentially viable populations. For the least cost path (LCP) analysis, LCP was defined as the best potential route between a source and destination based on a cost surface. The least costly route is essentially the path of least resistance, where resistance is defined by unsuitable or low-security habitat for the species in question. We created 6 different cost surfaces for each focal species. Cost surfaces variations included: habitat for focal species reclassified into a cost surface; habitat plus major roads; habitat, major roads, and edge effects; habitat, major roads, edge effects, and sea-level rise; habitat plus CLIP Landscape Integrity layer; and influence of roads, edge effects, and sea-level rise. The destinations included for the LCPs leading outward from Babcock Ranch were Big Cypress National Preserve, Okaloacoochee Slough State Forest, Fisheating Creek Wildlife Management Area, Bright Hour Watershed, the Myakka complex of conservation lands (Myakka), and the Avon Park Air Force Range. Therefore, with 6 cost surfaces and 6 destinations, there were 36 LCP results for each focal species.

We integrated results from these analyses into three conservation options: low, moderate, and high connectivity options. We used the following datasets to create the three connectivity options: The low connectivity option included existing conservation lands; the Caloosahatchee Ecoscape Florida Forever Project; one set of LCP results buffered by 1 mile between Babcock Ranch and the six selected destinations. The moderate connectivity option included existing conservation lands; Florida Forever Projects; two panther and two bear cost surface buffered LCP results buffered by 1 mile; all Critical Linkages within the Florida Ecological Greenways Network; all primary and secondary black bear habitat within primary range identified by FWC, all bear population habitat conservation recommendations delineated by T. Hoctor, or the new FWC bear SHCAs; all panther habitat within the USFWS Panther Subteam Primary and Dispersal Zones, or the older FWC Habitat Protection Plan areas, or the new FWC SHCAs; and the Integrated Habitat Network (given a value of 2 whereas all other areas within the option were given a value of 1). The high connectivity option included existing conservation lands; Florida Forever Projects; two panther and two bear cost surface buffered LCP results buffered by 1 mile; all areas within the Florida Ecological Greenways Network; all potential bear (primary and secondary), panther, and fox squirrel habitat (primary and secondary); all regional and local riparian corridors; and the Integrated Habitat Network (given a value of 2 whereas all other areas within the option were given a value of 1).

The LCPs clearly demonstrate potential options to connect Babcock Ranch to other large conservation areas in the study region. LCP results for the Florida panther and Florida black bear are similar in most cases. Although the fox squirrel LCPs showed some deviation for several destinations, the overall pattern of potential connectivity for fox squirrels is similar to that for panthers and bears; hence, we suggest that fox squirrel connectivity may be suitably addressed at the regional scale by the best options for panthers and bears. In addition, local to landscape-scale connectivity may be more important for fox squirrels within this region due to the fragmented habitat base and lower dispersal capabilities. Further research on fox squirrels in the region could include identification of core habitat areas and the opportunities to restore or maximize connectivity at the local to landscape scales through habitat management, restoration, and protection.

Our analysis of LCP overlap provided an objective method for evaluation of best potential corridors between Babcock Ranch and other large regional conservation areas. However, selection of best corridor options also requires a more subjective expert analysis of factors potentially critical to population persistence, including the number and location of road crossings, presence of bottlenecks/proximity to areas of intensive development, length of corridors, consistency with existing guiding features in the landscape such as riparian corridors, etc. Before developing the connectivity options, we conducted these additional visual assessments of LCP results to select the best potential corridor options. From this assessment, we determined that LCPs based on two separate cost surfaces for both panthers and bears were most applicable to developing the various conservation scenarios.

The three connectivity options fall along a gradient of political and economic feasibility. The low connectivity option primarily represents the minimum feasible or most constrained effort to functionally connect Babcock Ranch with other larger existing conservation lands in the region. The moderate connectivity option is intended to represent a primary option for protecting and restoring functional connectivity across the region. The high connectivity option represents almost all existing areas that contribute, or could contribute, to protection of a functionally connected ecological network in the study area. All options would require addition of lands to Florida's conservation area network. For example, approximately 1.7 million acres of private land is included in the moderate connectivity option, with approximately 500,000 of those acres within proposed Florida Forever projects, as well as 400,000 acres of wetlands.

Assuming that all potential habitat is suitable habitat and that individual animals can move freely through the corridor network, which is actually unlikely, we made crude estimates of potential population sizes for the three focal species under the three connectivity options. To partially correct for biases, we provided population estimates based on the unrealistic assumption that all potential habitat is suitable and compared these with estimates based on an arbitrary but more realistic assumption that only 75% (for panthers and bears) or 50% (for fox squirrels) of the potential habitat in each connectivity option is suitable. Applying the moderate connectivity option, the 75% suitable habitat assumption, and population densities obtained from a study in Ocala National Forest, for example, the study region could support 1582 to 2331 bears. Under the same option and 75% suitable habitat assumption, and using population densities calculated by Maehr et al. (1991), the study region could support 65 to 89 panthers. And under the same option, a 50% suitable habitat assumption, and density estimates from two studies of fox squirrels, the study region could support 4,609 to 13,829 fox squirrels. Nevertheless, these revised estimates are still highly optimistic, especially so for the fox squirrel, for which so little of the potential habitat is suitable today due to inappropriate management for the fox squirrel. Especially for habitat specialist species such as the fox squirrel, protection of large habitat blocks and connections among blocks is not enough to assure persistence. Ecological management to maintain suitable habitat – both within Babcock Ranch and within other existing and potential conservation areas within the study region – is essential to assure population viability. The fox squirrel, in particular, requires an open understory, as maintained historically by frequent growing-season fire in pinelands.

In summary, we found that options for maintaining connectivity for three focal species – Florida panther, Florida black bear, and Sherman's fox squirrel – between Babcock Ranch and other existing and potential conservation areas within the regional landscape are still relatively abundant and intact. Nevertheless, several problematic corridor bottlenecks are present already in the region and will constrain animal movement unless remedied by increased land protection and mitigation of impacts from roads and development. Moreover, unless potential conservation areas (e.g., Florida Forever projects) are protected soon, connectivity for our focal species and many other animals will be significantly diminished, especially if human population growth and development continue in the study region and if road impacts (increased traffic volume, road widening, etc.) are not reduced by properly located and designed wildlife crossings and associated barrier fencing. Impacts from sea-level rise, although predicted to be relatively minor in the immediate vicinity of Babcock Ranch, are likely to be severe in the southern and western portions of our study area and in the Lower Peace and Myakka River areas, where some of our identified LCPs will be severed by rising waters. Moreover, even inland areas substantially above 3 meters in elevation will be at high risk as displaced people flee the coasts over the coming decades. This likely phenomenon underscores the need to protect key core areas and landscape linkages soon.

Further work is needed to evaluate available tools to plan and seek to implement any of these connectivity options. Future Florida Forever or other acquisition programs, landowner incentives, private conservation efforts, innovative planning strategies, and other tools will be needed to actually accomplish the creation of a connectivity strategy.

Introduction

The Babcock Ranch, which covers 91,360 acres in Charlotte and Lee counties, Florida, includes 73,239 acres that was purchased by the State's Florida Forever program, the largest acquisition in the program's history. The 73,239-acre conservation area, named Babcock Ranch Preserve, possesses two key kinds of conservation value: (1) on-site values, including high-quality examples of natural communities in large patch sizes and sizable populations of many imperiled and declining species, several of them federally or state listed; and (2) landscape values related to Babcock Ranch's strategic location with respect to surrounding conservation areas, other areas of conservation interest, and riparian networks. Potential connections to other lands of high ecological value exist in all directions – south, north, east, and west. It has also been noted that protection of wildlife corridors in the Babcock Ranch area will assist with Caloosahatchee River protection efforts. For all of these reasons, Babcock Ranch has been identified as a high priority in the Florida Ecological Greenways Network, which identifies the most important conservation corridors and large, intact landscapes in the state (Hoctor et al. 2000; Hoctor 2003; Hoctor et al. 2008).

Our study sought to assess the opportunities for facilitating regional ecological connectivity between Babcock Ranch and surrounding lands of high ecological value by reviewing existing reports and spatial data and conducting new, updated analyses using currently available land-use data as well as new data from such studies as the Highlands County black bear study, the work of the Babcock Ranch Steering Committee, and new surveys of roadkill on the roads surrounding Babcock Ranch. Issues related to facilitating connectivity, including road crossings and potential corridor bottlenecks were also assessed, as was the need for additional research and analyses. The fundamental goal of our study was to identify the best potential ecological connections between Babcock Ranch and other regional conservation areas (existing and proposed) so that biodiversity and functional ecosystem processes are maintained.

Why is Connectivity Important?

Wildlife corridors are well known and popular mechanisms for conservation and have been proposed in Florida for many years, especially for wide-ranging species such as black bears and panthers (Harris 1985, Noss and Harris 1986, Noss 1987, Harris and Gallagher 1989, Harris and Atkins 1991, Harris and Scheck 1991, Hoctor et al. 2000, Maehr et al. 2002; Hoctor et al. 2008). The popularity of corridors as a conservation tool notwithstanding, what conservation biologists are interested in is not corridors per se, but rather *functional connectivity*, which involves the flow of individuals and their genes among habitats and populations (Noss and Cooperrider 1994, Beier and Noss 1998). The connectivity of a landscape can be measured by the degree to which it facilitates or impedes movement of organisms among habitat patches (Tischendorf and Fahrig 2000). Connectivity is determined by the intersection of a species' life history characteristics, including its behavior, and the structure of the landscape. Hence, connectivity is a very species-specific and landscape-specific property (Bennett 1999). Well-designed studies of corridors generally show that they provide connectivity for the species of interest (Beier and Noss 1998). Nevertheless, for a particular corridor or greenway to provide functional connectivity, we have to know a considerable amount about the species that we hope will benefit from the corridor, as well as about the habitat structure and landscape context of the corridor.

Corridors are often conceived as simple swaths of habitat that allow an animal to get from point A to point B. In real landscapes, however, there are many potential functions of connectivity. Besides their value in providing dwelling and breeding habitat for some species, corridors potentially facilitate: (1) movement of animals within home ranges; (2) seasonal migrations or wanderings of animals; and (3) dispersal of juveniles or adults of animal or plant species, which in turn provides for colonization or recolonization of suitable habitat patches and for movement of individuals among populations over a larger area. Large-bodied animals, in particular, have large home ranges, for example on the order of 416.5 km2 for male Florida panthers (Land et, al, 2004; Kautz et al. 2006). Dispersal and colonization of new habitats will be of critical importance in the adaptation of species to climate change (Noss 2001). In Florida, corridors to facilitate functional connectivity from current coastal areas to inland areas, and corridors south to north will both be important aspects of a conservation strategy to enable adaptation to climate change.

To meet their life-history needs across large areas, wide-ranging animals today must move through areas with varying degrees of human development; they must also cross many roads, which often cause mortality (Trombulak and Frissell 2000). Protected corridors that follow expected movement routes – which are generally the paths of least resistance through the landscape, based on habitat preferences, topography, and other factors – are expected to reduce mortality and conflicts with humans and facilitate safe movement among patches of suitable habitat (Noss and Cooperrider 1994). Based on empirical studies of cougars (i.e., the same species as the Florida panther) in California, Beier (1995; 1996) suggested that suitable corridors have the following characteristics: (1) located along natural travel routes (including riparian strips and ridges); (2) have ample woody cover; (3) include underpasses with ample fencing at large/high-speed road crossings; (4) lack artificial outdoor lighting; (5) have less than 1 human dwelling/16 hectares (approximately 40 acres); and (5) should be at least 100 m wide if less than 800 m long, but more than 400 m wide if 1-7 km in length.

In mountainous and northern landscapes, many large mammals make seasonal migrations between summer range and winter range. Elk, for example, typically make seasonal movements in response to forage conditions, and during these migrations they often depend on hiding or escape cover, as provided by forest corridors adjacent to open meadows (Pederson and Adams 1976, Winn 1976). In Florida, on the other hand, large terrestrial animals are not migratory in the traditional sense. Some species, however, make widespread movements at particular times of year. For example, fox squirrels exhibit an "autumn-shuffling" that includes adults as well as juveniles, and small-scale mass migrations are occasionally observed (Koprowski 1994). Sherman's fox squirrel has large home ranges (averaging 43 ha for males and 17 ha for females) and males make long-distance movements in search of food in August-September (Kantola and Humphrey 1990). Black bears in Florida also make seasonal movements to track food abundance and often use riparian corridors, in part, for both daily and seasonal movements (Harris 1985; Harris and Gallagher 1989). Seasonal movements of black bears in Florida include travel outside of normal home ranges to access important food resources such as saw palmetto (*Serenoa repens*) and acorns (Maehr et al. 2001a). These movements can be extensive, as male bears typically have home ranges of 50 to 120 square miles; female ranges generally are 10 to 25 square miles (Maehr et al. 2001a).

Dispersal refers to the movement of individual organisms away from their place of origin (Brown and Lomolino 1998) and is one of the most critical of all biological processes (Bullock et al. 2002). Dispersal often reduces competition within families, reduces inbreeding (when one sex disperses further than the other, i.e., female birds and male mammals), results in gene flow among populations, and can rescue small populations from extinction (Noss and Cooperrider 1994). A corridor can promote dispersal if individual animals or plant seeds travel from one population to another by means of the corridor, or if resident populations in the corridor allow the gradual flow of genes from one end to another.

Plants and animals have evolved many different ways to disperse. Fruits of many plants become attached to the fur of mammals, whereas fleshy fruits are eaten and passed through the gut of animals. Seeds of trees, such as oaks, hickories, and pines, are gathered by squirrels, jays, and other seed predators, but many of the cached nuts are never eaten and later germinate. Hence, as animals move across a landscape, the plants they carry also move. In one study, seeds of fruiting shrubs were dispersed by birds much more effectively when habitat patches were connected by corridors than when they were not. Moreover, movement of butterflies preferentially through corridors resulted in dramatic increases in movement of pollen. As a result, a significantly higher proportion of flowers produced fruit in connected patches than in unconnected patches (Tewksbury et al. 2002). Another study in the same area of South Carolina found that corridors increase plant species richness. Over time, connected patches became more species rich, containing 20% more plant species than unconnected patches over 5 years. Native species increased over time in connected patches, whereas non-native species showed no increase (Damschen et al. 2006).

Many species are distributed as metapopulations, that is, as systems of local populations linked by occasional dispersal (Hanski 1999). It is the fate of local populations in these systems to "wink" off and on over time. Dispersal of individuals across the landscape allows for colonization of vacated or other suitable habitats, so that the metapopulation as a whole persists despite local extinctions. If too many connections between habitat patches in a landscape are severed, the metapopulation is less likely to persist. Extinctions of local populations under these circumstances signal bit-by-bit extinction of the metapopulation or the entire species (Harrison 1994). The survival of metapopulations thus depends, in large part, on both the rate of local extinctions in habitat patches and the rate at which organisms move among patches, which in turn is affected by connectivity between patches. Corridors can lower the chances of extinction for small, local populations by augmenting population size and by increasing population growth rates (Merriam 1988). Corridors may also increase the likelihood that local extinctions can be reversed through recolonization of vacated patches. This, in turn, increases the chances that the entire metapopulation will survive.

Small, isolated populations are prone to two kinds of detrimental genetic effects: inbreeding depression and random genetic drift. Inbreeding depression is a result of mating between close relatives in normally outbreeding species. It occurs when individuals are not able to disperse and mate with individuals from other populations. By reducing genetic diversity and allowing harmful recessive genes to be expressed, inbreeding can raise mortality rates (especially among juveniles) and reduce individual health, vigor, and fertility. Data from recent studies confirm that inbred populations often experience reduced growth and increased rates of extinction (Keller and Waller 2002). Random genetic drift is a change in gene frequencies in a population due to chance. In small populations, where chance events play a greater role, genetic drift leads to the loss of genetic diversity. Not only do genetically impoverished populations often show reduced viability and fertility, but in the long run they will be less able to adapt to changing environmental conditions. Allendorf (1983) predicted that an exchange of one reproductively successful migrant, on average, between populations per generation is sufficient to avoid the loss of genetic diversity through drift but will still allow populations to diverge as a result of adaptation to local environments through natural selection. To the extent that corridors facilitate an exchange of individuals among populations, they help maintain genetically viable populations.

The Florida panther (*Puma concolor coryi*) and Florida black bear (*Ursus americanus floridanus*) were once found throughout Florida but now are limited to isolated populations over a small portion of their former range. The Florida panther has only one known breeding population, with females presumably limited to areas of southwest and south Florida south of the Caloosahatchee River. The Florida black bear still exists in seven populations across the state, though most of these populations appear to be currently functionally isolated from each other (Maehr et al. 2001a; Hoctor 2003). In the region around Babcock Ranch there are two bear populations, the Big Cypress population south of the Caloosahatchee River and the Highlands-Glades population east and northeast of Babcock; dispersing bears from both populations may occasionally move through the ranch. Re-establishing functional metapopulations is an important goal for both species. For the Florida panther, re-establishment of a breeding population north of the Caloosahatchee River would greatly enhance viability (Maehr et al. 2001b; Kautz et al. 2006; USFWS 2008). For the Florida black bear, a functional regional ecological network in southwest Florida would re-establish connectivity between the Big Cypress and Highlands-Glades populations and would increase the likelihood that connectivity could be re-established between the bear populations in south Florida with those further north, such as the Ocala population in central Florida (Maehr et al. 2001; Hoctor 2003; Dixon et al. 2006; Dixon et al. 2007).

Another declining animal, perhaps at least as imperiled as the Florida black bear, is the fox squirrel (*Sciurus niger*). Within our study region fox squirrels are currently considered to encompass two subspecies: Sherman's fox squirrel (*S.n. shermani*) north of the Caloosahatchee River and Big Cypress (formerly mangrove) fox squirrel (*S.n. avicennia*) south of the Caloosahatchee River. We suspect that there is gene flow between the Sherman's and Big Cypress fox squirrels across the Caloosahatchee River. Fox squirrels may swim surprisingly long distances (Koprowski 1994, Trauth and Jamieson 1997) and there are also anecdotal reports of fox squirrels on bridges across the Caloosahatchee River. Therefore, these two named subspecies may not be genetically distinct (N. Moncrief, pers. comm.). Regardless of genetic distinctiveness, fox squirrel habitat is currently highly fragmented across peninsular Florida, including in our study region, and the species is vulnerable to roadkill and other mortality when attempting to move between patches of suitable habitat. Hence, a network of protected habitat linking important core areas may be essential to the persistence of this species in the state.

Plant communities over much of North America have developed only within the last 4,000 to 8,000 years (Davis 1981, Webb 1987). Before this time, many of the species now found together were separated geographically; many of the communities (species combinations) we see today did not exist anywhere. Since the Pleistocene (Ice Age) ended about 10,000 years ago, the ranges of many plant species have shifted by over 1000 kilometers (620 miles). Because species migrated northward at different rates and by different routes, community composition has changed continuously over space and time (Davis 1981). A major concern today is that a system of mostly isolated conservation areas may be incapable of maintaining biodiversity during climate change (Peters and Darling 1985; Lovejoy and Hannah 2004). Even natural rates of change pose significant challenges to species confined to reserves surrounded by inhospitable habitat. The increased rates of change that would occur with a warming climate may eliminate all species but the most mobile as they fail to track shifting climatic conditions. Although the role of corridors in conserving species during a time of rapid climate change is not proven, "their incorporation into a strategy for dealing with the effects of climate change adds an option to what is otherwise a rather sparse repertoire." (Hobbs and Hopkins 1991) We predict that connectivity is more likely to be a successful strategy over the relatively small distances that coastal species would need to move in response to sea-level rise, which will have significant impacts in Florida over coming decades. In fact, biological impacts of sea-level rise are already strikingly evident in low-lying areas of Florida, such as the Florida Keys (Ross et al. 2009) and are predicted to become much worse over the next few decades as the current ranges of many species would be inundated with a 1+ m rise in sea level (Noss, Hoctor, Oetting et al. in preparation). Though more challenging, the protection of connected networks of conservation lands on a broad scale may provide the best opportunity to facilitate functional adaptation to climate change for various species that would not be able to negotiate otherwise human-dominated landscapes.

One concern about corridors, especially narrow ones, is that predators, including humans, may learn to concentrate their activity along animal movement routes. Thus, corridors could potentially act as mortality sinks (Simberloff and Cox 1987). For example, predators have been reported hunting in constructed wildlife crossings under roads (e.g., Foster and Humphrey 1995).

Nevertheless, the existing evidence suggests that highway crossings and other corridors designed for wildlife seldom function as prey-traps (Beier and Noss 1998; Little et al. 2002). More generally, greenways and wildlife crossings in developed landscapes should be designed and managed to provide adequate cover for wide-ranging species and to discourage human uses that might result in harassment. In wilder landscapes, intact roadless corridors should be maintained, and, where possible, roads should be closed to minimize conflicts between humans and wildlife.

In summary, the challenge of maintaining or restoring opportunities for animal movement in landscapes fragmented by human activities are best approached through a coordinated connectivity strategy of increasing or maintaining functional connectivity, such as by protecting or restoring specific habitat corridors and networks and preventing or reducing particular barriers or filters to movement, such as by modifying highways or by directing urban development or intensive agriculture to areas outside of specific habitat corridors and networks. We suggest that in the regional landscape surrounding Babcock Ranch, a combination of strategies is needed.

Study Area

The study area for this research included the lands immediately surrounding Babcock Ranch, nested within a larger landscape that extends, for least cost path analysis, northward to Tampa Bay, east to the Kissimmee River Valley, and south to Big Cypress (Fig. 1, red line); for long-term connectivity considerations, a still larger study area is appropriate, north to the Green Swamp and south to the Everglades (Fig. 1, yellow line). The major corridor destinations for least cost paths leading from Babcock Ranch include the Caloosahatchee Ecoscape, Avon Park Air Force Range, Big Cypress National Preserve, Bright Hour Ranch, Myakka State Park and contiguous conservation areas, Fisheating Creek Wildlife Management Area, Okaloacoochee Slough State Forest, and other conservation lands (Fig. 1). This regional landscape is a significant biodiversity hotspot and includes: the scrub and sandhills of the Lake Wales Ridge; the prairies, hammocks, and flatwoods of south-central and southwest Florida; major river and riparian wetland systems including the Peace, Myakka, and Caloosahatchee Rivers and Fisheating Creek; and other large wetland systems of south Florida including Okaloacootchee Slough, Corkscrew Swamp, and Big Cypress.

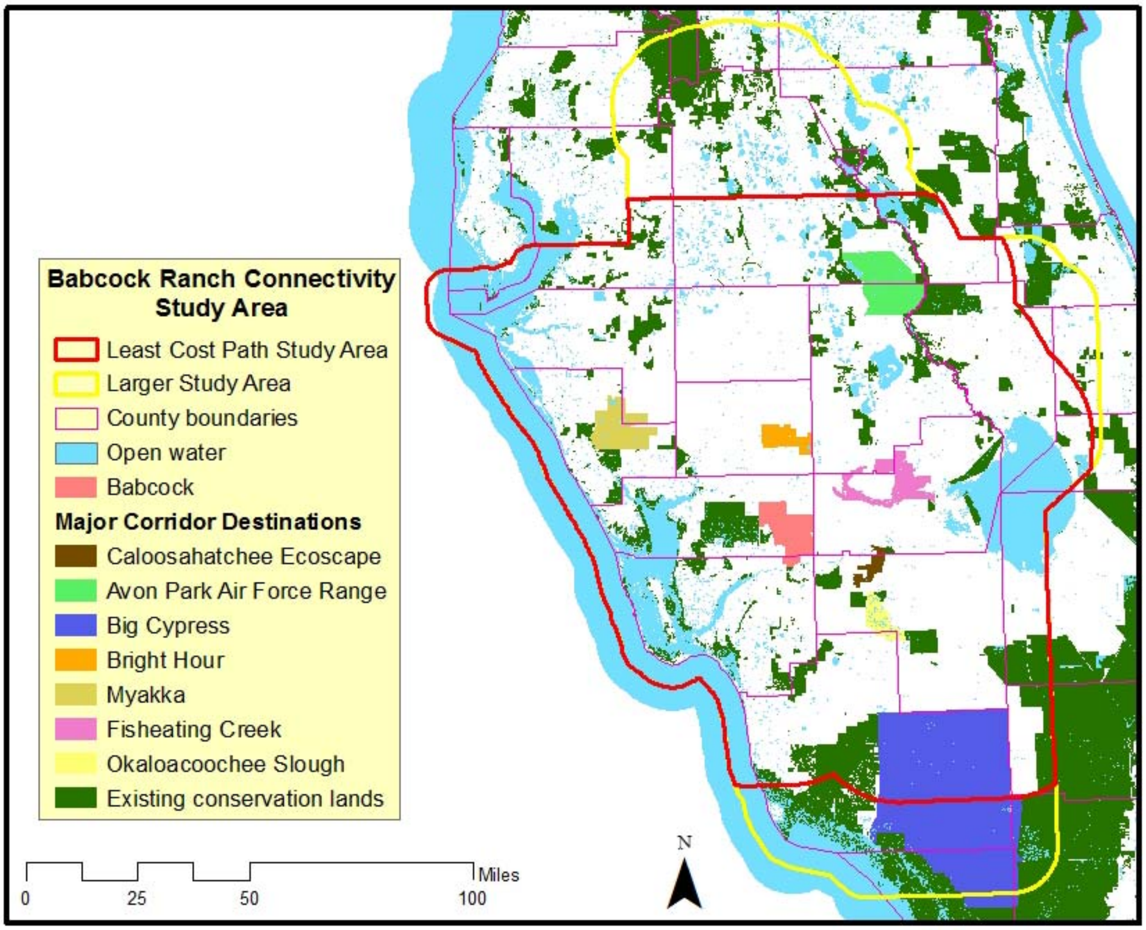


Figure 1. Babcock Ranch Connectivity Study Area, with major corridor destinations for the least cost path analysis (boundary marked in red line) and the broader region for long-term connectivity considerations (boundary marked in yellow line).

Methods

Databases and Literature

We reviewed and applied the following databases and literature in conducting this study:

- Existing conservation lands (from the Florida Natural Areas Inventory managed areas database plus mitigation banks from the Florida Department of Environmental Protection, conservation easements from the South Florida and Southwest Florida water management districts, U.S. Department of Agriculture easements, and additional conservation areas including easements from The Nature Conservancy)
- Florida Forever Projects
- Florida Ecological Greenways Network
- Water Management District 2004-2006 FLUCCS Land Use data
- Florida black bear Strategic Habitat Conservation Areas from FWC
- Florida panther Strategic Habitat Conservation Areas from FWC

- Florida black bear range from FWC
- FWC Black bear location data
- FWC Bear roadkill data
- Highlands-Glades Florida black bear population range from University of Kentucky
- University of Kentucky black bear telemetry data
- Florida black bear population conservation habitat priority areas by T. Hoctor
- FWC Panther location data
- FWC Panther mortality data
- Florida panther USFWS Panther Subteam Report and Habitat Conservation Zones
- Florida panther Habitat Protection Priority Areas from FWC
- National Hydrography Data Flowlines
- CLIP Landscape Integrity
- Florida Natural Areas Inventory (2008) Babcock Ranch Ecological Inventories - Report for FWC (Natural Community Mapping Project, Listed and Rare Plant Inventory, Listed and Rare Animal Inventory, Invasive Exotic Plant Inventory)
- Johnson Engineering roadkill data and other information from reports
- GIS data prepared by Johnson Engineering for the Babcock Ranch Steering Committee
- Babcock Ranch Primary Internal Transportation Plan, Primary Greenway Plan, Preserve Recreation Master Plan
- Primary literature (scientific journal articles, etc. cited in this report)

<u>Habitat Models</u>

Because biodiversity is too immense to measure and manage in its entirety, surrogates for biodiversity are used in conservation planning. Among the commonly applied surrogates, which are particularly useful for determining landscape configuration requirements and habitat management priorities are focal species (Lambeck 1997, Carroll et al. 2001, Noss et al. 2002). Focal species are simply the species that one focuses on in conservation planning, and they are assumed to be among the most sensitive species to the habitat qualities of importance (e.g., core area size, landscape connectivity, habitat quality) within a given planning region. We selected three focal species to investigate in detail in this study: the Florida panther, the Florida black bear, and Sherman's fox squirrel.

We developed and refined habitat models for the three focal species for use in determining source and destination areas and least cost paths for movement across the study region. These habitat models identify potential habitat for each focal species based on known land cover associations and other relevant parameters including patch size and buffer distances to identify areas that are more likely to support suitable habitat conditions. The word "potential" is important, because although these models do identify locations where each of these focal species are documented, identification of habitat in these models does not guarantee occupancy.

Florida panther
The Florida panther requires intact landscapes with no to low human activity dominated by land cover and land use that supports suitable cover and prey (Kautz et al. 2006, USFWS 2008). Various types of forest are of primary significance but panthers also use rural mosaics containing

upland and wetland forest, herbaceous wetlands, dry prairies, pasturelands, and other agricultural land uses (Kautz et al. 2006, Land et al. 2008. USFWS 2008). Panthers require large areas to support functional home ranges and the integrity of home ranges, with respect to impacts from roads and other human land use and activities, is an important consideration for maintaining or restoring suitable habitat (Kautz et al. 2006, USFWS 2008).

The Florida panther habitat model applied in this study was adapted from the potential habitat model created by the Florida Fish and Wildlife Conservation Commission as part of their update to Strategic Habitat Conservation Areas (http://research.myfwc.com/features/view_article.asp?id=29815). The model was created using 2004-2006 Water Management District land-use data at a 10 meter cell size to identify forest patches 2 hectares (approximately 5 acres) or larger and then adding all non developed (natural, semi-natural, agriculture) within 200 meters of such forest patches (Kautz et al. 2006). Forest patches 2 hectares or larger and all other habitats within 200 meters of these patches were all given a value of 1.

Florida black bear

The Florida black bear uses a wide variety of forest types such as pine flatwoods, hardwood and mixed swamps, cabbage palm forests, sand pine scrub, hardwood hammocks, and even mangroves (Maehr et al. 2001a, Hoctor 2003). The Florida black bear is omnivorous, but plant matter dominates as a food source. Black bears typically follow the phenology of plants in selecting food items seasonally (Maehr et al. 2001a, Hoctor 2003). Saw palmetto (*Seronoa repens*) fruits are heavily used in late summer and fall; cabbage palm (*Sabal palmetto*) hearts, tupelo (*Nyssa* spp.) fruits, acorns (*Quercus* spp.), blueberries (*Vaccinium* spp.), blackberries (*Rubus* spp.), and gallberry (*Ilex glabra*) are also important (Maehr and Wooding 1992, Maehr et al. 2001a, Hoctor 2003). Like the Florida panther, the Florida black bear has large home ranges and is sensitive to habitat fragmentation and human disturbance (Cox et al. 2004, Maehr et al. 2001a, Hoctor 2003).

The Florida black bear potential habitat model applied here was creating using documented information about Florida black bear habitat preferences and assessment of connectivity thresholds based on distance from primary habitat and land use type (Maehr et al 2001, Hoctor 2003, Orlando 2003). Habitat was identified using 2004-2006 Water Management District land-use data at a 10 meter cell size. Three types of habitat/land use were identified:

1) Primary habitat—forest cover including flatwoods, hammocks, scrub, and forested wetlands. All patches of primary habitat greater than 6 hectares (approximately 15 acres) were identified (Cox et al. 1994).

2) Secondary habitat—sandhills, shrub and brush, and freshwater shrub wetlands and freshwater herbaceous wetlands. Patches of secondary habitat or smaller patches of primary habitat that are near larger primary habitat (15 acres and larger) can also be used by bears. However, patches separated by intensive land uses that cannot be reached or easily reached may not be used. Therefore, "traversable matrix" land cover and land uses were also identified to determine which secondary patches were functionally connected to primary patches. All secondary habitat types

and all smaller patches of primary cover within 1.5 kilometers of primary patches and connected by traversable matrix were identified as potential habitat.

3) Traversable matrix—almost all other land use types that bears are capable of moving through when proximal to primary habitat including agriculture, mining lands, and saltmarsh. Roads also were included to model habitat patches across roads that bears might be able to access (Larkin et al. 2004). Large water bodies were not included as potential habitat, but narrow channels that might be crossed were identified and included within the traversable matrix. Narrow water gaps were defined as <100 meters (Dave Maehr, personal communication).

Then, all primary and secondary habitat were combined to identify connected blocks >10,000 acres. This was done to identify areas that are more likely to be large enough to serve as minimum functional habitat units for black bear (Hellgren and Maehr 1992). Within these areas, primary habitat was given a value of 1, secondary habitat was given a value of 2, and traversable matrix was given a value of 3.

Sherman's fox squirrel

It is a credible hypothesis that within peninsular Florida, fox squirrels have suffered more pronounced declines than any other mammal in the state over the last several decades. Regardless of taxonomy (see above), the Sherman's and Big Cypress fox squirrels (indeed all of the southern fox squirrels) have very similar habitat requirements and life histories (Weigl et al. 1989, Koprowski 1994). Fox squirrels require large tracts of sandhills, natural pine flatwoods, adjacent rangelands, and hardwood or wetland forests to meet their habitat requirements (Weigl et al. 1989; Kantola 1992; Cox et al. 1994). Fox squirrels are associated primarily with open, mature pinelands (pine flatwoods or sandhills) but also are found in open cypress stands and in oak hammocks, bottomland hardwood areas, and tropical hardwood hammocks. Although dense hardwood areas are not considered primary habitat, in some situations the squirrels make high use of ecotones between hammocks and pine savannas, to the extent that Kantola and Humphrey (1990) concluded that "proximity of longleaf pine savanna to live oak forest may define highest-quality habitat for this squirrel."

We used the following habitat model steps to identify fox squirrel habitat in the study area:

1) All potential primary suitable cover including upland coniferous forest (4100), pine flatwoods (4110s), longleaf pine-xeric oak (4120s), pine-mesic oak (4140), other pines/hunting plantations (4190), xeric oak (4210), and oak-pine-hickory (4230) that are in patches 50 acres and larger are identified as primary habitat blocks (Kantola and Humphrey 1990; Cox et al. 1994).

2) Then rangeland (3000s) and mixed hardwood-pine (4340) within 1000 meters of these primary cover types are identified as additional primary habitat.

3) All open lands (1900-1999), pasturelands (2100-2130), all rangelands (3000-3999), all upland forests (4000-4500), and all wetland forests (6100-6300s) other than mangroves within 200 meters of primary patches identified in step 1 are also identified (Cox et al. 1994). Other land use types (open lands, agriculture, all forest and wetlands, disturbed lands, and pipeline, rail, and electrical transmission corridors) are included as potentially traversable areas since fox squirrels

are capable of moving long distances to integrate habitat patches across a large landscape (Weigl et al. 1989).

The distances of 1000 and 200 meters used to identify additional habitat are at least somewhat arbitrary. Cox et al. (1994) used a distance of 120 meters but do not cite a source. Weigl et al. (1989) and Kantola (1992) indicate that other forest adjacent to longleaf pine flatwoods and sandhills can be very important habitat components but do not indicate specific distances fox squirrels venture into adjacent land cover types. Therefore, the distance of 1000 meters is based loosely on the minimum dispersal distance observed by Wooding (1997) and the distance of 200 meters is a slightly more ambitious version of the 120 meter distance used by Cox et al. (1994).

4) All identified habitat was separated into two patch classes to delineate patches more likely to support viable populations (Kantola and Humphrey 1990, Cox et al. 1994, Wooding 1997). Patches 5,000 acres or larger were given a value of 1 and patches between 250-5,000 acres were given a value of 2. Matrix land cover connected to patches at least 250 acres and larger are given a value of 3.

<u>Ground-truthing of habitat models and assessment of habitat quality for focal species within Babcock Ranch</u>

Connectivity to habitat blocks in the regional landscape surrounding Babcock Ranch is not especially meaningful if suitable habitat is not available for our focal species within the boundaries of the ranch. Florida panthers and black bears, relative to many other animal species, are habitat generalists and use habitat features at relatively coarse scales. Therefore, panther and bear habitat is readily assessed through remote sensing (aerial photos, satellite images, etc.), coarse maps of land use and land cover, and other geographically widespread GIS data. In contrast, fox squirrels are more specialized and have more demanding habitat and microhabitat requirements at the site level, which cannot be evaluated adequately without ground surveys in the field. Therefore, one of us (Noss) made four tours through Babcock Ranch during the course of this study (February 3 - April 30, 2009), evaluating and documenting with photographs habitat quality for fox squirrels. Of special interest was the quality of the understory and herbaceous vegetation. Fox squirrels favor open, well-burned understories in order to travel quickly between trees and remain vigilant for predators. As discussed later, a legacy of fire exclusion or dormant season burning, which allows undergrowth such as saw palmetto to grow high and dense, can make otherwise suitable habitat unusable by fox squirrels.

In addition to assessing habitat quality within Babcock Ranch for fox squirrels, we wanted to verify use of the ranch by black bears and panthers. Our field technician, David Hammel, recorded all observations of tracks of these species within Babcock Ranch during the study period. Although, due to budget and time limitations, these were not comprehensive surveys, they help validate habitat model data, radio-telemetry locations, and other information suggesting use of the ranch by these species.

Roadkill Surveys

We monitored roadkills and made observations of focal species along roads surrounding and within Babcock Ranch within the period February 3 - April 30, 2009. We focused our most intensive effort on 3 areas determined from maps, surveying the roads surrounding Babcock Ranch, and evaluating properties adjacent to roads as potential habitat (Fig. 3):

- Area 1- From intersection of Rts. 31 and 74, for 4 miles on SR 74 EAST
- Area 2 - From intersection of Rts. 31 and 74, for 4 miles on SR 31 SOUTH
- Area 3 - From intersection of SR 31 and SR 78, east from Telegraph Creek and Cypress Creek.

We monitored the roads twice weekly during the study period and documented roadkills of large herpetofauna (snakes, turtles, alligators), large birds, and medium-sized to large mammals. In addition, we monitored the roads around the entire perimeter of Babcock Ranch once per week, beginning in late March. The data collected for each individual roadkill was species, GPS location, lane (in road or side of road), sex and age class if possible, travel direction if possible, and weather at the time of survey. We also made an effort to survey for fox squirrels within Babcock Ranch and elsewhere within the surrounding landscape. Although the time and budget of this study did not allow a comprehensive study, our field technician, David Hammel, recorded sightings and noted GPS locations of all fox squirrels observed during the course of this study.

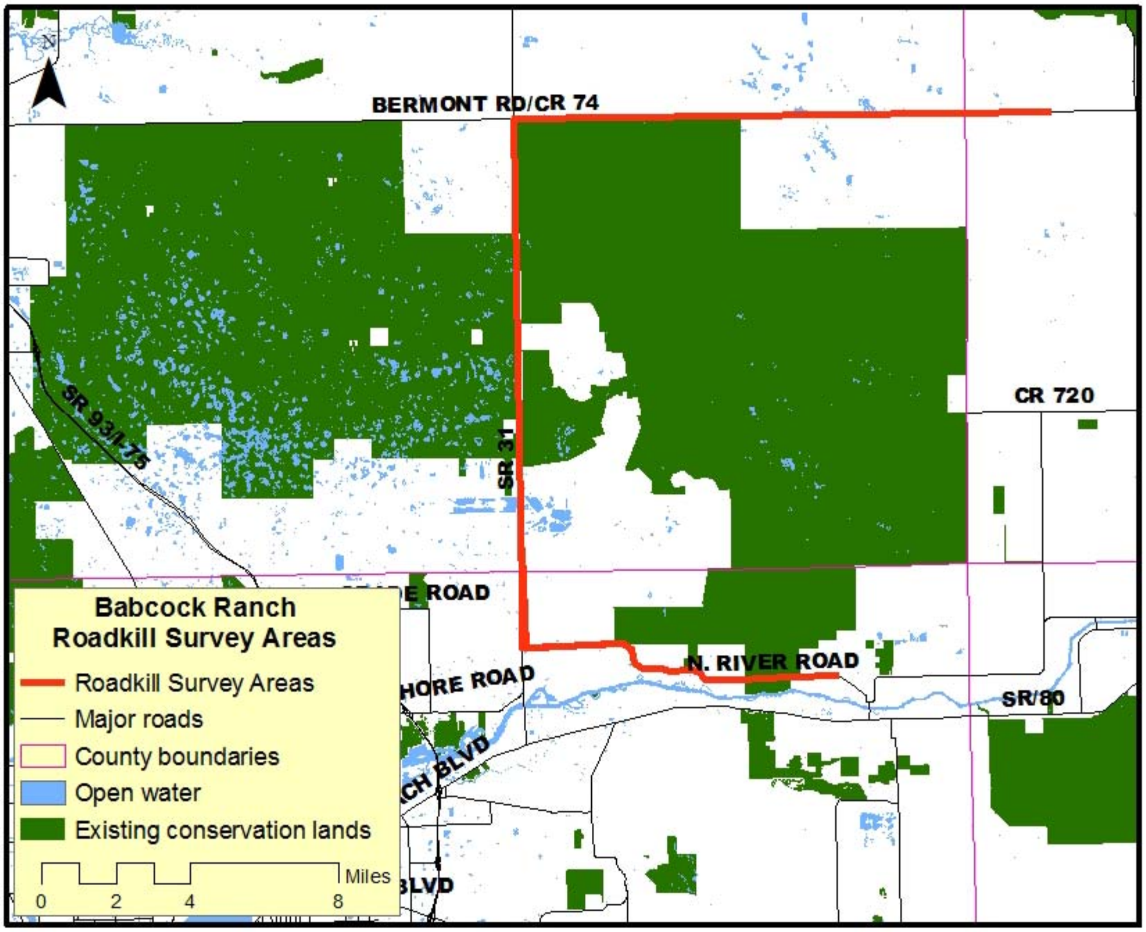


Figure 2. Map of roadkill survey areas.

Riparian Habitat/Corridors, Greenways and Habitat Combination Models

Since the Florida Ecological Greenways Network (FEGN) focuses on state and regional corridor priorities, at the regional to local scale there can be other significant corridors that are not included within the FEGN. Riparian networks including rivers, streams, lakeshores and associated wetlands, floodplains, and forests, are important guiding landscape features used by many species. Therefore, any intact riparian corridors that might provide additional connectivity within the study area were identified. The riparian corridor layer was created by combining all forested wetlands from Water Management District land use data with streams from NHD flowlines data. Then, we identified all additional natural or semi-natural land cover (defined as all FLUCCS values from 3000 to 7399) within 400 meters of these forested wetlands and streams. Values are:

1 = riparian habitat/corridor
0 = not riparian habitat/corridor

To serve as a starting point for evaluating potential connectivity, we combined the identified riparian habitat/corridors with the FEGN and the Florida black bear and Florida panther habitat models. First, we combined riparian habitat/corridors with the FEGN and identified all combined areas that were 1,000 acres or larger. Then, we took this combined data set and combined it with all bear and panther habitat and again identified all combined areas that were 1,000 acres or larger.

Least Cost Path Models

Least Cost Path (LCP) is a useful tool for assessing potential connectivity. LCP is a raster-based algorithm available in ESRI's ArcView Spatial Analyst or ArcGIS software. It is an optimization function that seeks the least costly route between a source and a destination. Typically this algorithm has been used to find the optimal path for linear infrastructure (including roads and transmission lines). LCP analysis can also be applied to wildlife corridor analysis where the best potential travel route between a source and destination is identified based on a cost surface ranking each cell's corridor suitability (Hoctor 2003; Larkin et al. 2004). The least costly route is essentially the path of least resistance, where resistance is defined by unsuitable or low-security habitat for the species in question.

Identifying LCPs requires the development of a cost surface, which is a raster map in which every cell (or pixel) is ranked for its potential suitability for accommodating a particular function. In the case of ecological connectivity, a cost surface ranks each cell based on its potential to support a functional ecological connection. Cells within the study area can be ranked using as many variables as deemed relevant for determining connectivity potential. These variables can include intrinsic qualities (such as the land use of the cell) or landscape or context values (such as whether the cell is part of a large forest block or near a large urban area).

We ran LCP analyses for all three focal species. In addition, we also tested the effects of using different cost surfaces in LCP results. Hoctor (2003) found that the structure of cost surfaces in interaction with the landscape structure can significantly influence LCP results. Therefore, for each of the three focal species, we constructed six different cost surfaces. The cost surface variations included:

1) Habitat for focal species reclassified into a cost surface
2) Habitat plus major roads
3) Habitat, major roads, and edge effects
4) Habitat, major roads, edge effects, and sea-level rise
5) Habitat plus CLIP Landscape Integrity layer
6) Habitat, Landscape Integrity, roads, edge effects, and sea-level rise

For each of the focal species the potential habitat models were reclassified to turn them into cost surfaces. For example, for the Florida black bear primary habitat was given a cost of 1 (which is the lowest possible cost and therefore the highest suitability), secondary habitat was given a cost of 5, and traversable matrix was given a cost of 10. In addition, all non-habitat was assigned as "No Data" which means that an LCP could not be located in these areas. However, for the Florida panther and fox squirrel, non-habitat was assigned a cost of 10 instead of No Data because these habitat models were not constructed to assess landscape-scale connectivity as in the black bear habitat model.

Major roads were included in the relevant cost surfaces by identifying to sets of highway segments included in the Florida Department of Transportation's Major Roads GIS data layer (obtained from the Florida Geographic Data Library, i.e., FGDL). Highways with four or more travel lanes or Average Daily Traffic (ADT) of 5,000 vehicles or greater were assigned a cost of 100 and all other highways were assigned a cost of 50. In the cost surfaces including highways, more emphasis is placed on avoiding such road crossings.

Edge effects were identified as areas proximal to residential or commercial land uses that could fragment potential corridors or cause various disturbances (i.e., human-caused mortality) that could reduce functional connectivity. In the appropriate cost surfaces, areas within 100 meters of such development was assigned No Data, areas from 100-300 meters from such development was assigned a cost of 100, and areas 300-1000 meters from such development was assigned a cost of 50. Therefore, lower cost areas more suitable for facilitating connectivity would have to be at least 1 kilometer away from intensive development.

Sea level rise (SLR) could affect potential corridors where water bodies will be widened as sea level inundates low-lying areas adjacent to current surface water levels near the sea. Examples in the Babcock Ranch study area include the lower Caloosahatchee and Peace Rivers. Since all of our focal species can cross water but avoid water crossings when possible, it is assumed that wider water bodies are less suitable for a corridor crossing than narrow water bodies. To account for increased water body width that could affect potential corridors crossing, we assigned areas that would be inundated by a 1 meter SLR a cost of 100 (including existing open water), and areas that would be inundated by a 3 meter SLR were assigned a cost of 50. The SLR data was created using the National Elevation Data and identifying areas adjacent to existing sea level with elevations either 1 meter or less or 3 meters or less (UA citation; Noss et al., unpublished data).

The Landscape Integrity layer from the CLIP project (Hoctor et al. 2008) was used to create the final two cost surfaces. In the first cost surface, the Landscape Integrity layer's values of 10 to 1 (where 10 signifies the highest landscape integrity and 1 the lowest) were inverted to match cost surface values. These inverted Landscape Integrity costs were then averaged with the reclassified potential habitat model costs to result in a cost surface with values of 1 to 10, where a cost of 1 occurs in areas of primary habitat that also had the highest landscape integrity (defined as areas within large natural and semi-natural patches with little impact from intensive land uses).

The final cost surface included all elements described above where major roads and SLR were assigned costs of 100 or 50 as described above. However, potential habitat, Landscape Integrity, and edge effects were averaged together to create a different combination of habitat and landscape suitability. In this averaging, the reclassified habitat costs and Landscape Integrity values were assigned the same values as described above. However, the edge effect costs were modified, such that areas within 100 meters of intensive development were assigned No Data, areas within 100-300 meters were assigned a cost of 10, areas with 300-1000 meters were assigned a cost of 5, and areas beyond 1000 meters of intensive development were assigned a cost of 1. These reclassified edge effect costs were then averaged with the habitat and Landscape Integrity costs to create one corridor suitability index with costs of 1 to 10, with other areas assigned costs of 50 or 100 where they overlapped with major roads or areas affected by SLR (See Fig. 2).

These six cost surfaces were created for each of the three focal species, since the potential habitat models were different for each species. In addition, we selected six regional destinations to determine LCPs between Babcock Ranch and other key existing conservation lands within the study region that would likely serve as major "hubs" in a regional ecological network. The destinations included: Big Cypress National Preserve, Okaloacoochee Slough State Forest, Fisheating Creek Wildlife Management Area, Bright Hour Watershed, the Myakka complex of conservation lands (Myakka), and the Avon Park Air Force Range (see Fig. 1). Therefore, with 6 cost surfaces and 6 destinations, there were 36 LCP results for each focal species.

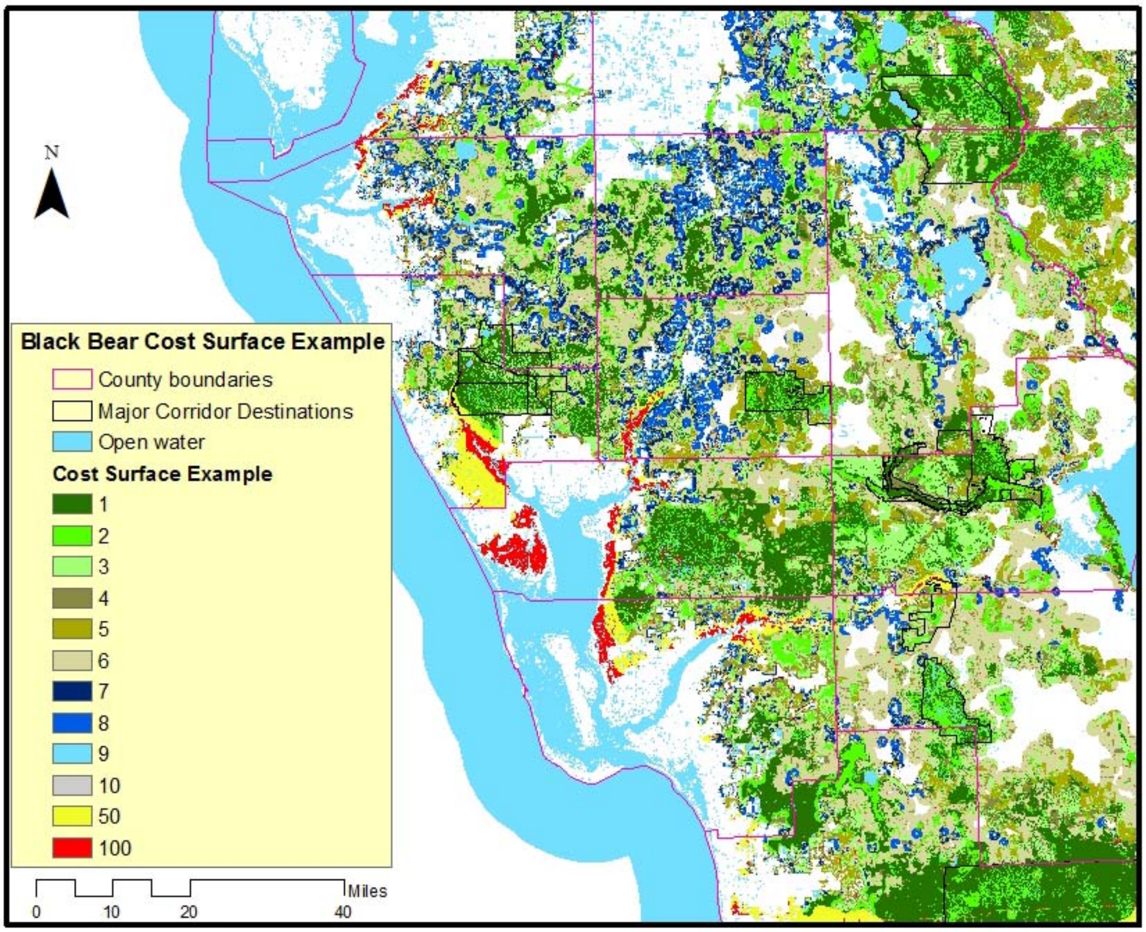


Figure 3. Example cost surface, which is the final of the 6 cost surface variations combining potential habitat, CLIP Landscape Integrity, and edge effects with costs ranging from 1-10 and then assigning highways or areas potentially affected by sea level rise costs of either 50 or 100. Roads that have been assigned costs of 50 or 100 do not show up on this map because of the scale.

Identification of Regional-scale Habitat Corridor Network Options

We identified three habitat corridor network (ecological network) options through a collective analysis and assessment of potential habitat model results for the three focal species, the LCP model results, the roadkill surveys, and other relevant data including the Florida Ecological Greenways Network, the Florida Panther Subteam report and Panther Habitat Conservation Zones, the Panther Habitat Protection Priorities, panther and bear telemetry and roadkill locations, bear range maps, and Integrated Habitat Network from Florida Department of Environmental Protection. The goal of the three connectivity options was to identify the best opportunities to maintain or restore ecological connectivity in the region surrounding Babcock Ranch. The connectivity options range from low, moderate, to high, with more proposed conservation acreage and more, and generally wider, corridors in the moderate and high connectivity options.

We first examined the patterns in potential habitat for each of the focal species, including larger areas of habitat and patterns of habitat connectedness in the habitat model results. LCP model results were assessed in several ways. First, we conducted an analysis of the overlap of LCP results for each of the focal species and then for all three focal species combined. The overlap analysis was conducted by examining the intersection of each LCP GIS shapefile with a shapefile of the study area that separated into square mile cells. The number of times each of these cells was crossed by an LCP was then counted for each of the focal species and then for all species combined. We also compared the LCP results visually with the focal species habitat model results, existing and proposed conservation lands, riparian corridors and networks, road and water body crossings, and potential bottlenecks near developed areas. Based on the LCP assessments, we then selected LCP results that we considered to be the most suitable for representing connectivity opportunities for the low, moderate, and high connectivity options.

Finally, we considered other relevant data for inclusion in the three connectivity options. Existing conservation lands were considered necessary areas to include where they contributed to a connectivity option. Florida Forever projects are also potentially significant for facilitating connectivity, and those considered important in this respect were included in the various connectivity options. Specifically, the Caloosahatchee Ecoscape Florida Forever Project is considered essential to providing functional connectivity between conservation lands south and north of the Caloosahatchee River; therefore, the Caloosahatchee Ecoscape was included in all of the connectivity options. The Florida Ecological Greenways Network (FEGN) identifies state and regional priorities for protecting large, intact landscapes and ecological corridors across Florida. It is therefore an essential dataset for assessing connectivity at all scales within the state, including regional and local.

Although the boundaries of the FEGN are general and should not be used as the basis for site-scale conservation boundary delineation, areas within the FEGN do represent important opportunities to protect ecological and focal species connectivity. In addition, although the FEGN is prioritized, these priorities are meant to guide state to regional scale planning; areas within the FEGN should be considered potentially significant at regional to local scales. For this analysis, we used the FEGN highest priorities in delineating the moderate connectivity option, and all areas within the FEGN were used in delineating the high connectivity option.

We also used data on habitat conservation priorities for the Florida black bear and Florida panther to delineate the moderate and high connectivity options. Given that funding and time constraints prevented us from conducting a regional, spatially explicit population viability analysis for bears and panthers, existing data on habitat conservation priorities constitute the best available information for identifying significant areas for maintaining/restoring functionally connected habitat blocks that will contribute to population viability for both species. We used the new Florida Fish and Wildlife Conservation Commission (FWC) Strategic Habitat Conservation Areas for both the Florida black bear and Florida panther, as well as the U.S. Fish and Wildlife Service's MERIT Panther Subteam's Primary and Dispersal Habitat Conservation Zones for this analysis. In addition, the Florida Panther Habitat Preservation Plan areas from 1993 were included since these are the best available data for delineating potential habitat conservation priorities north of the Caloosahatchee River to augment the Panther Subteam's Conservation Zones, which are largely limited to areas south of the river (except for a small portion of the Dispersal Zone). Finally, the primary range for the Florida black bear identified by FWC and habitat protection priorities for the Highlands-Glades bear population identified by Tom Hoctor were used (see Fig. 4). In all cases, only areas of habitat identified in our Florida panther and Florida black bear potential habitat models that also were within these various habitat conservation priorities were included in the appropriate connectivity option.

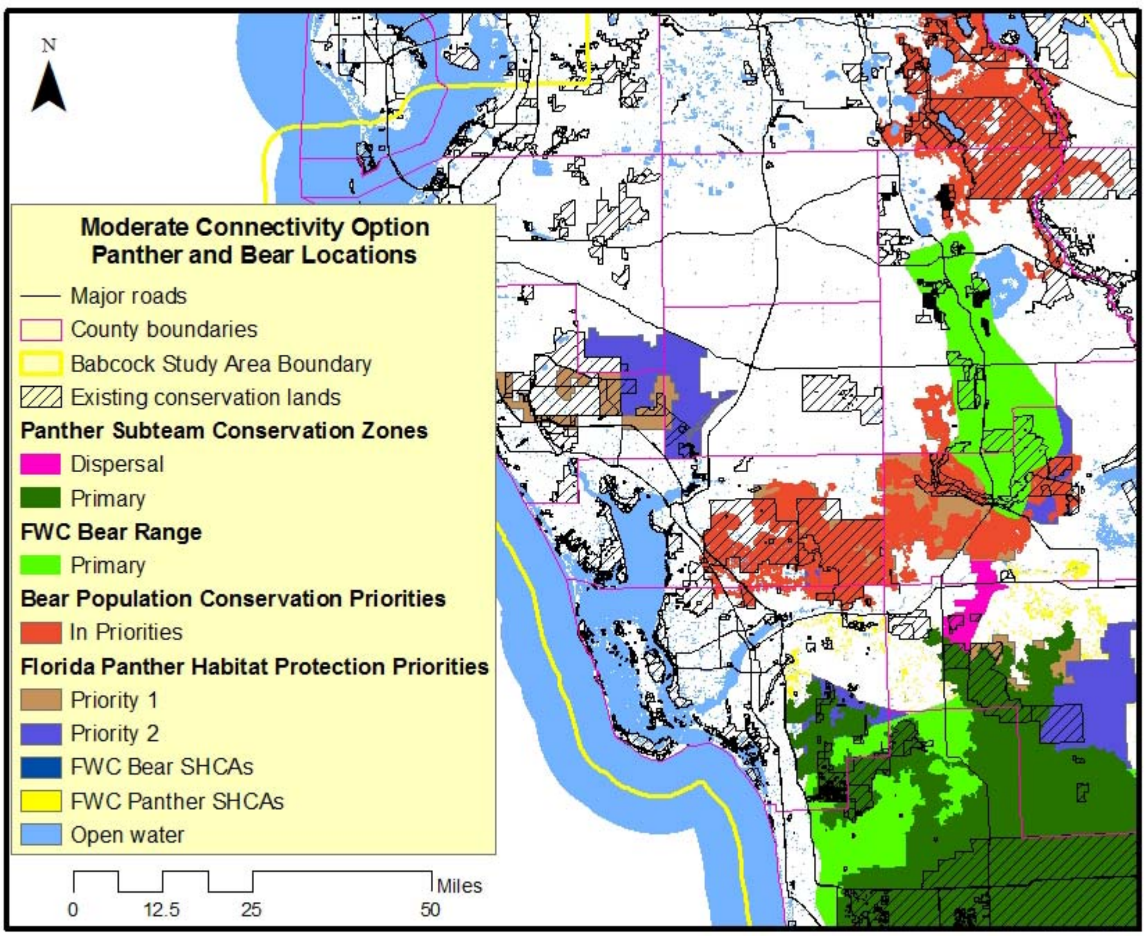


Figure 4. Florida panther and Florida black bear habitat conservation priority areas used to delineate the moderate and high connectivity options.

After discussions with the Wildlife Corridor Study Steering Committee and the Lands Surrounding Babcock Ranch Steering Committee, we added one more data layer, the Integrated Habitat Network (IHN), to identify additional riparian networks in both the moderate and high connectivity options. The IHN identifies existing and proposed protected riparian corridor networks in southwest and west-central Florida, focused on the Peace River and Myakka River watersheds and several other river systems. The IHN riparian networks augment the primary areas identified in the moderate and high connectivity options further to the south with additional northern corridor options and a potential corridor of statewide significance between southwest Florida and the Green Swamp.

We used the following datasets to create the three connectivity options:

1) Low Connectivity Option
a. Existing conservation lands
b. Caloosahatchee Ecoscape Florida Forever Project
c. One set of LCP results buffered by 1 mile for the three focal species between Babcock Ranch and the six selected destinations (Myakka, Bright Hour, Avon Park Air Force Range, Fisheating Creek Conservation Easement, Caloosahatchee Ecoscape, Okaloacoochee Slough State Forest, and Big Cypress National Preserve).

2) Moderate Connectivity Option
a. Existing conservation lands
b. Florida Forever projects
c. Two panther and two bear cost surface buffered LCP results buffered by 1 mile.
d. All Critical Linkages within the Florida Ecological Greenways Network
e. All primary and secondary black bear habitat within: all potential habitat within primary range identified by FWC, or all bear population habitat conservation recommendations delineated by T. Hoctor, or the new FWC bear SHCAs.
f. All panther habitat within: the USFWS Panther Subteam Primary and Dispersal Zones, or the older FWC Habitat Protection Plan areas, or the new FWC SHCAs
g. Integrated Habitat Network (given a value of 2 whereas all other areas within the option were given a value of 1)

3) High Connectivity Option
a. Existing conservation lands
b. Florida Forever Projects
c. Two panther and two bear cost surface buffered LCP results buffered by 1 mile.
d. All areas within the Florida Ecological Greenways Network
e. All potential bear (primary and secondary), panther, and fox squirrel habitat (primary and secondary)
f. All regional and local riparian corridors
g. Integrated Habitat Network (given a value of 2 whereas all other areas within the option were given a value of 1)

Comparison of Results to Future Scenarios

Future urban and suburban development and sea level rise (SLR) are two important potential impacts that could significantly affect the integrity of focal species habitat and corridors in the study area. To serve as coarse examples of what these impacts might be, we compared the moderate connectivity option results to data representing potential future development and SLR in the study area. We used the Florida 2060 growth projection model results to represent potential future development that might threaten potential priority conservation areas (Zwick and Carr 2006). It should be noted that the Florida 2060 model is a coarse, statewide model that projects future development based on current county-level human population densities and predicted future county population growth. Therefore, the amount and pattern of development is at best an approximate representation of future growth based on little to no consideration of sustainable development patterns. However, overlap between potential future growth and the moderate connectivity option does serve to highlight areas that might be most susceptible to future growth conflicts if sound planning practices and growth plans with conservation planning strategies are not enacted. We used the same SLR data described above regarding creation of our LCP cost surfaces to compare with the moderate connectivity option. SLR impacts could be extremely severe and wide-ranging in south and southwest Florida including the inundation of large areas of public conservation land. However, in the SLR comparison for this study, we focused on the potential impact of SLR on potential corridor crossings of the Caloosahatchee River and Peace River. We will discuss additional implications of SLR on focal species and corridor conservation in the Discussion section below.

Results

Data Products

The results of this study include the production of a series of GIS data products, which can be used for conservation planning by Babcock Ranch and other identified parties within the study region and beyond. These products include:

- Black bear habitat
- Florida panther habitat
- Fox squirrel habitat
- Riparian corridors
- Florida Ecological Greenways Network and Riparian Corridors
- Greenways, Riparian Corridors, and Focal Species Habitat Combined
- Least Cost Path modeling results
- Low Connectivity Option
- Moderate Connectivity Option
- High Connectivity Option

Habitat Models

Regarding habitat models, we are interested in major patterns of potential available habitat with respect to existing conservation areas, large habitat patches, areas dominated by potential habitat, and potential connectivity suggested by habitat configurations. All three focal species have significant areas of potential habitat available in the study area, with the fox squirrel having the most limited potential habitat base. However, there is an important difference between potential habitat and occupied habitat. For all three focal species, we know that there is significantly more potential habitat identified in these models than there is occupied habitat. This is likely due to either the habitat models not identifying all of the landscape, land-use, and land cover characteristics required to support populations, or to potentially suitable habitat being unoccupied because of past or current human pressures including historic hunting and poaching (e.g., Williams 1978). Sherman's and Big Cypress fox squirrels are habitat specialists that require well managed pine uplands in large landscapes. Our habitat model, which identifies all pine flatwoods and pine uplands as one of the modeling steps, likely overestimates suitable habitat because many pine flatwoods and uplands are not burned appropriately to maintain suitable or high quality habitat. Regarding panther and bear, both species are relative generalists in terms of types of suitable land cover, but they are both wide-ranging species requiring large areas with low human land-use intensity and activity to support individuals and populations. In some cases, our identification of potential habitat for these species may not be sensitive enough to the unknowns about suitability thresholds; therefore, potential habitat may be identified in areas that are not suitable. However, due to historic hunting of both species throughout Florida, it is also feasible that other areas of potential habitat identified in our habitat models are suitable but are currently unoccupied by breeding populations because resident animals were hunted out in the past. Below we will summarize the major habitat patterns in the habitat models for each focal species with these important caveats in mind.

The only known breeding population of the Florida panther is relegated to areas south of the Caloosahatchee River. However, there are significant areas of potential habitat for this species north of the Caloosahatchee River that were identified in this study as well as others (e.g., Kautz et al. 2006). In addition, telemetry and other data indicate that at least sub-adult male panthers have traveled extensively and occupied potential habitat throughout south-central Florida (Maehr et al. 2002, unpublished Florida Fish and Wildlife Conservation Commission panther telemetry and GPS panther location data). Our panther habitat model confirms that, based on proximity to breeding range and the extent and connectedness of potential habitat, Babcock Ranch is central to a hub of potential habitat that ranges from Cecil Webb WMA west of Babcock Ranch, east through Babcock Ranch, and then east and northeast through large areas within and surrounding conservation easements along Fisheating Creek (Fig. 5 and Fig. 6). This area is likely the most relevant for efforts to expand the existing breeding population to areas north of the Caloosahatchee River, which the USFWS Panther Subteam stated would significantly increase the viability of the population if such an expansion was successful (Florida Panther Subteam 2002). Farther north there are three areas of potential habitat that are potentially significant based on the extent of potential habitat and location relative to existing conservation areas. Northwest of Babcock Ranch, the Myakka complex of existing conservation lands and additional lands in the Myakka River and lower Peace River watershed support a network of potential habitat in Sarasota, Desoto, Hardee, and Manatee counties (Fig. 5 and Fig. 6). Northeast of Babcock Ranch and north of Fisheating Creek, a network of potential habitat occurs through the Lake Wales Ridge, including Archbold Biological Station, various scrub reserves on the Ridge, Highlands Hammock State Park, Lake Wales Ridge State Forest, Avon Park Air Force Range, and further north along the upper Kissimmee River watershed (Fig. 5 and Fig. 6). This habitat network has demonstrated use based on available FWC panther telemetry and GPS location data (Fig 7). Further north, the Green Swamp supports a large area of potential habitat, which might be accessible to panthers through narrow corridors either through the upper Peace River watershed or the upper Kissimmee River watershed (Fig. 5).

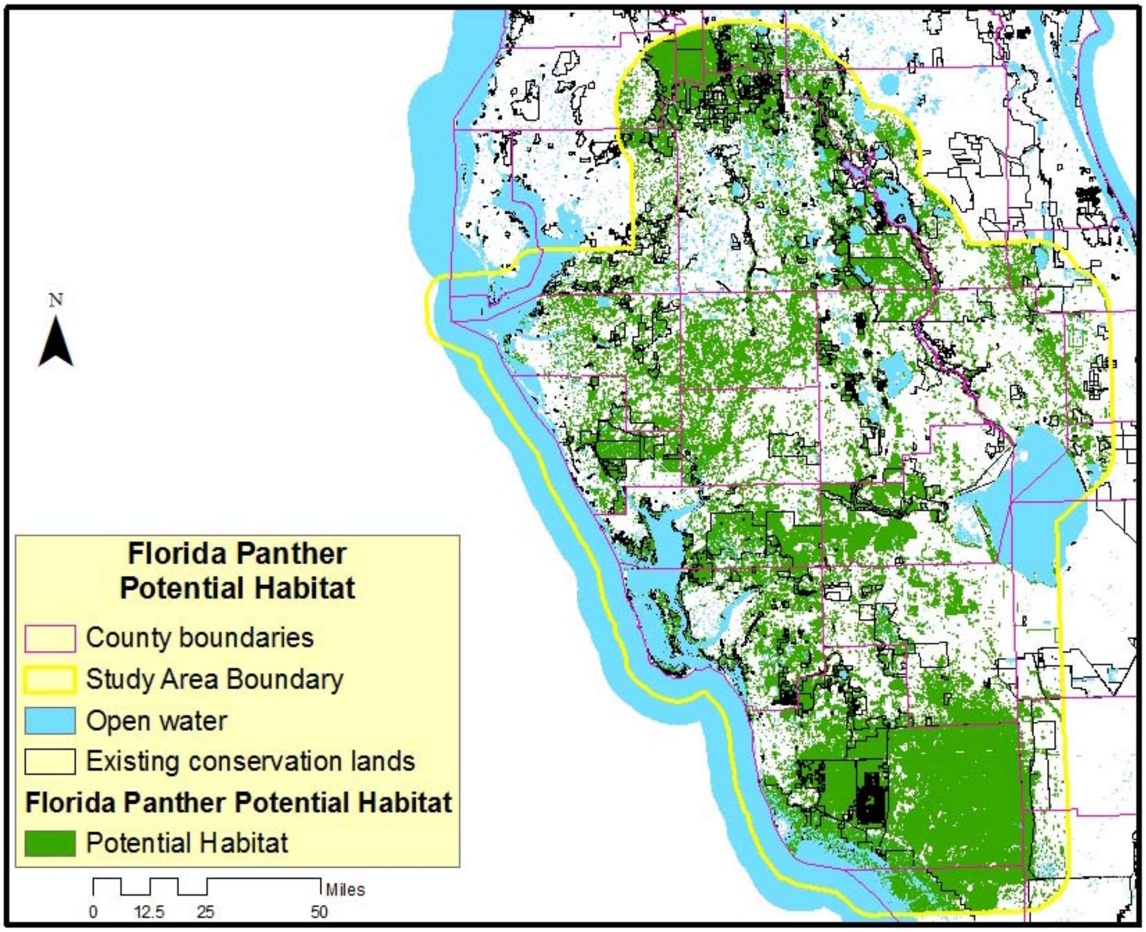


Figure 5. Map of potential Florida Panther habitat within the Babcock study area.

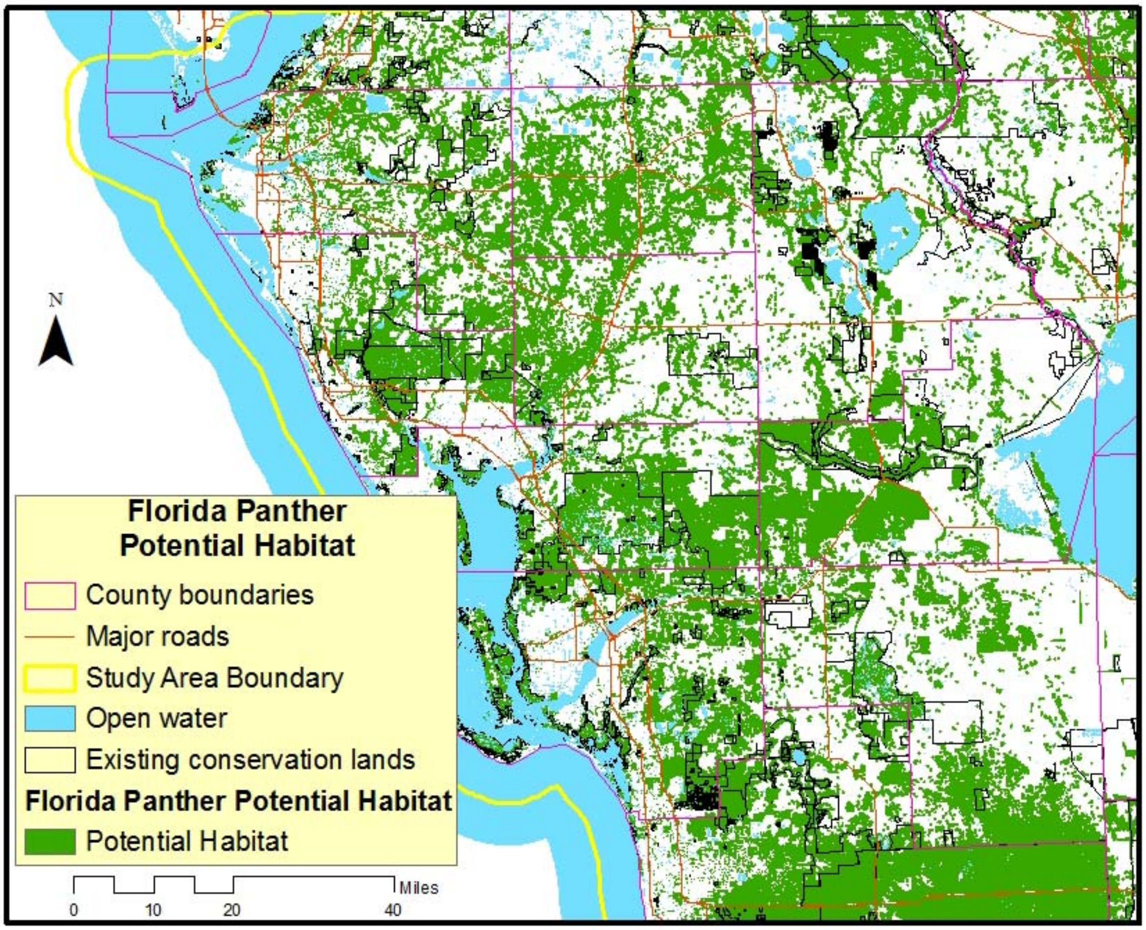


Figure 6. Zoom-in map of potential Florida Panther habitat within the Babcock study area.

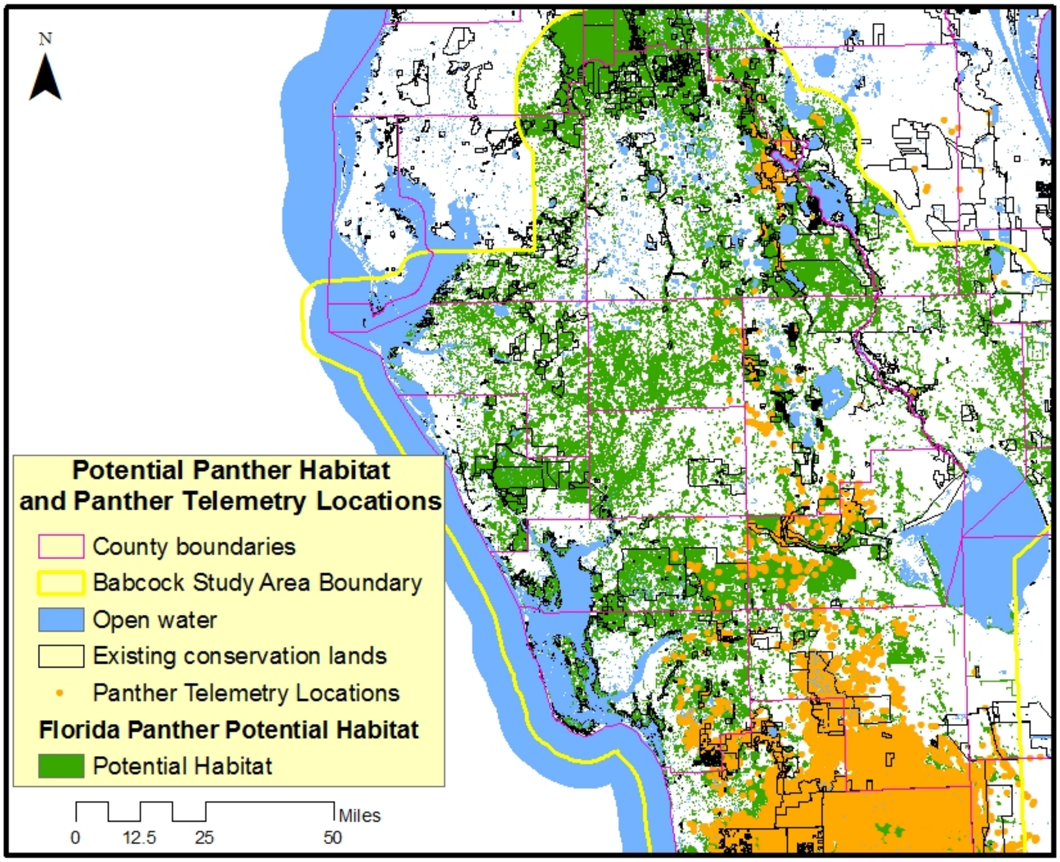


Figure 7. Potential panther habitat and telemetry locations.

Potential Florida black bear habitat exhibits an extent and distribution similar to potential panther habitat. One key difference between the bear and panther habitat models is the inclusion of traversable matrix and a large area size threshold in determining potential bear habitat suitability. Traversable matrix includes land uses that bears may not use for foraging or denning, but which they are capable of moving through. The size threshold criterion in the bear habitat model requires that, to be considered potential habitat, at least 10,000 acres of primary or secondary bear habitat must be within one patch connected at least by traversable matrix. This criterion eliminates the identification of isolated patches that bears are unlikely to find or use within a home range or during dispersal. However, the potential habitat map shows that relatively broad areas still support potential habitat, despite these relatively stringent connectedness and size thresholds (Fig. 8 and Fig. 9). Between Big Cypress National Preserve and the Caloosahatchee River, larger patches of potential habitat exist in Okaloacoochee Slough State Forest, Corckscrew Swamp, and, interestingly, in eastern Lee County due south of Babcock Ranch and north of Corkscrew Swamp. The status of this potential habitat in Lee County, which is outside of primary bear range but within secondary bear range, should be investigated in the near future (Fig. 10). This area will also be discussed below with respect to the Least Cost Path modeling results and in the connectivity option results.

North of the Caloosahatchee River the potential bear habitat distribution is similar to that for panthers: a large patch of connected potential habitat from Cecil Webb Wildlife Management Area to Fisheating Creek; more potential habitat in the Myakka conservation complex and Myakka and Peace River watersheds; a network of potential habitat from Fisheating Creek north to Avon Park Air Force Range and even further north along the upper Kissimmee River watershed; and a large swath of potential habitat in Green Swamp. Comparison of the potential bear habitat model results and current bear range suggests that the potential for functional connectivity between the Highlands-Glades bear population and the Big Cypress population is at least relatively high (Fig. 10). However, recent genetic analysis of these populations suggests that they are differentiated genetically to the extent that, at least in the recent past, there apparently has not been widespread interchange between the populations, although these populations are more similar genetically to each other than they are to other Florida black bear populations (Dixon et al. 2007). The Highlands-Glades population is one of three remaining small Florida black bear populations, and restoring functional connectivity between it and the Big Cypress population is an important goal for protecting a viable population north of the Caloosahatchee River (Maehr et al. 2001a, Hoctor 2003). Although occasional bears may travel through Babcock Ranch, it is considered outside current bear range (Fig. 10). Nevertheless, expansion of the Highlands-Glades population to the southwest into Babcock Ranch could significantly increase the size of the population and protected habitat. In addition, if a breeding bear population could be supported in the Myakka-Peace area, this could also significantly increase regional bear population viability.

Until 2004 the black bears of Highlands and Glades counties (HG) were the last unstudied population of this threatened species in Florida. These bears inhabit the southern portion of the highly biodiverse and globally imperiled Lake Wales Ridge Ecoregion (LWRE) that forms an important linkage within a statewide bear metapopulation. During the past 30 years the LWRE has been severely fragmented and altered by agricultural and urban development. Unlike other major bear populations in Florida that occur on public lands, research has indicated that bears in this area primarily inhabit private lands, particularly cattle ranches (Ulrey 2008). A patchwork of public lands has facilitated movements of individual bears (particularly males) outside of core habitat, and some of these lands support a few resident individuals in more urbanized areas (J. Cox, pers. comm.).

The black bear's wide-ranging movements (Maehr 1997) and diverse food requirements (Maehr and DeFazio 1985) incorporate virtually all native habitats in the region to some degree. At the landscape scale these bears select forest, scrub, and citrus, but avoid urban areas; within home ranges they select bay swamp and hardwood hammock, but avoid urban areas and grassland (Ulrey 2008). Private ranches in this area that support bears are typically several thousand acres or larger in size, relatively unfragmented as compared to surrounding lands, and contain a mosaic of diverse native habitats that includes upland forest, bayhead, and scrub components, which collectively provide a temporal variety of soft and hard mast, as well as suitable denning sites (Ulrey 2008).

Some connectivity between the HG bear population and other protected lands has been documented, with Maehr et al. (1988) noting interchange with the Big Cypress population. In 2007 a radio-collared HG male bear made a circuitous movement to Babcock-Webb WMA and back. Despite these documented linkages to other protected areas, Dixon et. al (2007) found that HG bears were relatively isolated, with the second lowest level of genetic diversity of all of Florida's major bear populations. Re-establishing a functional connection to the Big Cypress bear population is an important goal for maintaining, and potentially increasing, the genetic diversity of the HG population and enhancing the viability of the bear population north of the Caloosahatchee River in south-central Florida. In addition, achieving functional connectivity between the HG and Big Cypress bear populations can significantly complement efforts to conserve a viable Florida panther population in south Florida by improving connectivity between panther habitat south and north of the Caloosahatchee River and securing additional habitat for panthers north of the Caloosahatchee River.

Babcock Ranch is a potential keystone site for these efforts given its size, suitable habitat, and location between Cecil Webb WMA and conservation lands in the Fisheating Creek watershed. Habitat management objectives should incorporate landscape-based approaches that balance restoration of suitable habitat conditions for fox squirrels, which prefer open pine stands with grassy understory, and bears, which need saw palmetto and other shrubby plant species for foraging and den cover. HG bears currently occupy habitat within easy dispersal distance of Babcock Ranch; therefore, with appropriate population and habitat management, Babcock Ranch could become an important part of an expanded occupied habitat base for the HG bear population.

However, land use changes in south-central Florida significantly threaten efforts to achieve these conservation goals. For example, the Highlands County human population grew by 27.7% from 1990 to 2000, a 4% faster rate than the mean for Florida (U.S. Census Bureau 2002). The loss of citrus groves as the result of recent severe winter freezes in central Florida has resulted in the conversion of former agricultural land to residential development. This has created rapidly growing highway traffic. Highways are a significant feature of the modern landscape and represent potential barriers between important bear habitats. Vehicle collisions were the cause of 82% of mortality to adult bears in the HG area (Ulrey 2008). As highways are enlarged to accommodate burgeoning vehicle use, regional highways will become increasingly problematic barriers to dispersal and seasonal movements of the HG bear population. Further curtailment of movements to access food, mates, and winter den sites will reduce the capacity of the region to support the black bear.

Conservation of bears and other threatened and endangered species in south-central Florida presents unique conservation challenges for wildlife managers and land use planners. The findings of current research on the HG bear population will be important for conservation planning and management that utilize the black bear as a focal species, as well as planning for human population growth. In a region that is experiencing both rapid human population growth and significant land acquisition and stewardship actions by governmental and non-governmental organizations, understanding the habitat and spatial requirements of the wide-ranging black bear will be crucial to identifying important landscape linkages.

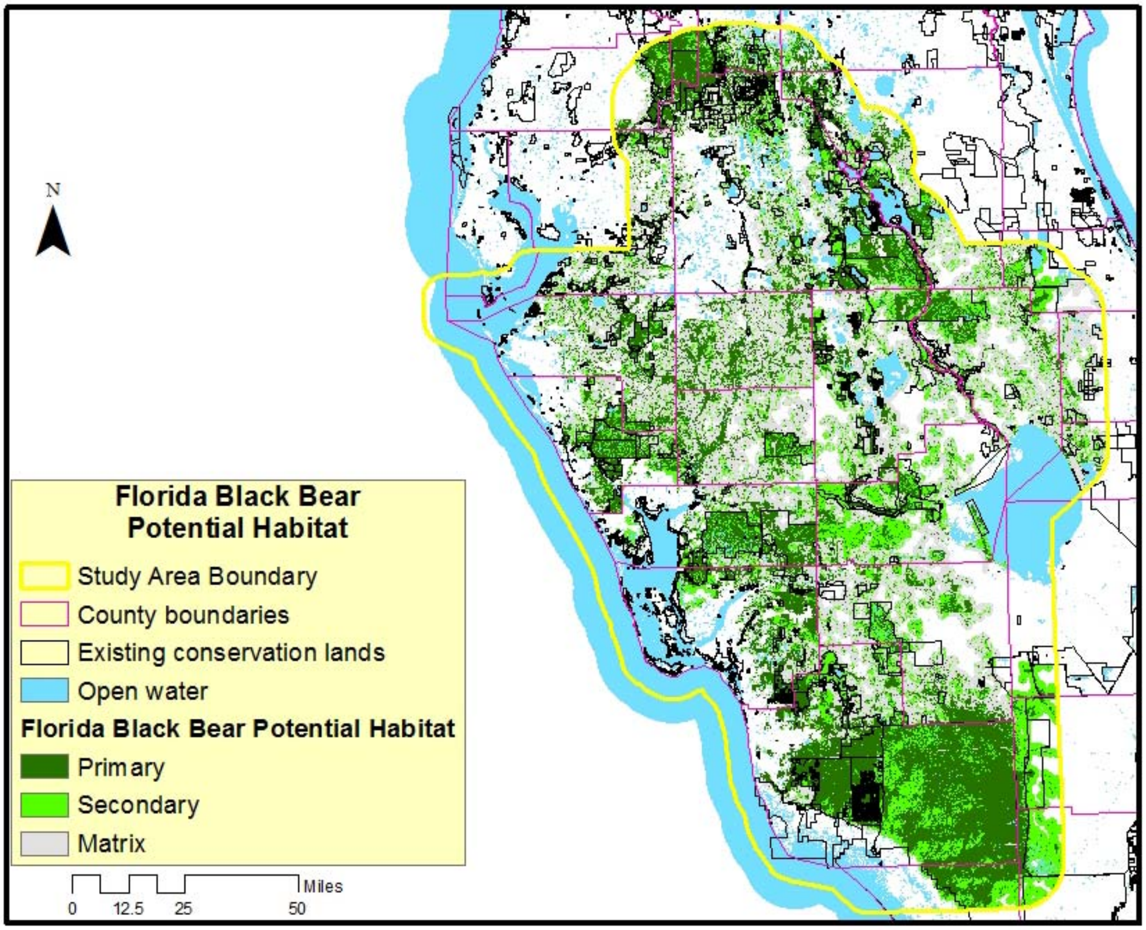


Figure 8. Map of potential Florida black bear habitat within the Babcock study area.

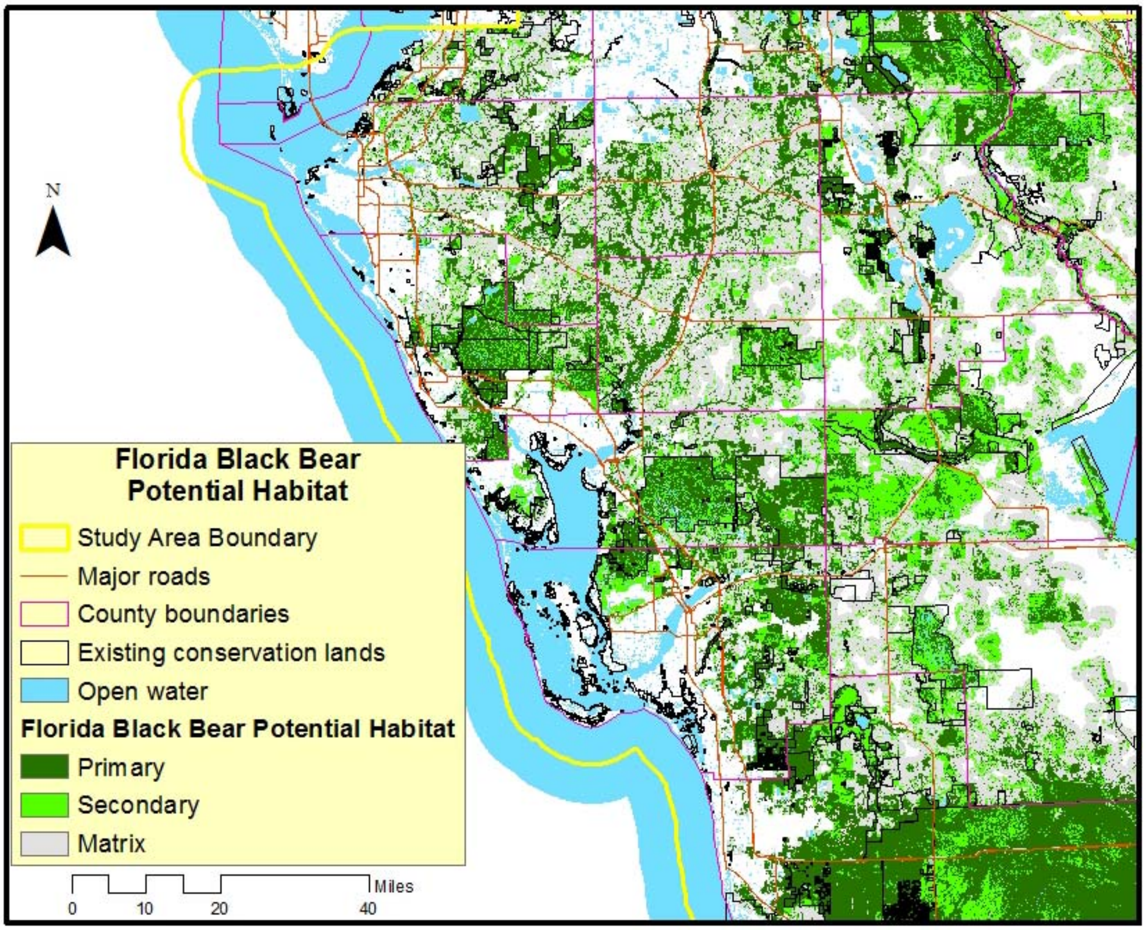


Figure *9. Zoom-in map of potential Florida black bear habitat within the Babcock study area.*

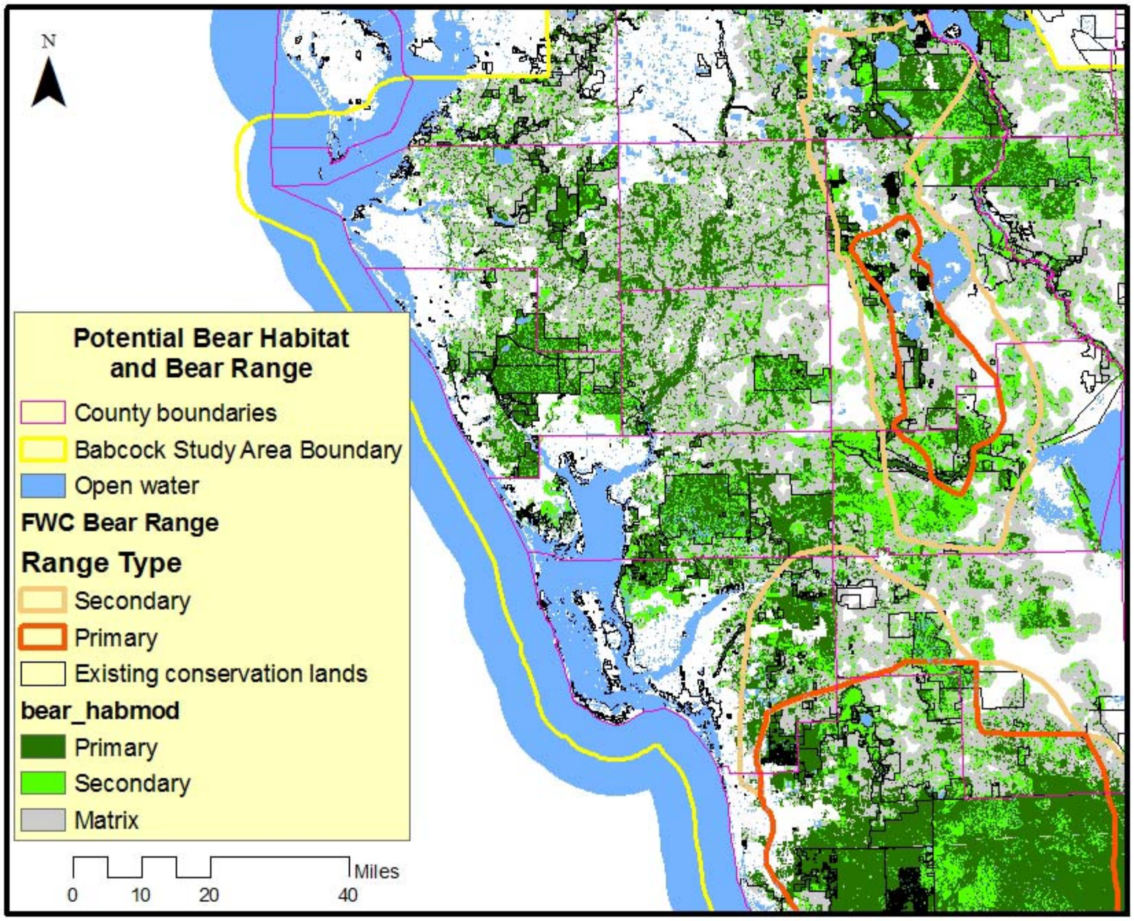


Figure 10. Potential bear habitat and the range of the Big Cypress and Highlands-Glades Florida black bear populations.

Fox squirrel potential habitat is much less extensive and much more fragmented than potential panther and bear habitat (Fig. 11 and Fig. 12). Almost all of the larger patches of potential habitat are found on existing conservation lands including, from south to north, Big Cypress National Preserve, Okaloacoochee Slough State Forest, Babcock Ranch and Cecil Webb Wildlife Management Area, the Myakka complex of conservation lands, Duette Park in Manatee County, several of the Lake Wales Ridge reserves, Lake Wales Ridge State Forest, Avon Park Air Force Range, and the Green Swamp. Several notable large patches of potential habitat exist on private lands, including areas in Hendry County, areas north and south of Corkscrew Swamp (including the potential bear habitat area in Lee County between Corkscrew and Babcock Ranch), areas east and northeast of Myakka River State Park, and on the Bombing Range Ridge Florida Forever Project north of Avon Park Air Force Range. Finally, as state above, many of these areas may potentially support fox squirrels, but habitat suitability is dependent on the maintenance of open pineland areas with grassy understory. Due to fire suppression or dormant-season burning, many natural or semi-natural pinelands are either low quality or unsuitable for fox squirrels. Thorough survey work is needed to establish fox squirrel presence/absence and develop management recommendations to improve habitat quality.

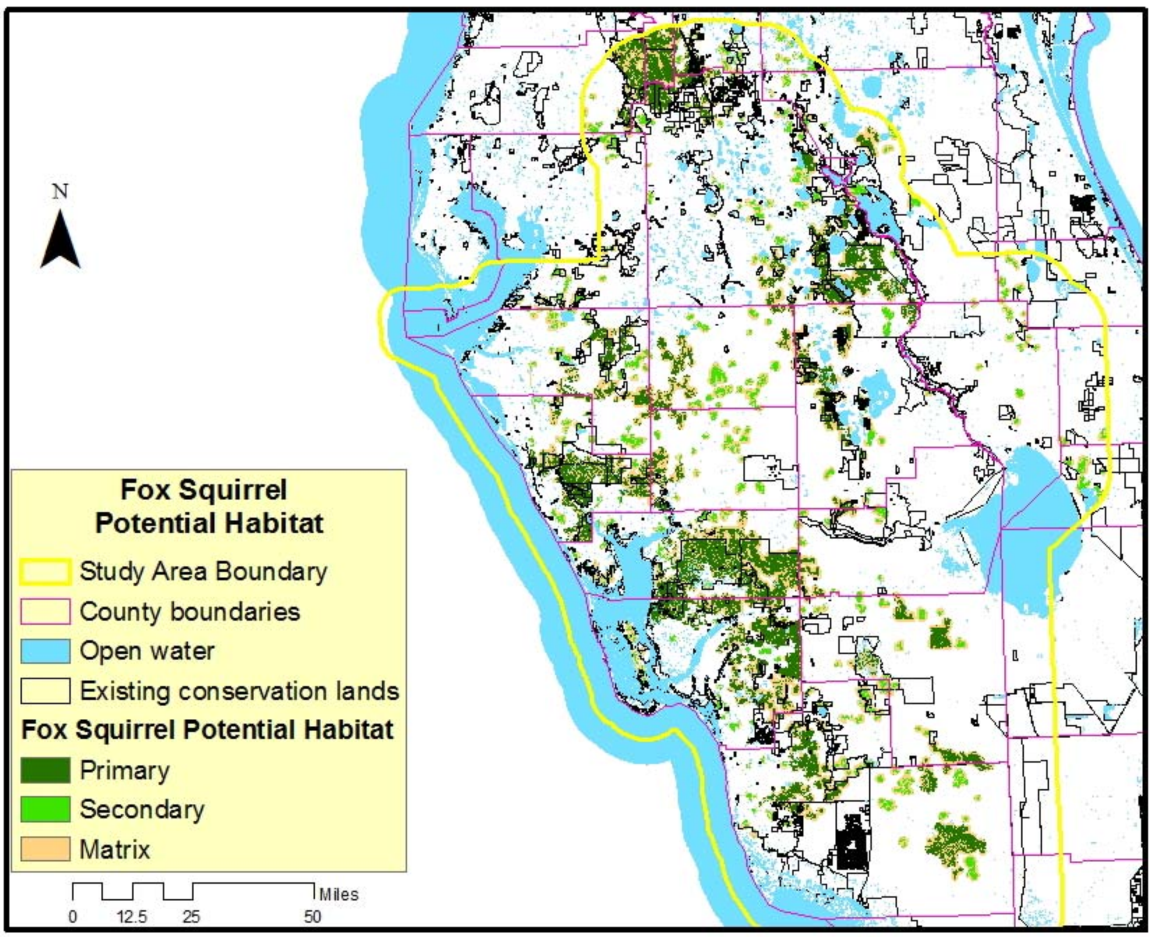


Figure 11. Map of potential Sherman's fox squirrel habitat within the Babcock study area.

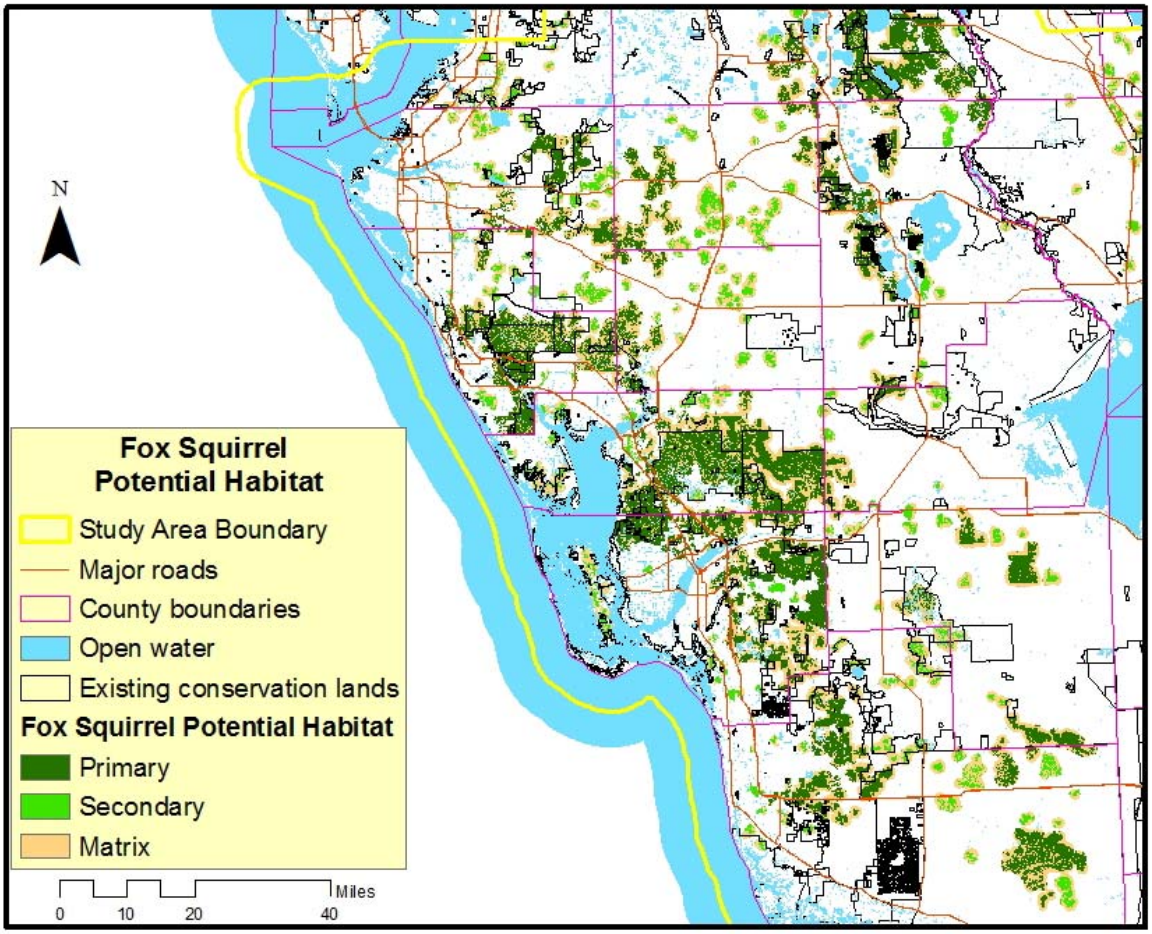


Figure 12. Zoom-in map of potential Sherman's fox squirrel habitat within the Babcock study area.

<u>Roadkills and Fox Squirrel Sightings</u>

As noted earlier, we collected data on roadkills of large herpetofauna (snakes, turtles, alligators), large birds, and medium-sized to large mammals. While conducting these surveys we also recorded all sightings of fox squirrels. Our results are shown in the following three figures, with Fig. 13 showing the general pattern of roadkills and fox squirrel sightings, Fig. 14 showing the species-level breakdown of roadkills and sightings (i.e., all fox squirrel points are sightings, not roadkills), and Fig. 15 showing data for species of particular interest, with bobcat roadkills and fox squirrel sightings indicated by larger circles. The data show that roadkills are broadly distributed along the roads surveyed, but with greatest concentrations on CR 74 near the junction with SR 31, on SR 31 along an approximately 4-mile stretch south of that intersection, and finally on SR 31 along a stretch approximately 7-10 miles south of that intersection. Fox squirrel sightings are within Babcock Ranch and along SR 78 (N River Rd.) in the area adjacent to the Caloosahatchee River Regional Park.

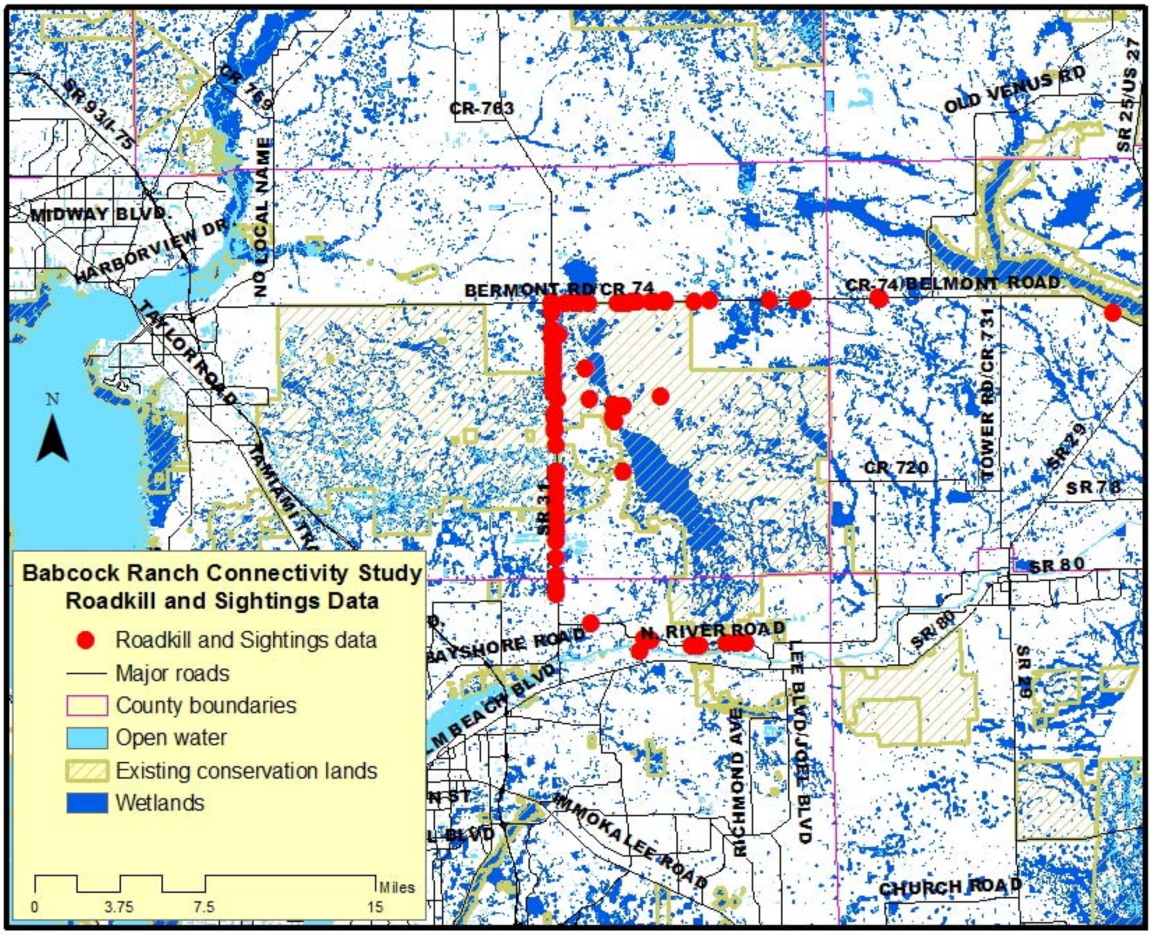
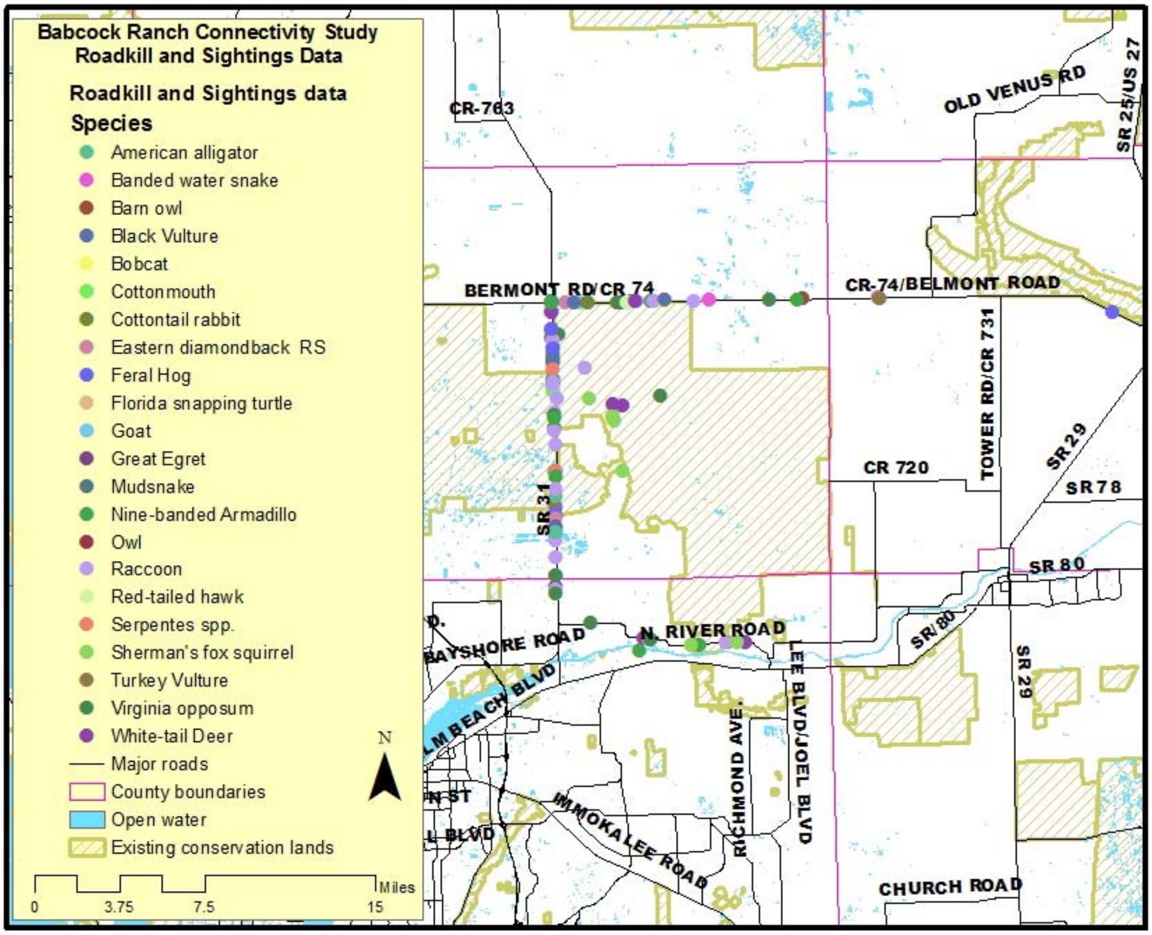


Figure 13. Summary map of GPS point locations of roadkill (plus fox squirrel sightings) data collected in areas surrounding the Babcock study site.



F*igure 14. Species map of GPS point locations of roadkills (and fox squirrel sightings) collected in areas surrounding the Babcock study site.*

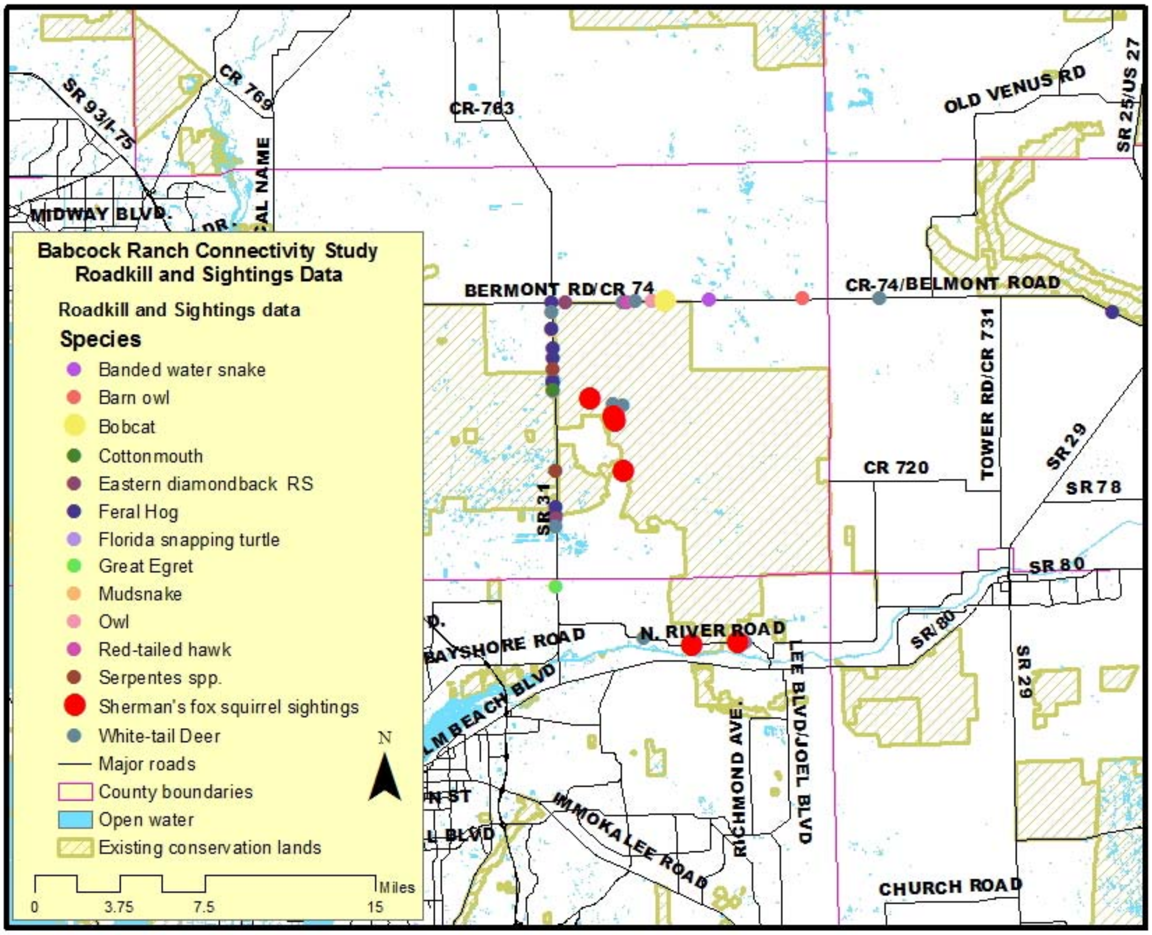


Figure 15. Species map of GPS point locations of roadkill and fox squirrel sightings collected in areas surrounding the Babcock study site, with species of particular interest highlighted by larger circles.

Riparian Corridor, Greenways and Habitat Combination Models

These data layers were created to aid the decision-making process regarding development of the three connectivity options. These models represent various existing corridors and ecological linkages including forested corridors along waterways, major landscape-scale ecological greenways in the Florida Ecological Greenways Network, and larger patches of focal species habitat within or connected to these ecological networks.

The riparian habitat and corridors identifies both forested stream corridors and larger forested wetlands with surrounding natural and semi-natural buffers. These areas represent corridors in some cases but also blocks of forested riparian habitat (Fig. 16 and Fig. 17). Many of the larger existing conservation lands in the study region contain large areas of riparian habitat or riparian corridors. The most obvious riparian corridor network appearing in our results includes riparian habitat along the Peace River and its major tributaries.

The Florida Ecological Greenways Network (FEGN) identifies landscape connections of state and regional significance. The FEGN is prioritized into 8 priority levels, with the two highest priorities called Priority 1 Critical Linkages and Priority 2 Critical Linkages. Within the study area, a combination of Priority 1 Critical Linkages and Priority 2 Critical Linkages form an ecological network from Big Cypress National Preserve on the south end, then north through Okaloacoochee Slough State Forest, the Caloosahatchee Ecoscape Florida Forever Project, Babcock Ranch, and Fisheating Creek (Fig. 18 and Fig. 19). At Fisheating Creek, the Priority 1 and Priority 2 Critical Linkages split into eastern and western corridors. The eastern corridor follows the lower Kissimmee River to Avon Park Air Force Range and Kissimmee Prairie Preserve State Park. The western corridor includes Archbold Biological Station, Bright Hour Ranch, Highlands Hammock State Park, Lake Wales Ridge State Forest, and then Avon Park Air Force Range before heading northeast towards the St. Johns River basin and out of our study area. Though a lower priority at the state scale, the Peace River and Myakka River watersheds include a Priority 3 ecological network within the FEGN that is also important within the study area.

The combination of riparian habitat and corridors with natural and semi-natural areas within all priority levels of the FEGN reveals a pattern similar to the riparian habitat and corridors by themselves, but with several additional features of potential significance. These features include a potential corridor between Big Cypress National Preserve and Okaloacoochee Slough State Forest; the large hub of significant habitat north of the Caloosahatchee River from Cecil Webb Wildlife Management Area to the west and Fisheating Creek to the east; the connections between the large Myakka conservation complex hub and the riparian network of the Myakka River and Peace River watersheds; a potential corridor between the Peace River basin and Avon Park Air Force Range; and a potential ecological network from Avon Park Air Force Range and Kissimmee Prairie Preserve State Park north through the upper Kissimmee River watershed.

The dataset combining riparian habitat and corridors, the FEGN, and panther and bear habitat accentuates the overall patterns described in the data layers above in this section. In addition, this combination also identified the potential corridor due south of Babcock Ranch through eastern Lee County, Corkscrew Swamp, and within and west of Camp Keais Strand.

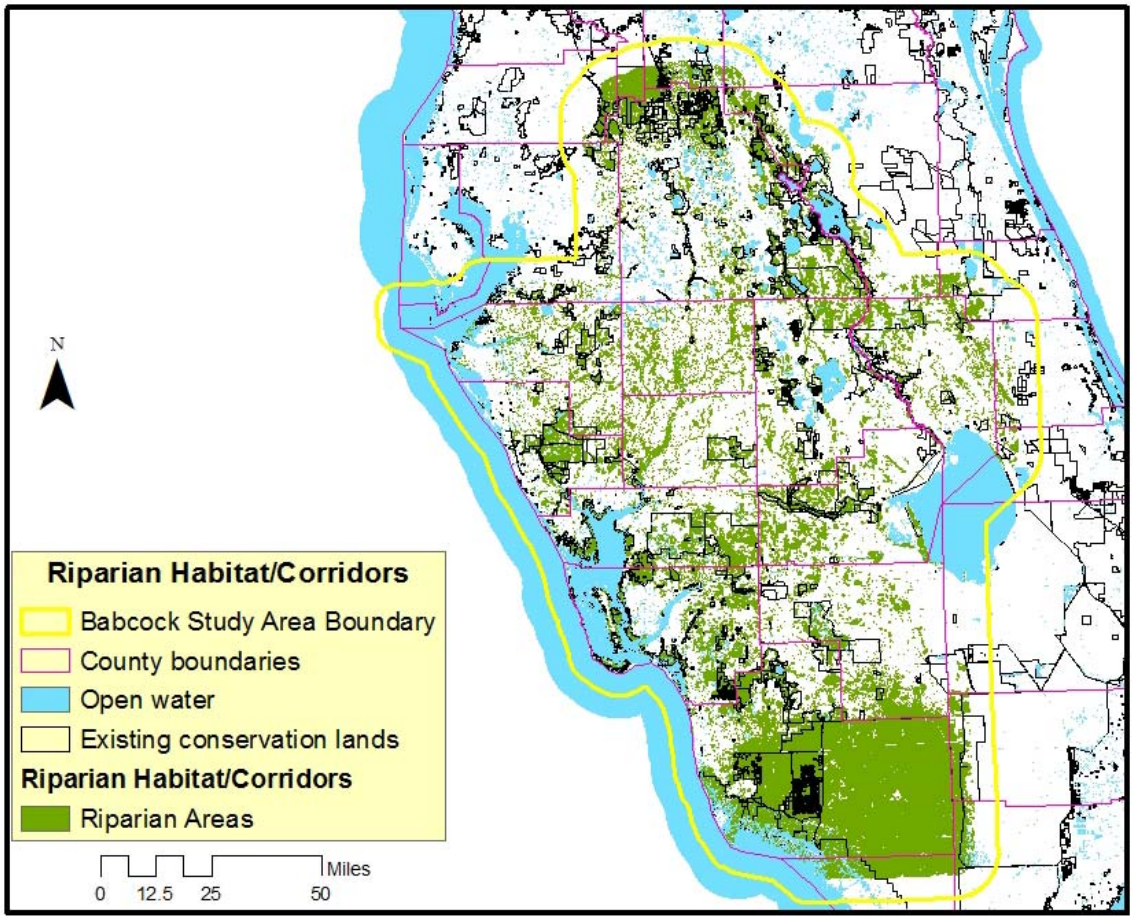


Figure 16. Map of riparian habitat and corridors within the Babcock study area.

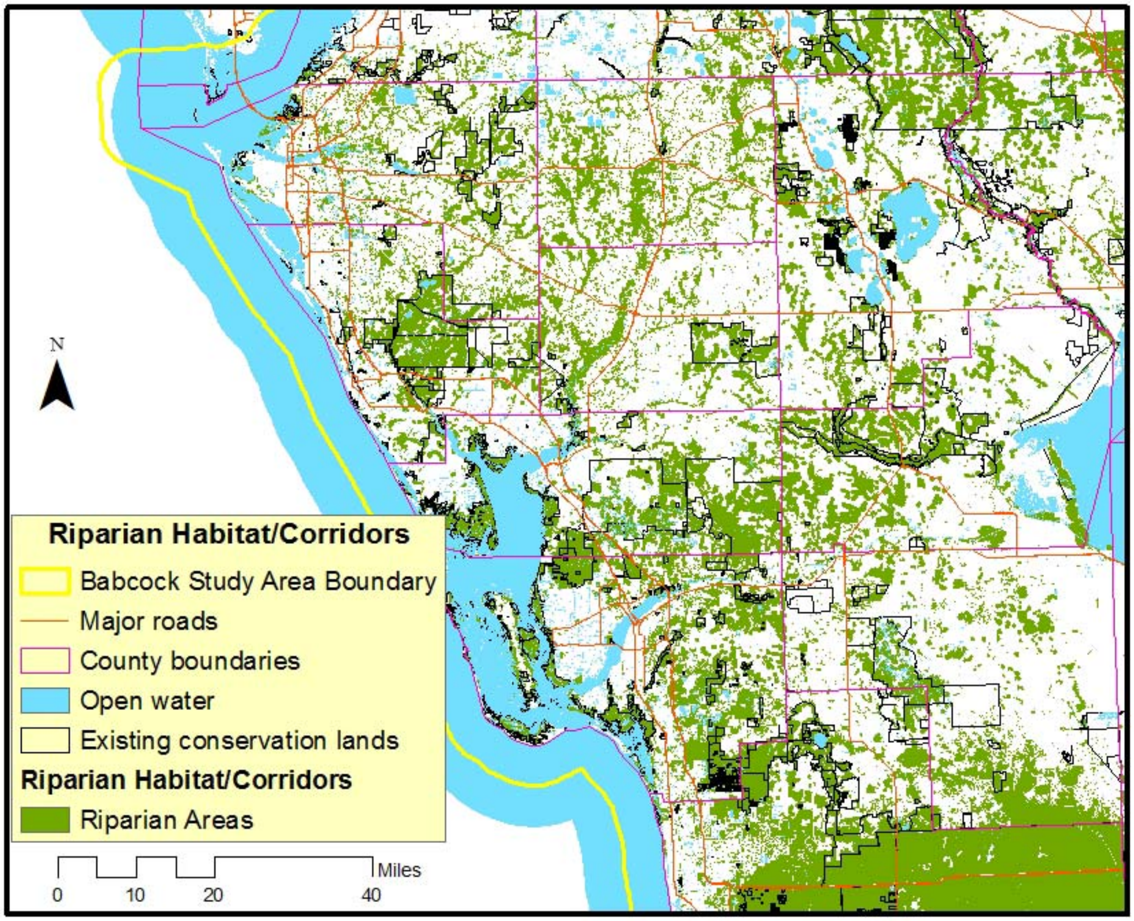


Figure 17. Zoom-in map of riparian habitat and corridors within the Babcock study area.

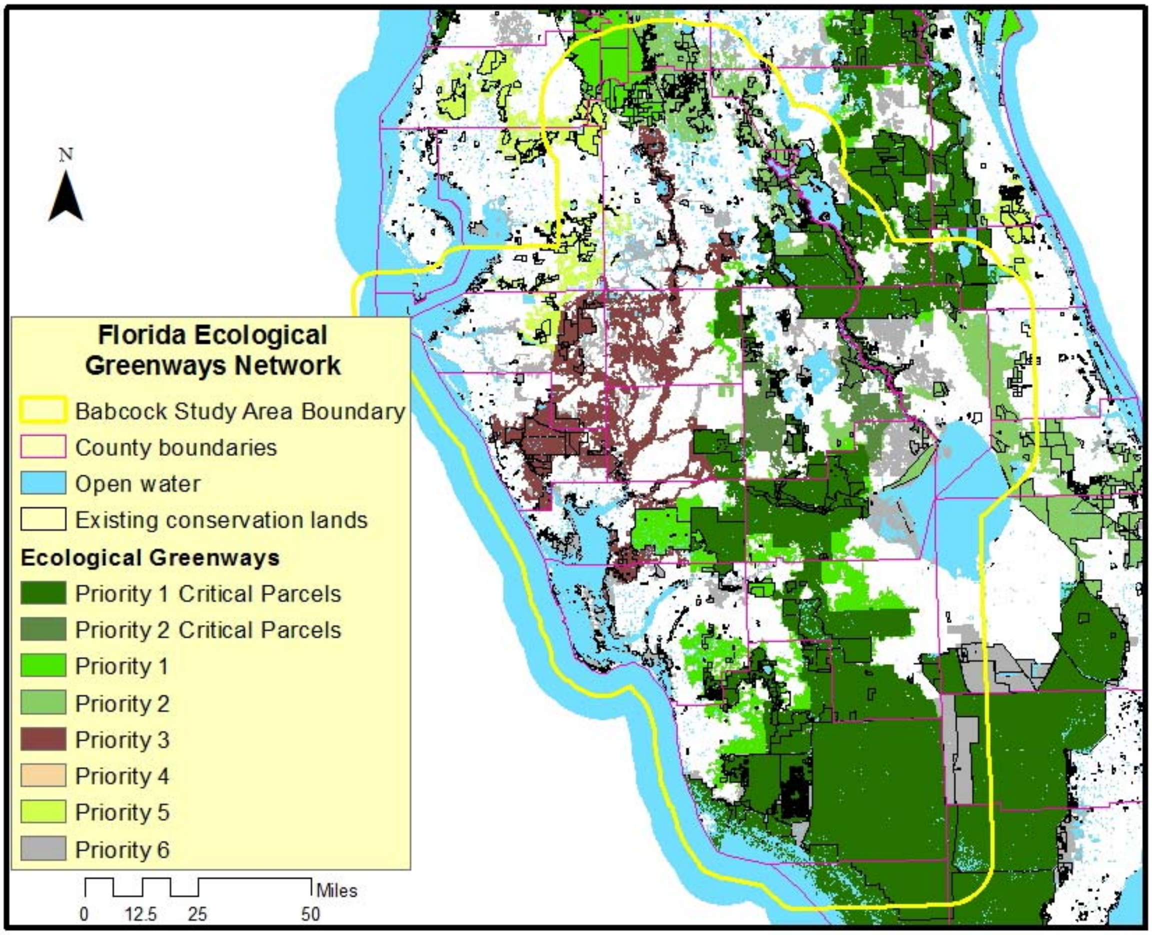


Figure 18. Map of the CLIP priority status of the Florida Ecological Greenways Network and riparian corridors within the Babcock study area.

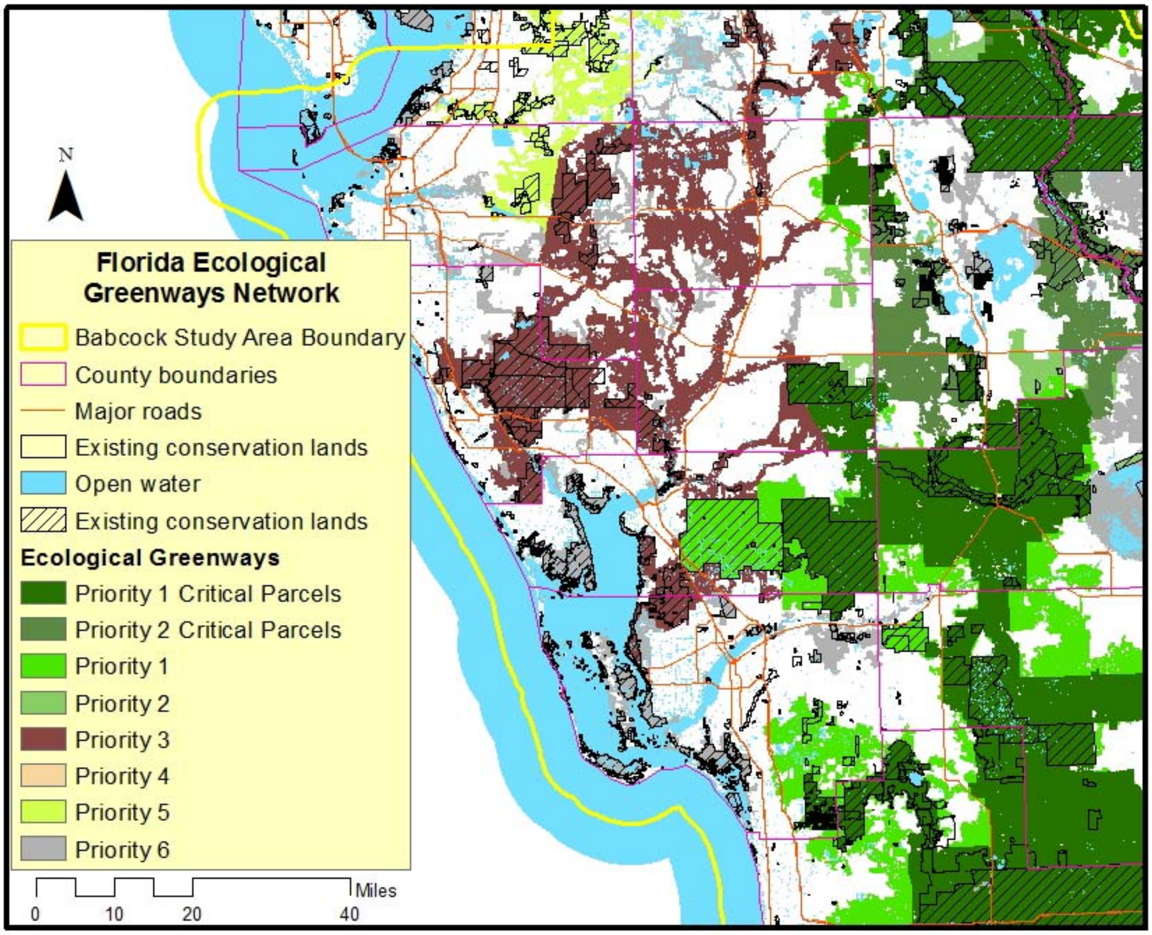


Figure 19. Zoom-in map of the CLIP priority status of the Florida Ecological Greenways Network and riparian corridors within the Babcock study area.

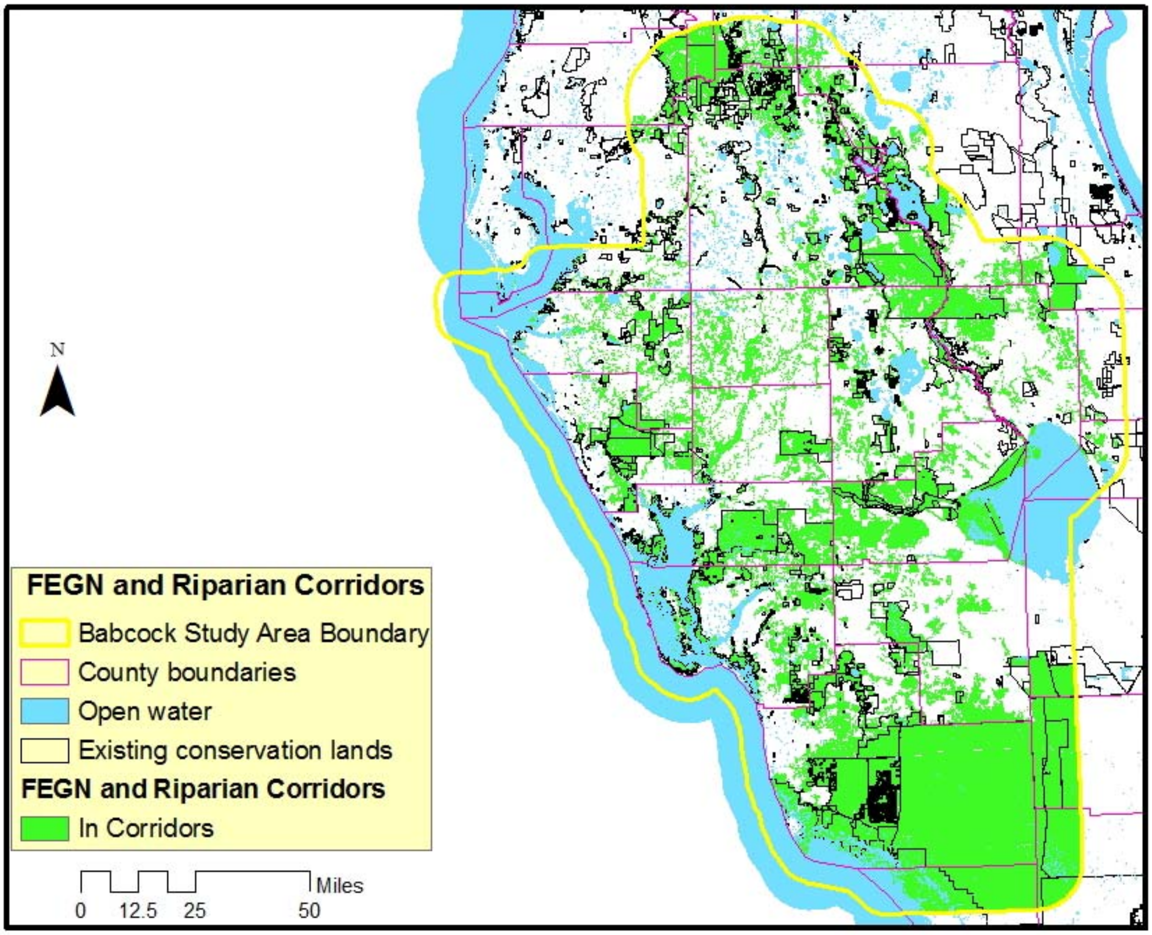


Figure 20. Map of the Florida Ecological Greenways Network and riparian corridors combined within the Babcock study area.

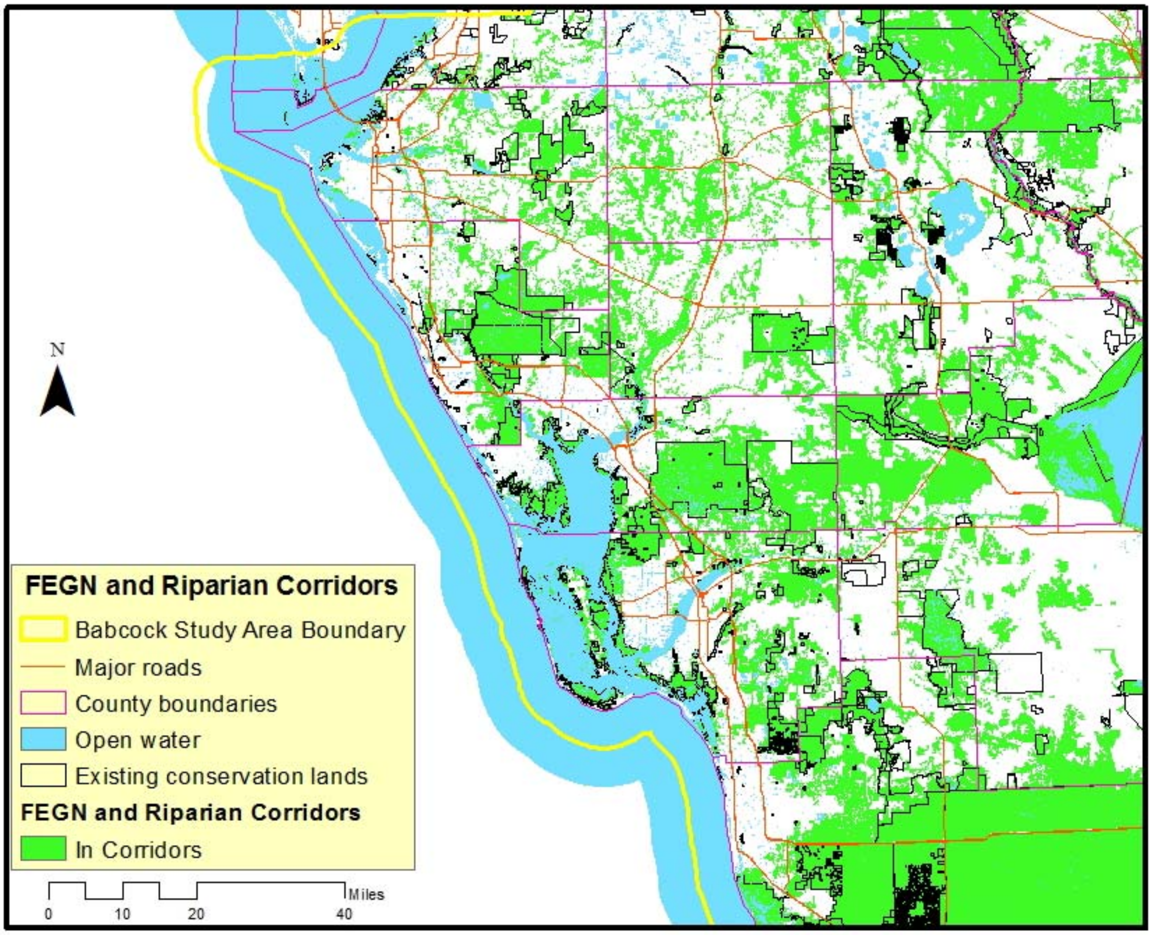


Figure 21. Zoom-in map of the Florida Ecological Greenways Network and riparian corridors combined within the Babcock study area.

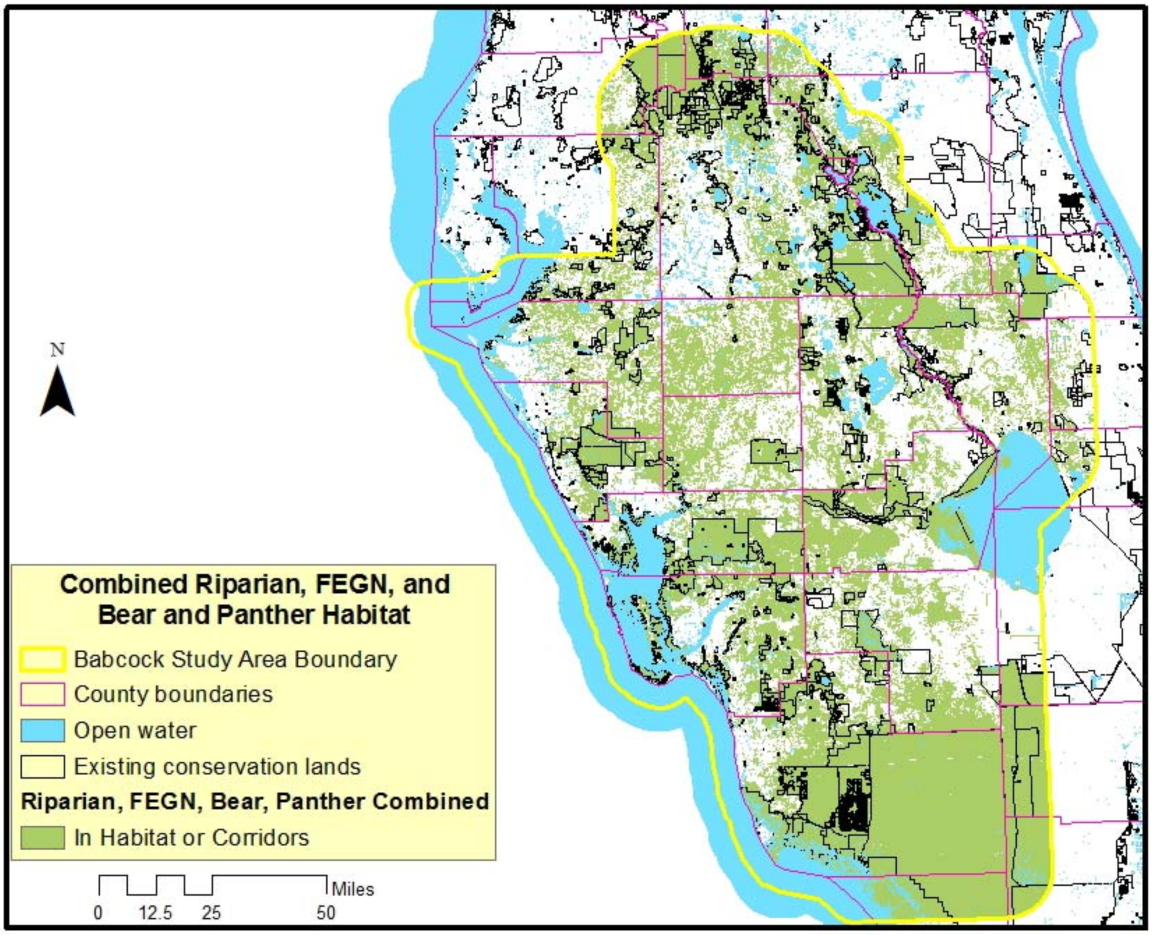


Figure 22. Map of the Florida Ecological Greenways Network, riparian corridors, and Florida Black Bear and Florida Panther habitat that fall within the boundaries of at least one habitat connectivity scenario the within the Babcock study area.

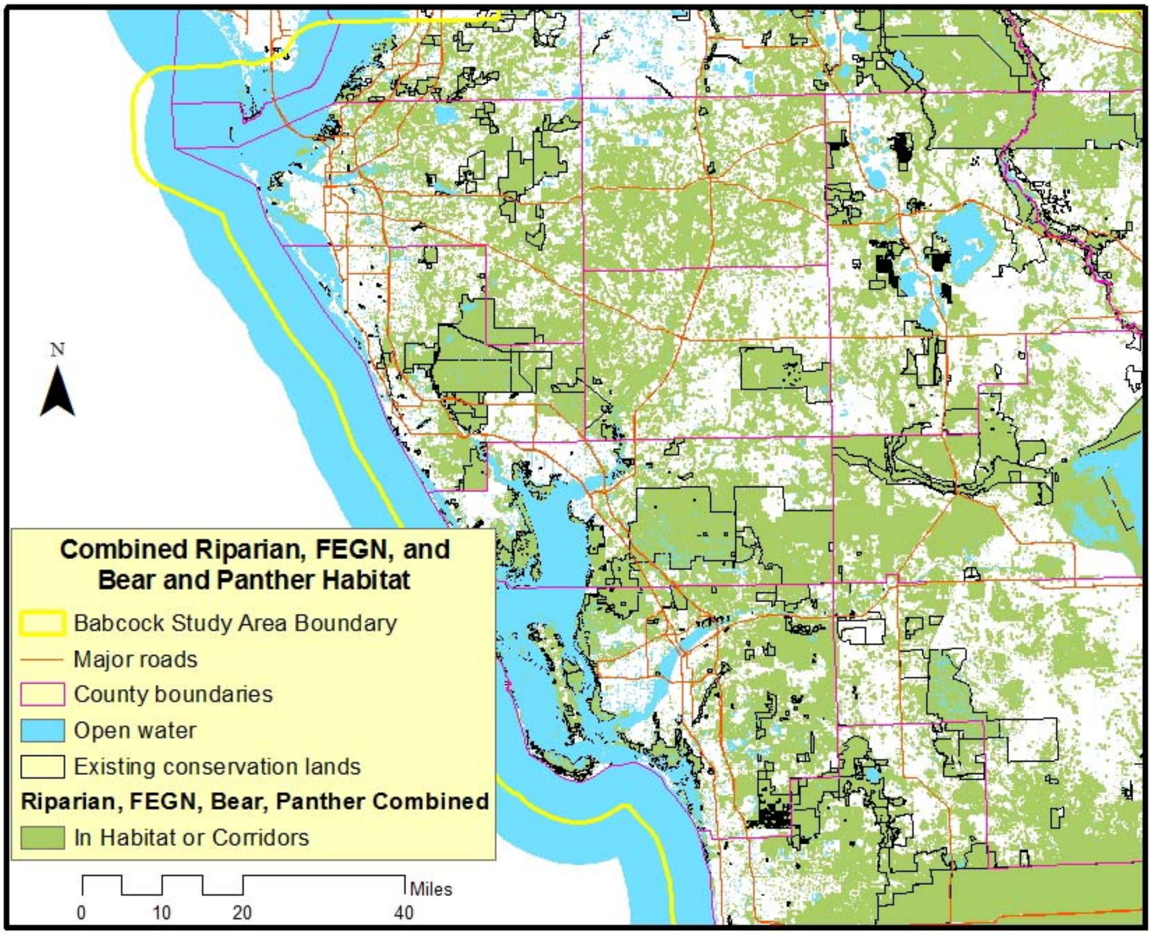


Figure 23. Zoom-in map of the Florida Ecological Greenways Network, riparian corridors, and Florida Black Bear and Florida Panther habitat that fall within the boundaries of at least one habitat connectivity scenario the within the Babcock study area.

Least-Cost Path Models

For each focal species we ran six Least Cost Path (LCP) models using 6 different cost surfaces from Babcock Ranch to six destinations. Therefore, for each focal species there are 6 different LCP results between Babcock Ranch and each destination and a total of 36 LCPs overall for each species. Each LCP is a one cell wide (a cell was 10 meters wide in our modeling) but the LCPs were turned into GIS shapefiles that result in some buffering to a larger width to aid in viewing the maps. The six destinations were Big Cypress National Preserve, Okalaocoochee Slough State Forest, Fisheating Creek, Bright Hour, Avon Park Air Force Range, and the Myakka conservation complex. Below we briefly describe the major patterns of results for each focal species.

The Florida panther LCPs demonstrate options to potentially connect Babcock Ranch to other large conservation areas in the study area. As expected, different cost surfaces sometimes result in LCPs that are remarkably different (Fig. 24). Overall, when evaluating these cost surface results we tend to consider the more thorough cost surface-based LCPs to be the most reliable, given that they factor in more variables that could affect corridor suitability such as major roads, negative edge effects, land-use intensity and integrity, sea-level rise, etc. However, all results help determine options for connectivity and the assessment of best corridor options to include in the connectivity options. For the two destinations to the south of Babcock Ranch, there were two primary paths selected in the LCP analyses. For Okaloachoochee Slough, almost all of the LCPs run east-southeast from Babcock and primarily cross the Caloosahathchee River where the Caloosahatchee Ecoscape Florida Forever Project is located, which was considered the primary panther corridor in the work of the USFWS Panther Subteam (Kautz et al. 2006). One LCP heads due south from Babcock Ranch and then turns east to reach Okaloacoochee Slough. The LCPs between Babcock Ranch and Big Cypress also follow this due-south route through eastern Lee County, then through Corkscrew Swamp and Camp Keais Strand to reach Big Cypress. This incorporates a second potential crossing area of the Caloosahatchee River evaluated by the Panther Subteam but not adopted because of concerns about ongoing and future development that could either degrade or completely fragment this potential corridor. However, our habitat models and these LCP results suggest that given land-use conditions in 2004-2005 (which is the time frame of the Water Management District land-use data) these areas still have some potential to support a functional corridor. The Fisheating Creek LCPs are by far the shortest and they all are primarily clustered within the Fisheating Creek Florida Forever project boundaries to reach the Fisheating Creek conservation easement. The LCPs between Babcock and Bright Hour are the most consistent with each other; they all follow an area almost due north of Babcock to reach Bright Hour, and this same pattern is also seen for the Florida black bear and fox squirrel LCPs between Babcock and Bright Hour. This tight clustering of six different LCPs for all three focal species suggests that this route is the best option for a functional connection between these two conservation areas.

The LCP results for the potential connection between Babcock and Myakka may be the most interesting. In general, the LCPs for cost surfaces that did not include negative edge effects associated with intensive land uses tended to follow the shortest distance route by crossing the Peace River near its mouth. However, LCPs based on cost surfaces with edge effects included followed more northerly routes, with the LCP based on the cost surface with the highest costs assigned to edge effects selecting the most northerly route. Closer examination of these results confirm that the shortest route crossing near the mouth of the Peace River traverses areas of scattered development that serve as potential bottlenecks for the corridor. The route further to the north also passes scattered development along US 17 but less development than the southerly route. The most northerly route avoids almost all existing intensive development. In addition, the more northerly routes are less influenced by sea-level rise (which increases the cost of southerly routes), because the mouth of the Peace River is likely to become wider, presenting a larger water gap that is less likely to be crossed by panthers or other species. These results suggest that one approach to the Myakka connection would be closer examination of the potential issues with the more southerly route, since it does have the advantage of being a much more direct route between the two conservation areas, but that protection of a functional corridor may require investment in a longer route through more rural landscapes with less potential for being degraded by future development and sea-level rise.

Finally, the LCP results between Babcock Ranch and Avon Park Air Force Range exhibit various options for functionally connecting these conservation areas that are all consistent with observed movement patterns of bears in the Highlands-Glades population and panther telemetry data collected from sub-adult males traversing these areas. There are three options demonstrated: 1) a western route along the west side of the Lake Wales Ridge that passes through various scrub reserves, Highlands Hammock State Park, the Charlie Creek watershed, and Lake Wales Ridge State Forest to connect to the northwest corner of Avon Park Air Force Range; an eastern route that passes on the east side of the Lake Wales Ridge from Fisheating Creek north through several scrub reserves on or near the western shore of Lake Istokpoga and then follows part of Arbuckle Creek to reach the southwest corner of Avon Park Air Force Range.; and 3) a hybrid route that combines most of the two options above by first following the western route but then turns east and crosses US 27 along the Josephine Creek corridor and merges with the eastern route near Arbuckle Creek.

For black bear, the LCPs are very similar to the panther LCPs for Big Cypress, Okaloacoochee Slough, Fisheating Creek, and Bright Hour (Fig. 25 and Fig. 27). The LCP results for Myakka are also similar, except the most southerly routes taken by LCPs without edge effects included areas further north than those for the panther LCPs. The bear LCPs for the Avon Park Air Force Range connection are most different from the panther LCPs. One set of LCPs follow the "hybrid" route described for panther LCPs above, but most of the bear LCPs follow a much more westerly route. This route heads through Bright Hour ranch and then north-northeast along tributaries of the Peace River to reach the upper Charlie Creek watershed, and then cross US 27 to reach the Lake Wales Ridge State Forest and Avon Park Air Force Range following the same path as the western route for the panther LCPs.

The fox squirrel LCPs are similar in pattern to the panther and bear LCPs but with some deviation for several destinations (Fig. 26 and Fig. 27). First, the fox squirrel LCPs for the corridor to Big Cypress tend to be further west than the panther and bear LCPs, especially south of Corkscrew Swamp. The fox squirrel LCPs to Avon Park Air Force Range follow the western and "hybrid" routes generally found in the panther and bear LCPs but also tend to be further west in both cases over parts of their paths. Finally, some of the fox squirrel LCPs to Okaloacoochee Slough State Forest head almost due southeast of Babcock Ranch to reach the state forest versus the Caloosahatchee Ecoscape pathway taken by most of the panther and bear LCPs. All of these differences are likely explained by the more limited potential habitat distribution for fox squirrels. Nevertheless, overall, the pattern of potential connectivity is similar to that for panthers and bears, and we suggest that fox squirrel connectivity may be suitably addressed at the regional scale by the best options for panthers and bears. In addition, local to landscape-scale connectivity may be more important for fox squirrels within this region due to the fragmented habitat base and lower dispersal capabilities. Further research on fox squirrels in the region could include identification of core habitat areas and the opportunities to restore or maximize connectivity at the local to landscape scales through habitat management, restoration, and protection.

The next step in the analysis of the LCP model results was to examine the overlap between the LCP models for each destination for each focal species and all three focal species cumulatively. This approach helps to indicate how often a potential path was selected. To conduct this analysis, we developed a grid representing the entire study area in one square mile cells. These cells were then used as "selection units" where we intersected each of the LCP results for each destination with the selection units to determine how often they were selected. The assumption of this analysis is that paths selected more frequently are potentially more suitable for facilitating connectivity.

Figures 28-31 show the results of the selection unit analysis for each of the focal species individually (Figs. 28-30) and then cumulatively for all three focal species (Fig. 31). On all of these maps, the lightest pink color represents paths selected least frequently and the darkest red represents paths selected most frequently. These results indicate that the most overlap across LCPs occurs for the route between Babcock Ranch and Bright Hour Ranch. Other potential corridor routes that are frequently selected across species include Fisheating Creek (although panther LCPs show a slightly different pattern than bear or fox squirrel). For panther and bear LCPs, the southern half of the route to Avon Park Air Force Range is also generally consistent across LCPs. For panthers, the LCPs to Big Cypress uniformly follow Camp Keais Strand south of Corkscrew whereas bear LCPs follow a more westerly route south of Corkscrew.

The analysis of LCP overlap provided an objective method for evaluation of best potential corridors between Babcock Ranch and other larger regional conservation areas. However, selection of best corridor options also requires a more subjective expert analysis of factors potentially critical to population persistence, including the number and location of road crossings, presence of bottlenecks/proximity to areas of intensive development, length of corridors, consistency with existing guiding features in the landscape such as riparian corridors, etc. Before developing the connectivity options discussed below, we conducted these additional visual assessments of LCP results to select the best potential corridor options. From this assessment, we determined that LCPs based on two separate cost surfaces for both panthers and bears were most applicable to developing the various conservation scenarios. The selected corridor options will be discussed in more detail below in the connectivity options section.

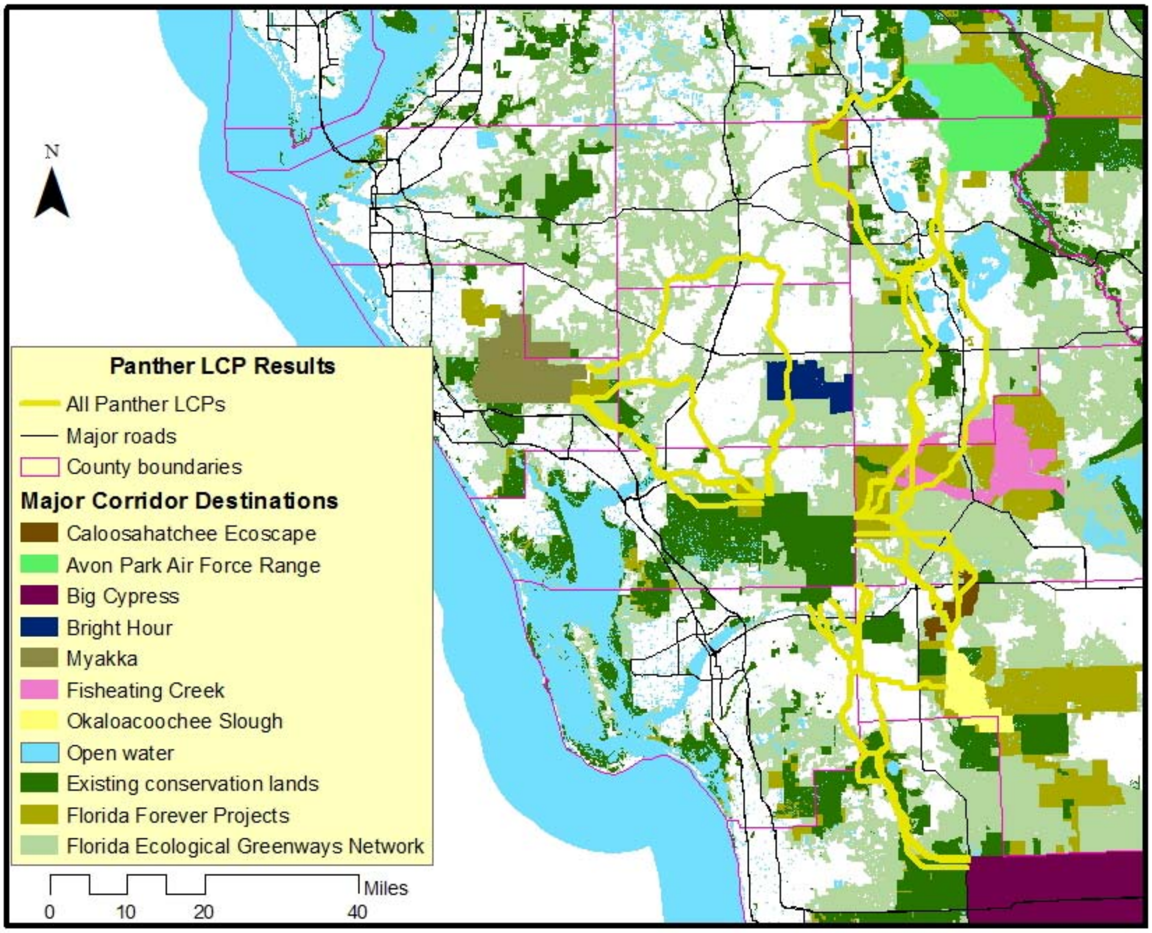


Figure 24. Map summarizing the predicted Least Cost Paths for Florida Panther movement from the Babcock study site to each of the six selected habitat patch destinations.

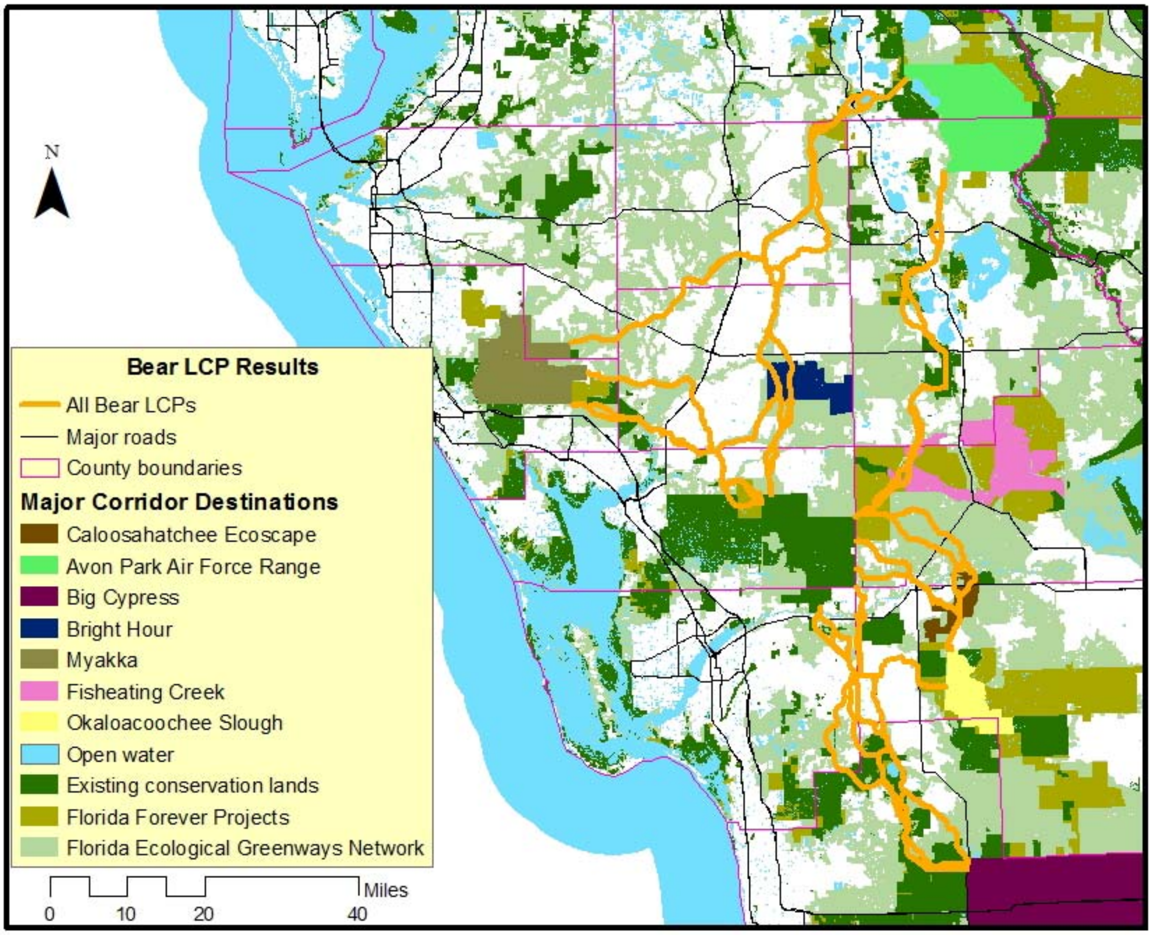


Figure 25. Map summarizing the predicted Least Cost Paths for Florida black bear movement from the Babcock study site to each of the six selected habitat patch destinations.

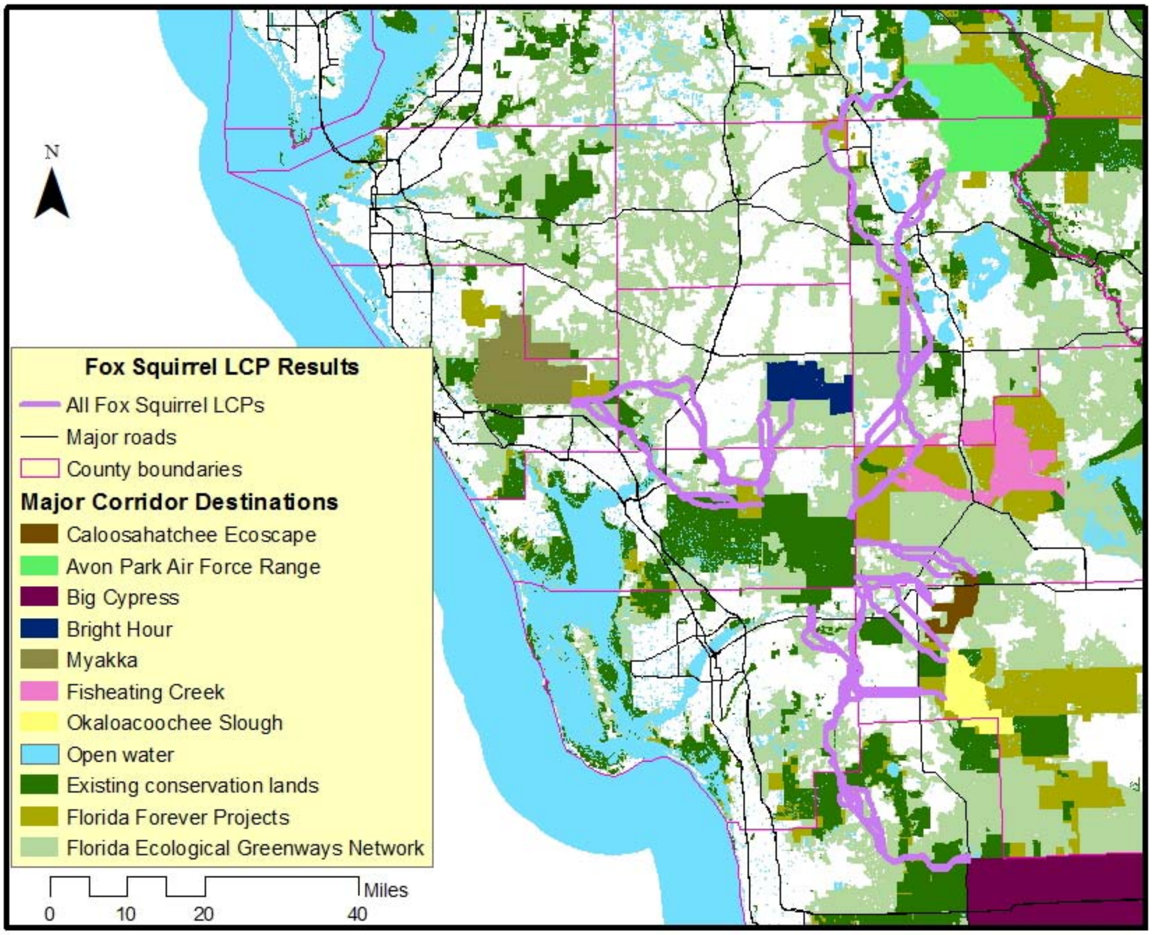


Figure 26. Map summarizing the predicted Least Cost Paths for fox squirrel movement from the Babcock study site to each of the six selected habitat patch destinations.

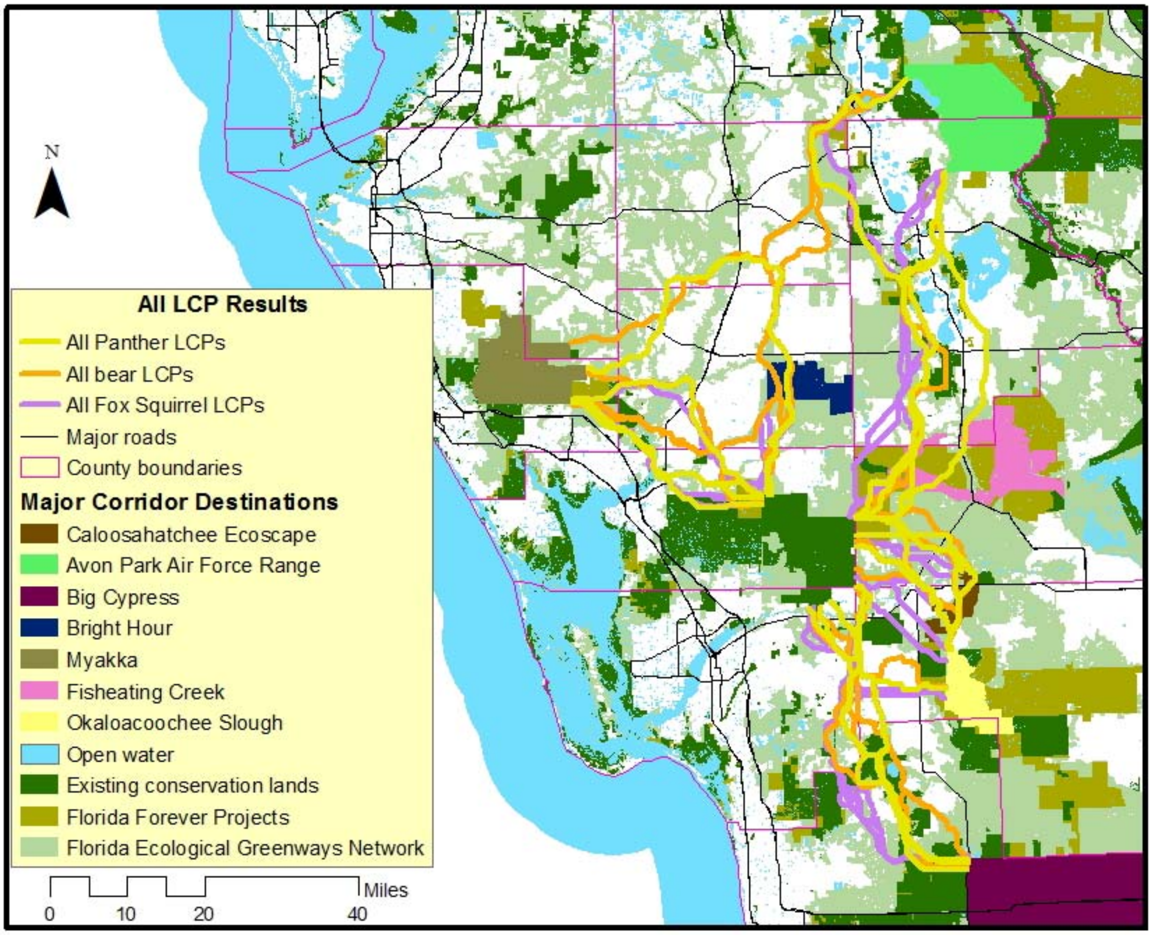


Figure 27. Map summarizing the predicted Least Cost Paths for all three species (panther, bear, fox squirrel) movement from the Babcock study site to each of the six selected habitat patch destinations.

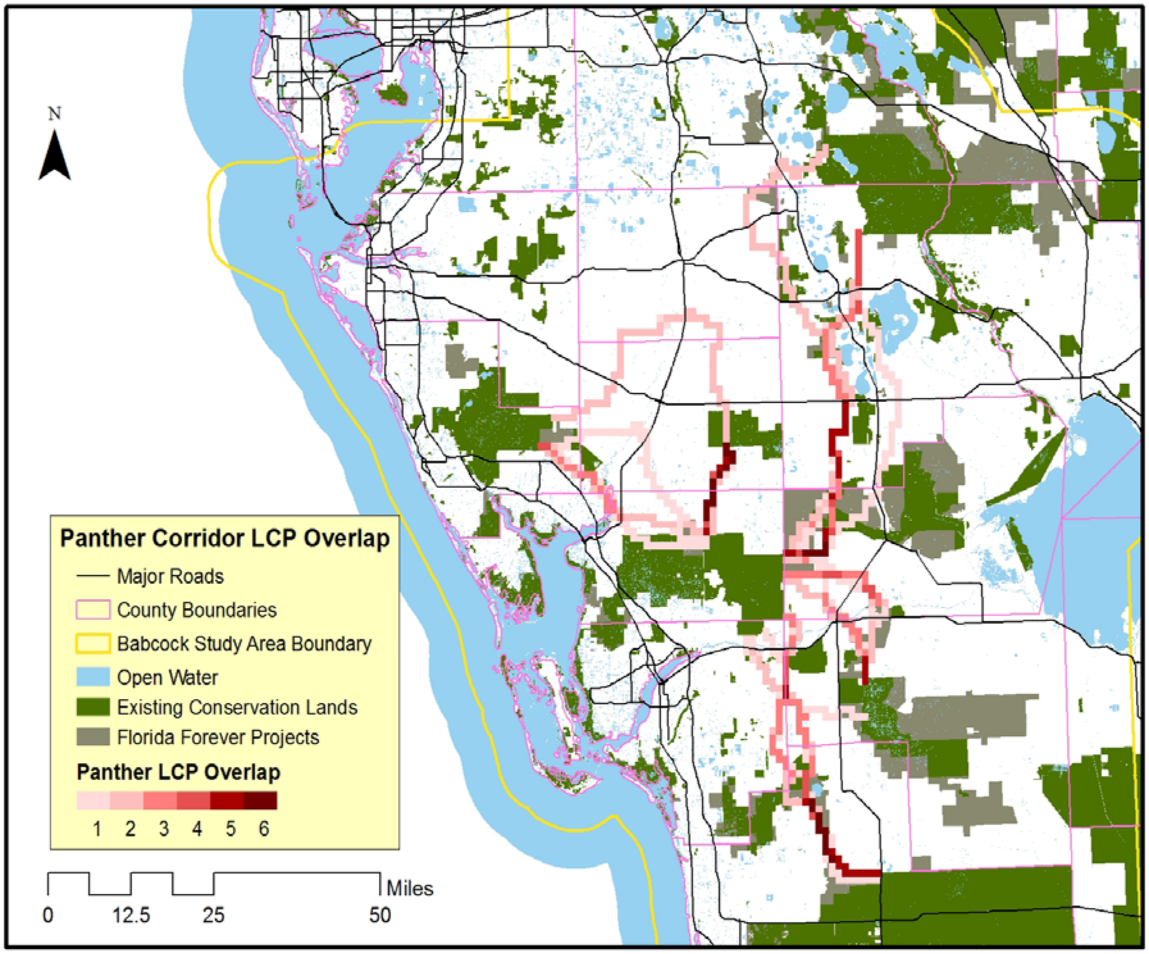


Figure 28. Map summary of the frequency of overlap of the predicted Least Cost Paths for Florida Panther movement from the Babcock study site to each of the six selected habitat patch destinations.

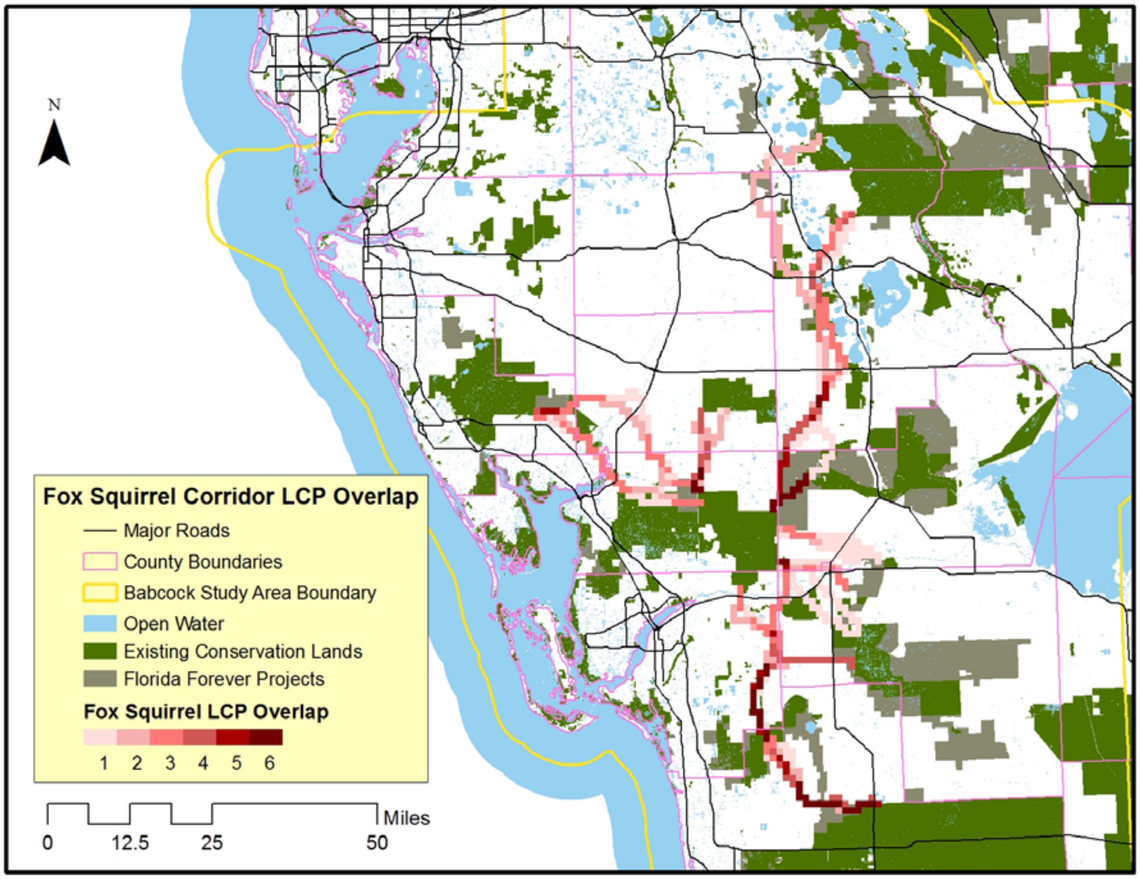


Figure 29. Map summary of the frequency of overlap of the predicted Least Cost Paths for Florida black bear movement from the Babcock study site to each of the six selected habitat patch destinations.

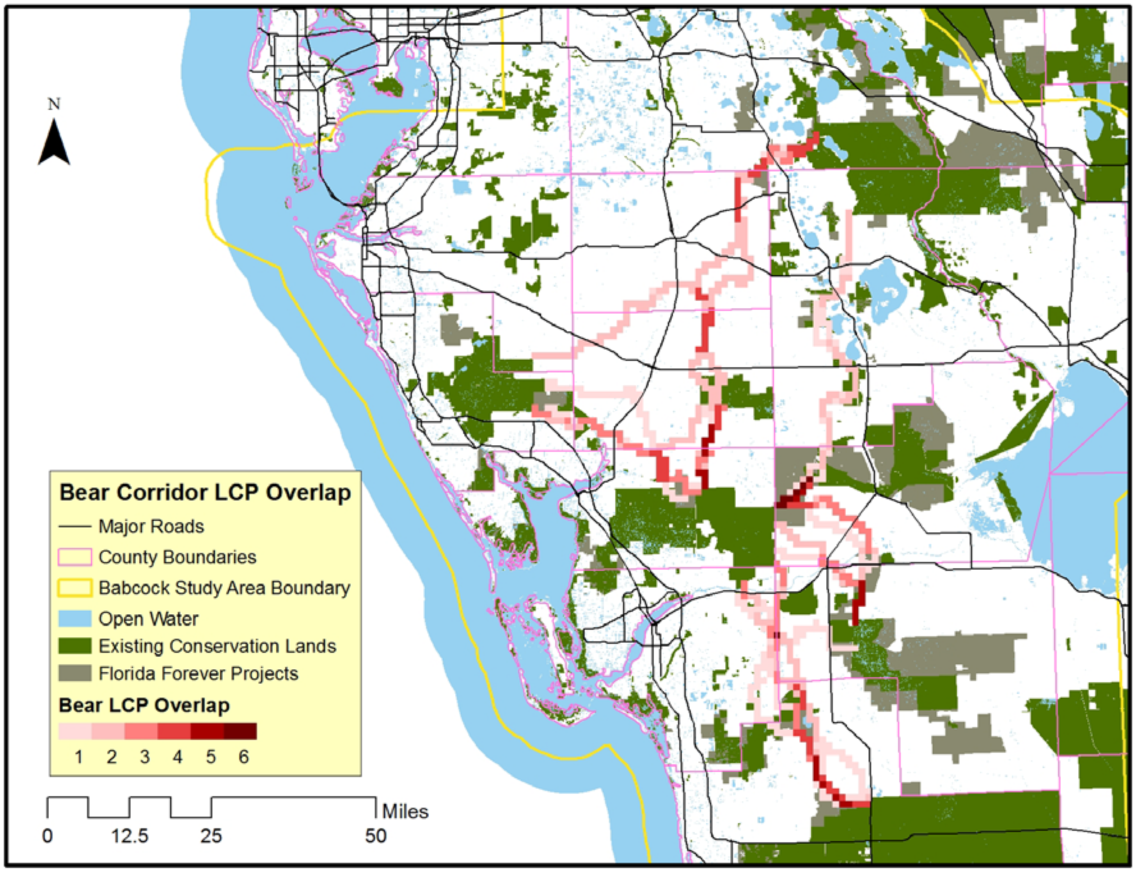


Figure 30. Map summary of the frequency of overlap of the predicted Least Cost Paths for fox squirrel movement from the Babcock study site to each of the six selected habitat patch destinations.

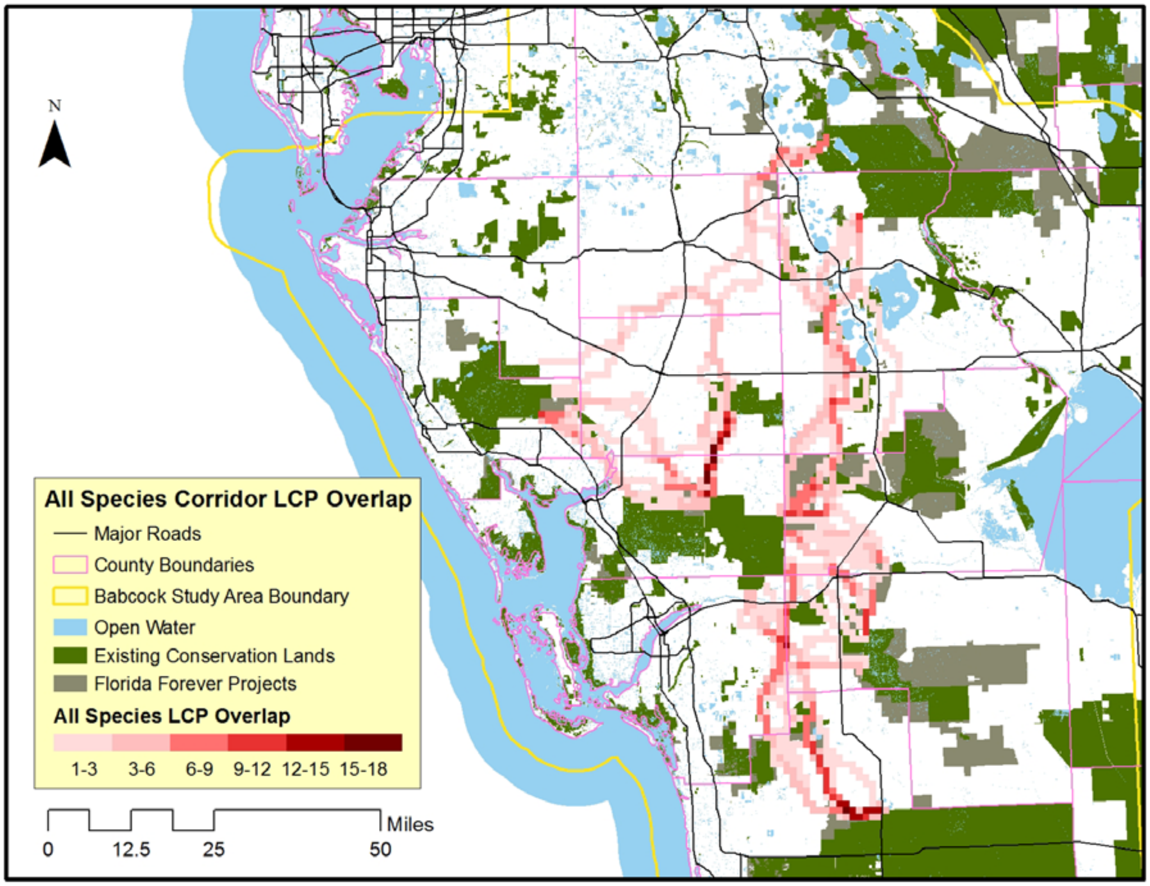


Figure 31. Map summary of the frequency of overlap of the predicted Least Cost Paths for all three study species (panther, bear, fox squirrel) movement from the Babcock study site to each of the six selected habitat patch destinations.

Regional Connectivity Options

We identified three habitat corridor network (or ecological network) options through a collective analysis and assessment of the three focal species potential habitat model results, the Least Cost Path (LCP) model results, the roadkill surveys, and other relevant data. The goal of the three connectivity options was to identify, under three alternative conditions of feasibility, the best opportunities to maintain or restore ecological connectivity in the region surrounding Babcock Ranch. The connectivity options range from low, moderate, to high, with more proposed conservation area and more, and generally wider, corridors in the moderate and high connectivity options.

The low connectivity option primarily represents a minimum feasible or most constrained effort to functionally connect Babcock Ranch with other larger existing conservation lands in the region (Fig. 32). To accomplish this, we identified the one set of LCP results that appear to represent the best potential option for achieving functional connectivity, which was the panther LCPs for the most inclusive cost surface (the cost surface with habitat, landscape integrity, edge effects, roads, and sea level rise). The LCPs for each destination include the due south corridor from Babcock to Big Cypress through eastern Lee County, Corkscrew Swamp, and Camp Keais Strand; the Caloosahatchee Ecoscape corridor to connect to Okaloacoochee Slough State Forest; an east-northeast corridor to connect to the nearby Fisheating Creek Conservation Easement; the "hybrid" corridor to Avon Park Air Force Range that follows the western side of the Lake Wales Ridge before turning east along Josephine Creek and then north along Arbuckle Creek; the due north corridor selected in virtually every LCP analysis to connect to Bright Hour Ranch; and a corridor to Myakka that does not cross near the mouth of the Peace River but also does not veer as far north as some of the other LCP results. To complete the depiction of this option we buffered each of the selected LCPs by one mile to represent an approximate relevant corridor width appropriate to the scale and distance of the various corridors. Then we included all of the existing conservation lands connected to the LCPs, including Babcock Ranch and the six destination conservation areas. Finally, due to its importance for completing a functional corridor across the Caloosahatchee River, we also included all areas within the Caloosahatchee Ecoscape Florida Forever Project within the low connectivity scenario.

The moderate connectivity option is intended to represent a primary option for protecting and restoring functional connectivity in the region (Figs. 33-35). This is achieved by including additional LCP-based options for additional corridors between Babcock and the six destinations and by including priority areas of potential habitat for both the Florida panther and Florida black bear that will result in better opportunities to protect viable populations of each focal species. We also include all Critical Linkages within the FEGN. These priority habitat areas and Critical Linkages also provide wider corridors to connect many of the destinations to Babcock Ranch, which increases the likelihood of achieving functional connectivity. All existing conservation lands and Florida Forever projects connected to these LCPs and priority habitat areas were also included in this option. Finally, to better represent potential connectivity in the Peace River and Myakka River watersheds, we added the Integrated Habitat Network (IHN) to an alternative version of the moderate connectivity option. The IHN fills in potentially important gaps in the large riparian networks in these watersheds, provides some additional corridor redundancy to potentially increase connectivity, and suggests the opportunity to protect a corridor between

Babcock Ranch and Green Swamp through the upper Peace River basin. For more detailed views of the moderate connectivity option, see Figures 39-44.

The high connectivity option represents almost all existing areas that contribute, or could contribute, to protection of a functionally connected ecological network in the study area (Figs 36-38). This scenario is not intended to represent a prioritization of connectivity option, but instead shows the optimal alternative for protection of regional green infrastructure if there were no constraints for protecting such a large area. To delineate this option, we combined all existing conservation lands, all Florida Forever Projects, the two panther and two bear cost surface buffered LCPs used in the moderate connectivity option, all areas within the Florida Ecological Greenways Network, all potential panther, bear (primary and secondary), and fox squirrel habitat (primary and secondary), and all regional and local riparian corridors. As with the moderate connectivity option, we also included the IHN in an alternative version of the high connectivity option.

To help compare the three connectivity options, we generated statistics indicating how acres within relevant conservation status or land-use categories in Table 1. These statistics show that there is a large increase in area included in the three options including both existing conservation and private lands. Approximately 130,000 acres of private land is included in the low connectivity option, with approximately 43,000 of those acres within Florida Forever projects as well as 26,000 acres of wetlands; approximately1.7 million acres of private land is included in the moderate connectivity option, with approximately 500,000 of those acres within Florida Forever projects as well as 400,000 acres of wetlands; and approximately 3.9 million acres of private land is included in the high connectivity option, with approximately 700,000 of those acres within Florida Forever projects as well as 900,000 acres of wetlands (Table 1).

Finally, based on a request by the Babcock Ranch Steering Committee, we also created basic assessments of the number of individual panthers, bears, and fox squirrels that could be potentially supported in the three connectivity options (Tables 2-4). It is extremely important that all users of this report understand that these are coarse analyses based on several estimates of population densities for each focal species contained in the scientific literature and the acres of potential habitat contained within each connectivity option. As discussed above regarding the potential habitat models, the assumption that all potential habitat is suitable is unreasonable, and therefore these population size estimates must be considered optimistic. To partially account for this bias, we provided population estimates based on the unrealistic assumption that all potential habitat is suitable and, alternatively, based on an assumption that only 75% (for panthers and bears) or 50% (for fox squirrels) of the potential habitat in each connectivity option is suitable. Though these percentage estimates are arbitrary, they are likely more realistic than the population estimates based on the assumption that all potential habitat is suitable. Nevertheless, these revised estimates are still quite optimistic, especially so for the fox squirrel, for which, as noted earlier and discussed further below, so little of the potential habitat is likely to be suitable due to management issues. Further data gathering and analysis on this topic would be necessary before accurate predictions could be made.

It is important to understand that these are modeling results and that additional work is needed, including site specific analysis of corridor locations and widths, to create the actual corridors.

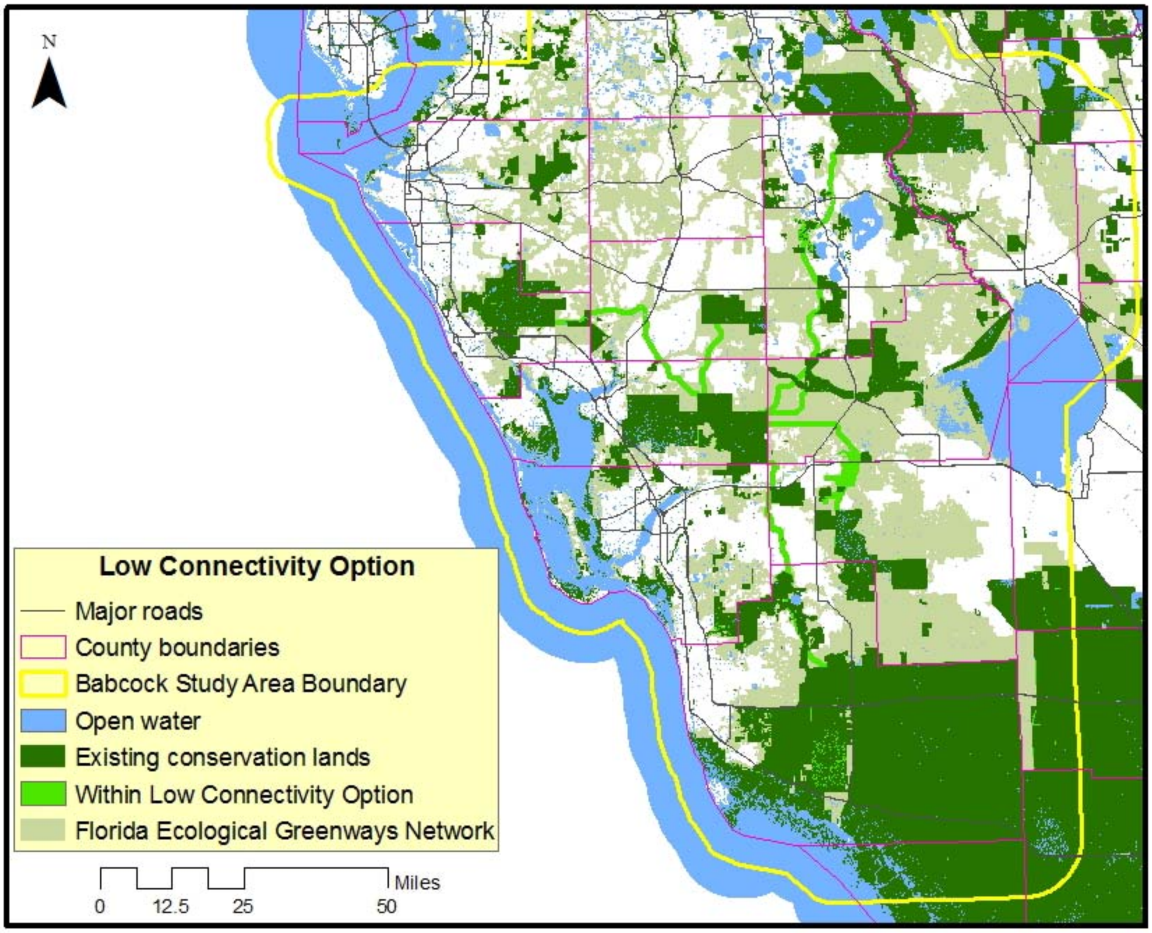


Figure 32. Map of the low connectivity scenario within the Babcock study area.

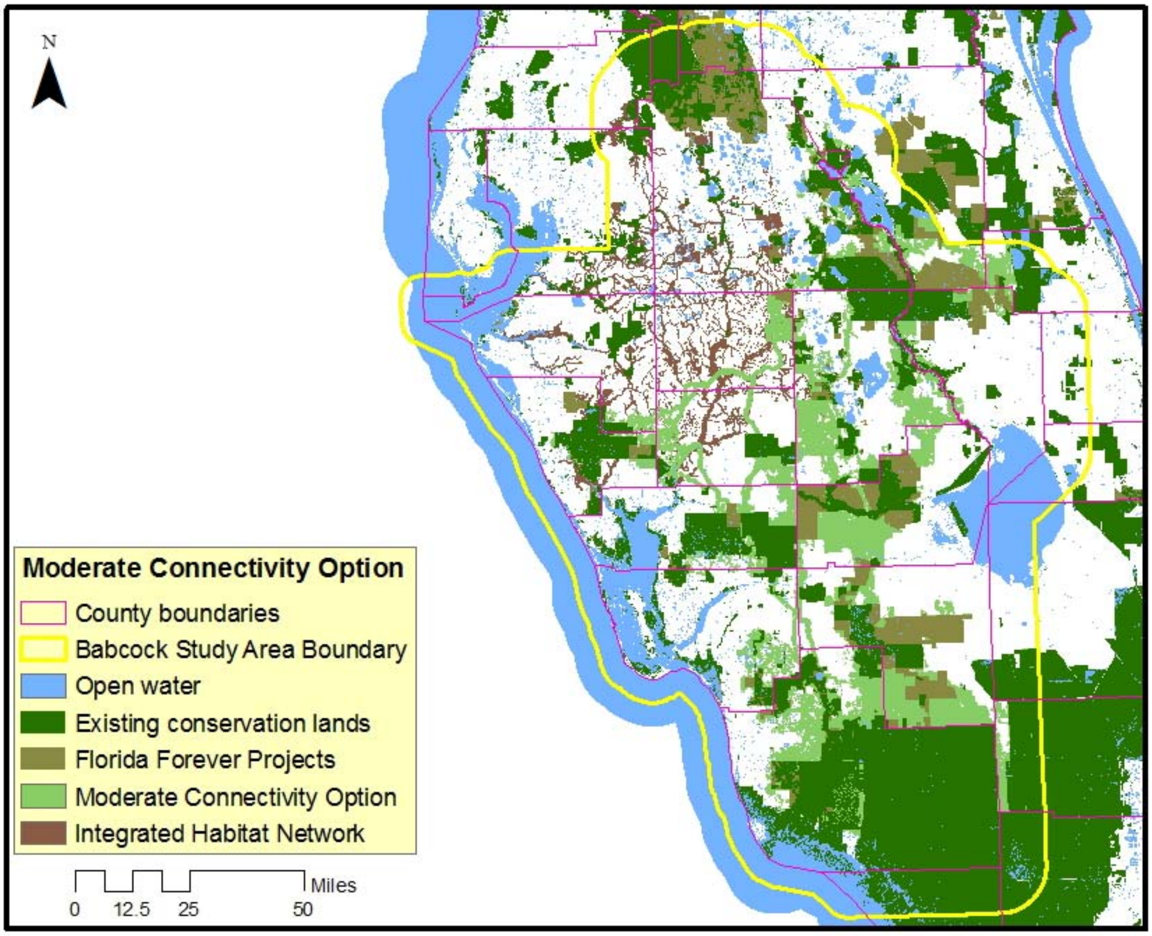


Figure 33. Region-wide map of the moderate connectivity scenario plus the integrated habitat network within the Babcock study area.

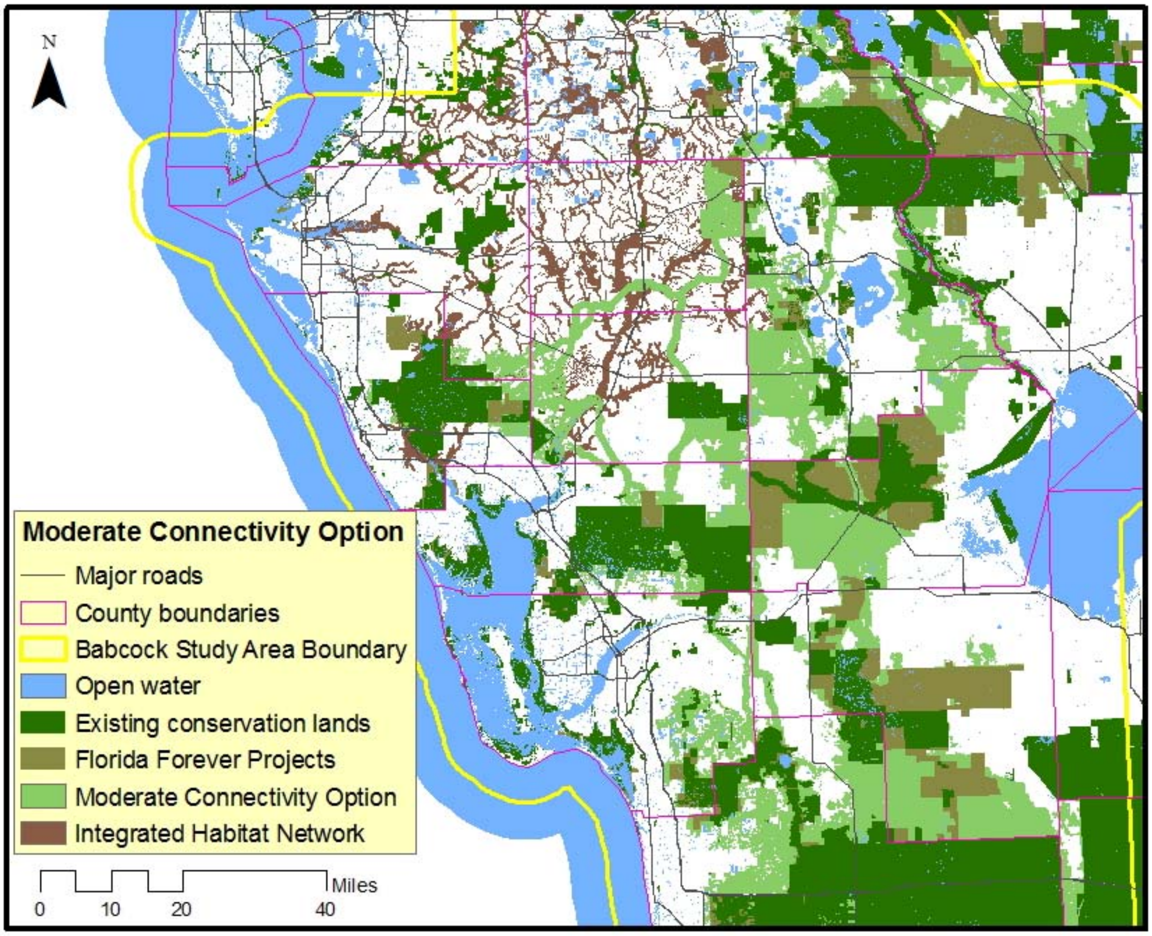


Figure 34. Zoom-in map of the moderate connectivity scenario plus the integrated habitat within the Babcock study area.

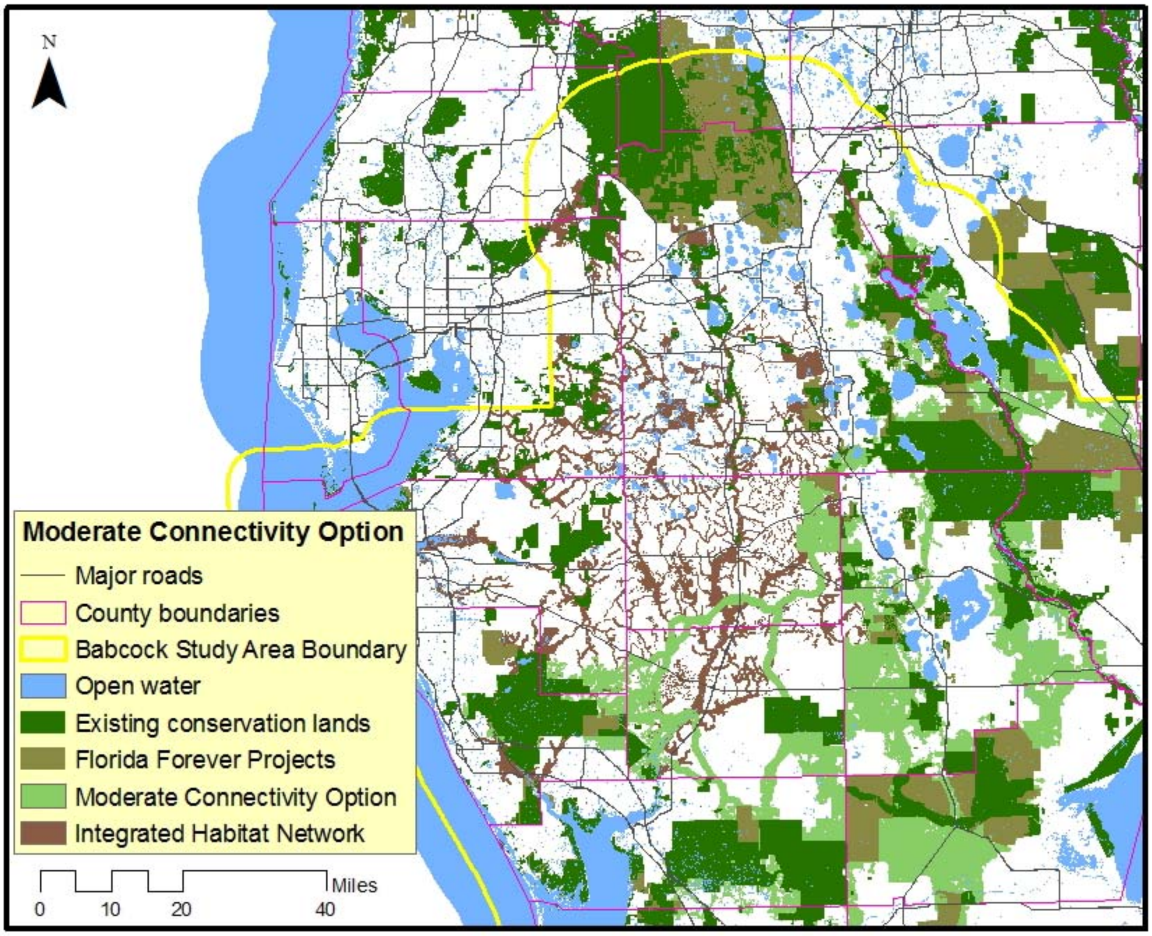


Figure 35. Zoom-in map of the moderate connectivity scenario plus the integrated habitat within the Babcock study area.

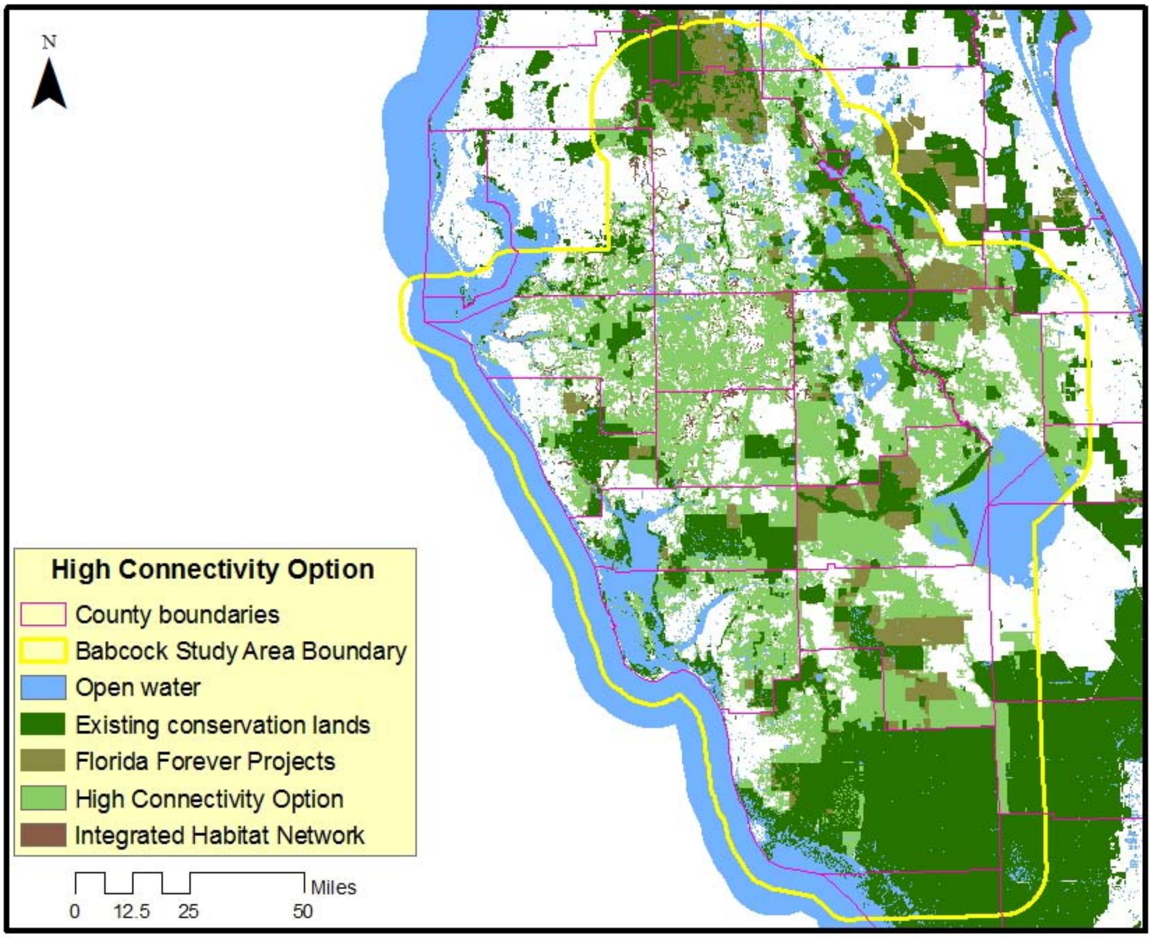


Figure 36. Region-wide map of the high connectivity scenario plus the integrated habitat network within the Babcock study area.

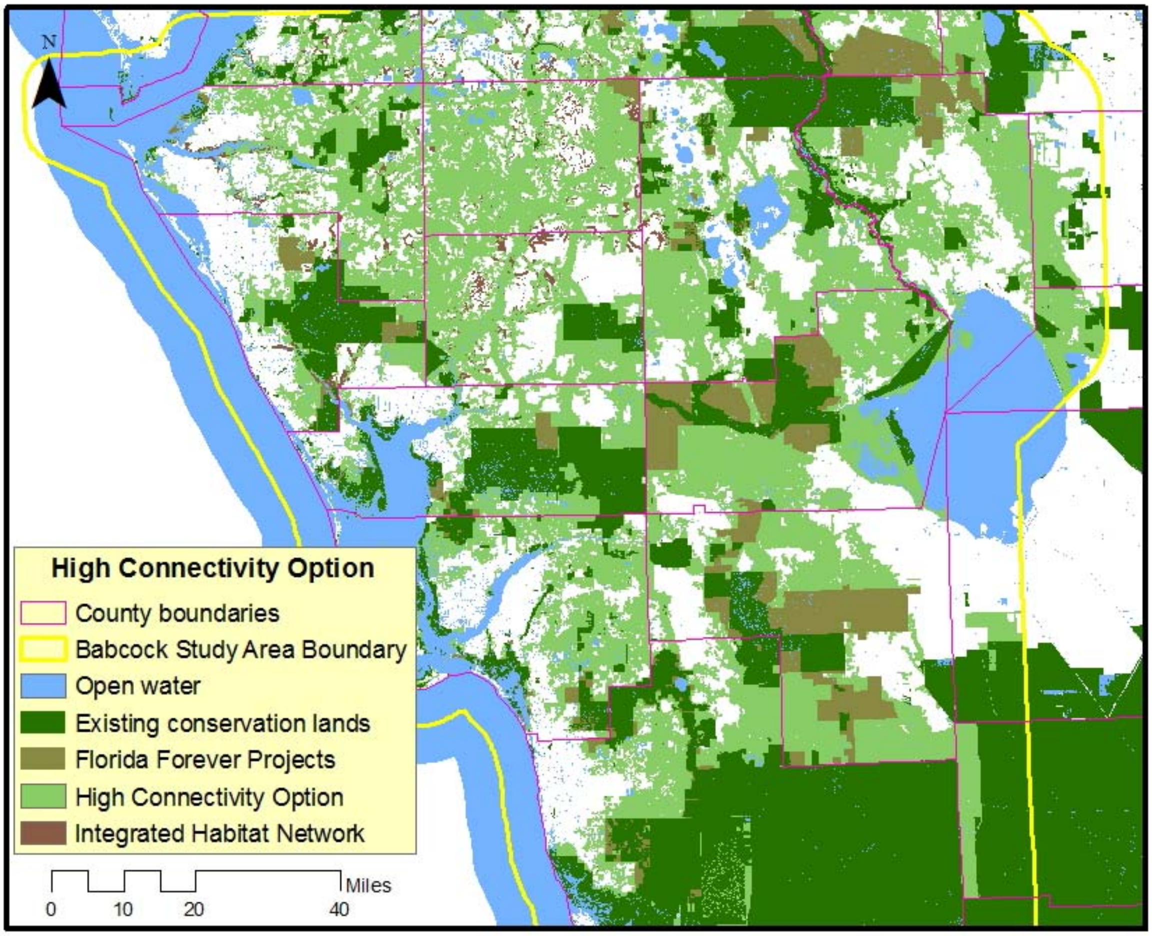


Figure 37. Zoom-in map of the high connectivity scenario plus the integrated habitat within the Babcock study area.

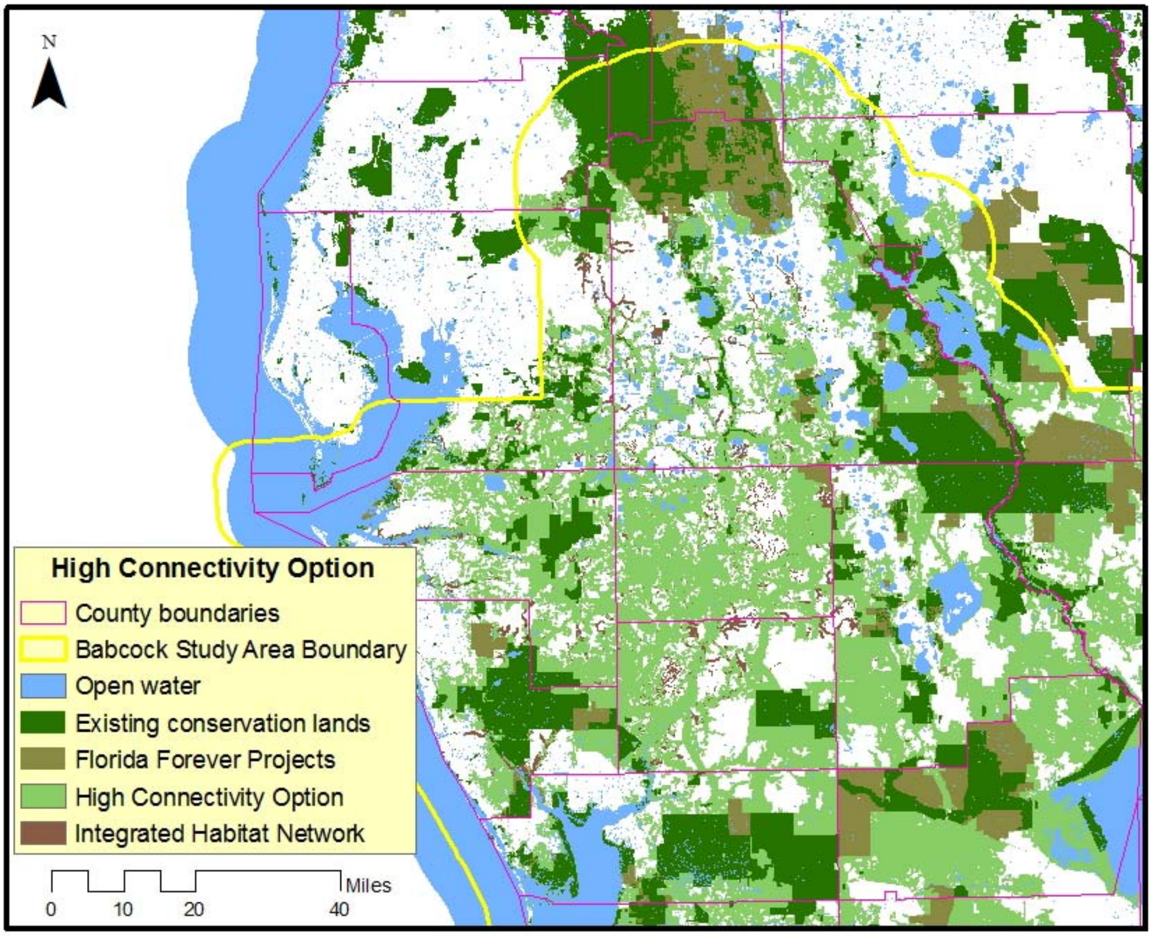


Figure 38. Zoom-in map of the high connectivity scenario plus the integrated habitat within the Babcock study area.

Table 1. Summary of acres of five habitat/land-use classes within each connectivity scenario.

	Conservation Status within Connectivity Scenarios (Acres)					
Connectivity Scenario	**Existing Conservation Land**	**Proposed Florida Forever Project Land**	**Open Water**	**Other Terrestrial Land**	**Other Wetlands**	**Total Private Lands**
Low Connectivity	2,199,448	42,943	1,731	61,694	25,915	130,552
Moderate Connectivity	2,439,105	511,636	20,820	785,435	374,775	1,671,846
Alternative Moderate Connectivity	2,501,586	521,492	40,936	1,083,432	488,916	2,093,840
High Connectivity	2,990,571	698,962	578,114	2,355,037	892,961	3,946,960
Alternative High Connectivity	2,991,697	699,217	581,738	2,443,884	901,545	4,044,646

Table 2. Estimated Florida back bear population supported within potential bear habitat (ac) encompassed by each of five connectivity scenarios. For each connectivity scenario population estimations were calculated based on 100% and 75% of the total available potential habitat. Population estimations were determined by utilizing density calculations obtained from previous Florida black bear studies completed within Ocala National Forest, Eglin Air Force Base and across the Highlands-Glades region.

		Bear Population Estimation (95%CI)		
Connectivity Scenario	**Available Habitat (ac)**	**Based on Ocala Study**	**Based on Eglin Study**	**Based on Highlands-Glades Study**
Minimum (100% habitat)	1,720,917	1324 - 1951	209 - 348	1425 - 1436
Minimum (75% habitat)	1,290,687	993 - 1463	157 - 261	1069 - 1077
Moderate (100% habitat)	2,741,431	2109 - 3108	333 - 555	2272 - 2287
Moderate (75% habitat)	2,056,073	1582 - 2331	250 - 416	1704 - 1716
Moderate: Alternative Areas (100% habitat)	*219,836*	*169 - 249*	*28 - 45*	*155 - 182*
Moderate: Alternative Areas (75% habitat)	*164,877*	*126 -187*	*20 - 33*	*137 - 137*
High (100% habitat)	4,155,684	3197 - 4712	505 - 841	3443 - 3468
High (75% habitat)	3,116,763	2398 - 3534	379 - 631	2583 - 2601
High: Alternative Areas (100% habitat)	*9,975*	*8 - 11*	*1 - 2*	*7 - 8*
High: Alternative Areas (75% habitat)	*7,481*	*6 - 8*	*1- 2*	*6 - 6*

Table 3. Estimated Florida Panther population supported within potential panther habitat (ac) encompassed by each of five connectivity scenarios. For each connectivity scenario population estimations were calculated based on 100% and 75% of the total available potential habitat. Population estimations were determined by utilizing density calculations obtained from previous Florida Panther studies completed in south west Florida.

		Panther Population Estimation (95%CI)	
Connectivity Scenario	**Available Habitat (ac)**	**Based on Maehr et al. 1991 Study**	**Based on McBride 2000 Study**
Minimum (100% habitat)	1,635,377	53 - 73	51
Minimum (75% habitat)	1,226,533	40 - 55	29
Moderate (100% habitat)	2,664,109	86 - 119	83
Moderate (75% habitat)	1,998,082	65 - 89	47
Moderate: Alternative Areas (100% habitat)	*291,934*	*10 - 13*	*9*
Moderate: Alternative Areas (75% habitat)	*218,950*	*7 - 7*	*7*
High (100% habitat)	4,485,883	145 - 200	141
High (75% habitat)	3,364,412	109 - 150	79
High: Alternative Areas (100% habitat)	*12,227*	*0 - 1*	*0*
High: Alternative Areas (75% habitat)	*9,170*	*0 - 0*	*0*

Table 4. Estimated Sherman's fox squirrel population supported within potential Sherman's fox squirrel habitat (ac) encompassed within each connectivity scenario. For each connectivity scenario population estimations were calculated based on 100% and 50% of the total available potential habitat. Population estimations were determined by utilizing density calculations obtained from previous Sherman's Fox Squirrel studies.

		Sherman's Fox Squirrel Population Estimation	
Connectivity Scenario	**Available Habitat (ac)**	**Based on Moore 1957 Study**	**Based on Kantola and Humphrey 1990 Study**
Minimum (100% habitat)	310,006	5,020	15,063
Minimum (50% habitat)	155,003	2,510	7,532
Moderate (100% habitat)	569,211	9,218	27,658
Moderate (50% habitat)	284,606	4,609	13,829
Moderate: Alternative Areas (100% habitat)	*54,278*	*878.99*	*2,637*
Moderate: Alternative Areas (50% habitat)	*27,139*	*439.495*	*1,319*
High (100% habitat)	1,048,857	16,986	50,965
High (50% habitat)	524,428	8,493	25,482
High: Alternative Areas (100% habitat)	*876*	*14*	*43*
High: Alternative Areas (50% habitat)	*438*	*7*	*21*

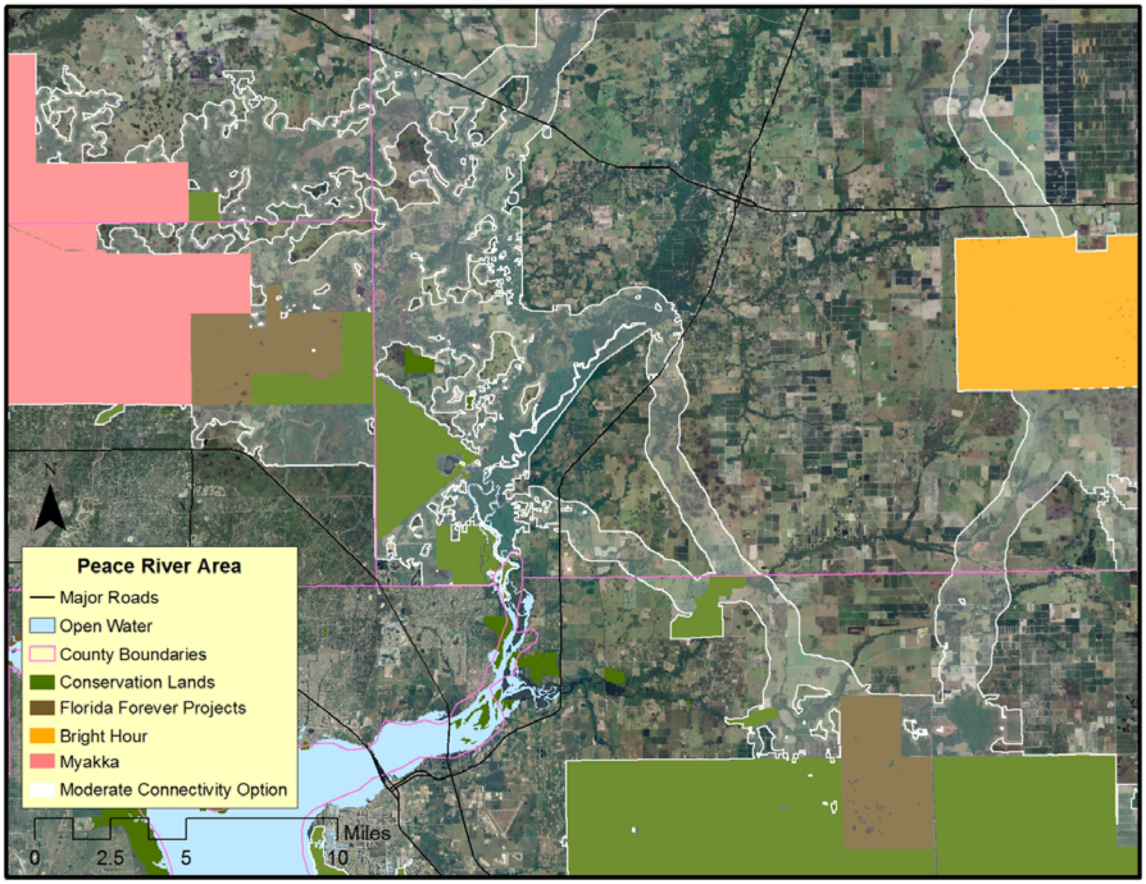


Figure 39. Overlay of the moderate habitat connectivity scenario onto 1-meter resolution Digital Ortho Quarter Quads in the Peace River region of the Babcock study area.

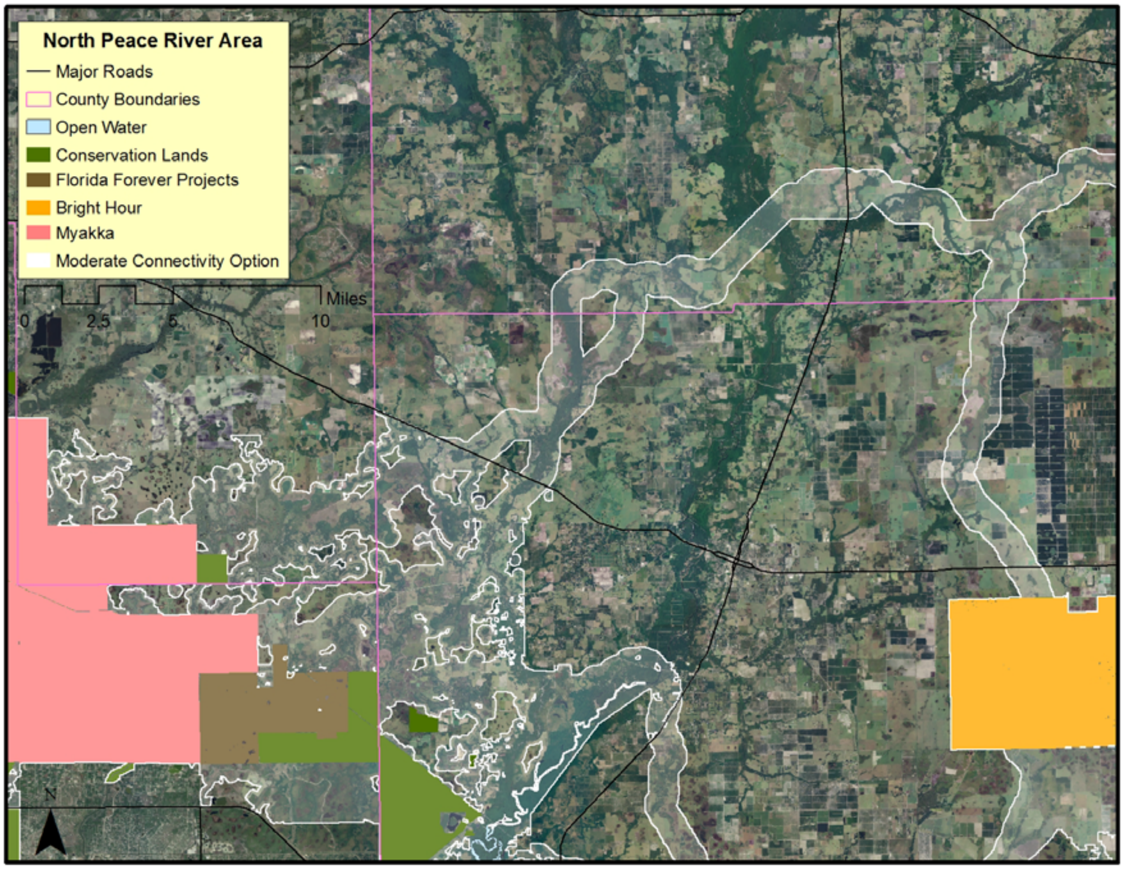


Figure 40. Overlay of the moderate habitat connectivity scenario onto 1-meter resolution Digital Ortho Quarter Quads in the northern Extent of Peace River region of the Babcock study area.

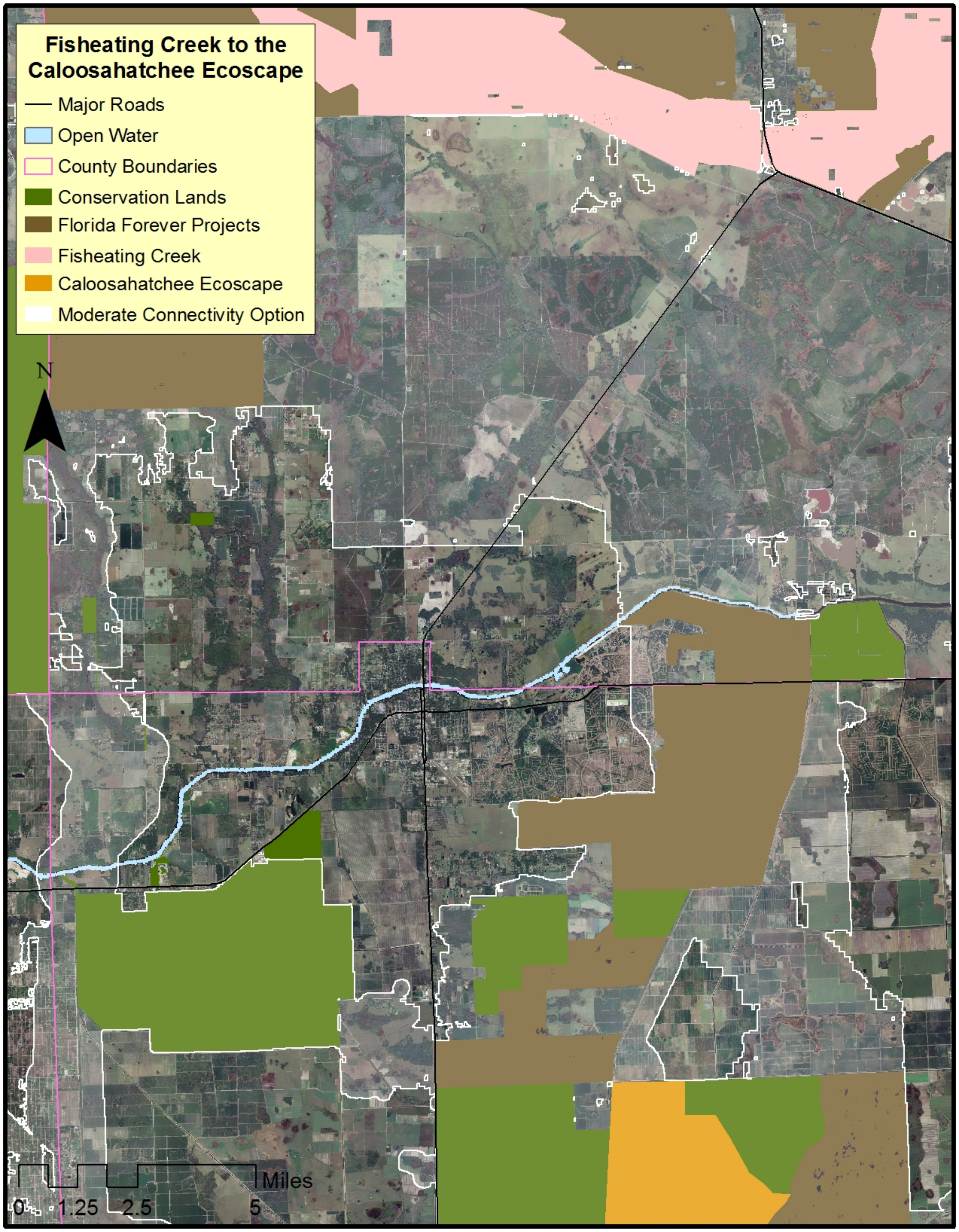


Figure 41. Overlay of the moderate habitat connectivity scenario onto 1-meter resolution Digital Ortho Quarter Quads for the Caloosahatchee Ecoscape region of the Babcock study area.

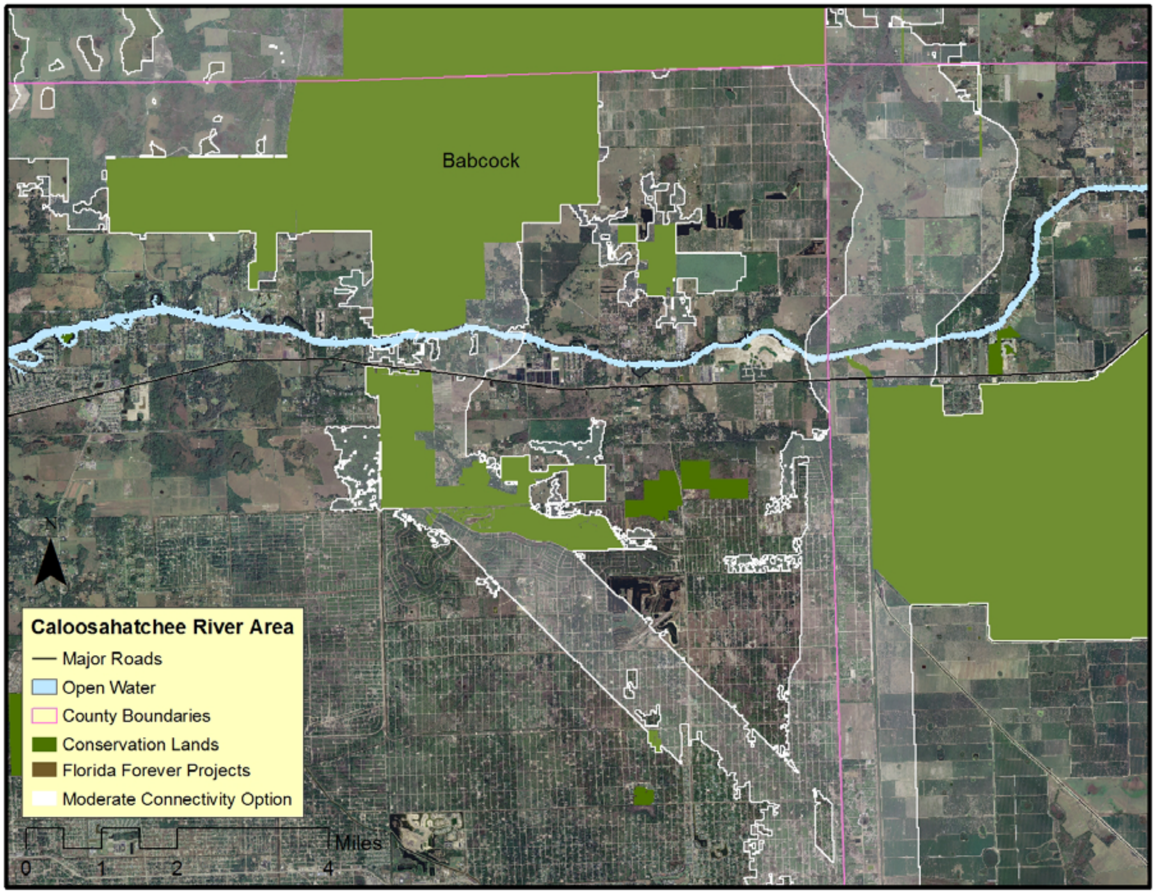


Figure 42. Overlay of the moderate habitat connectivity scenario onto 1-meter resolution Digital Ortho Quarter Quads for the Caloosahatchee River region of the Babcock study area.

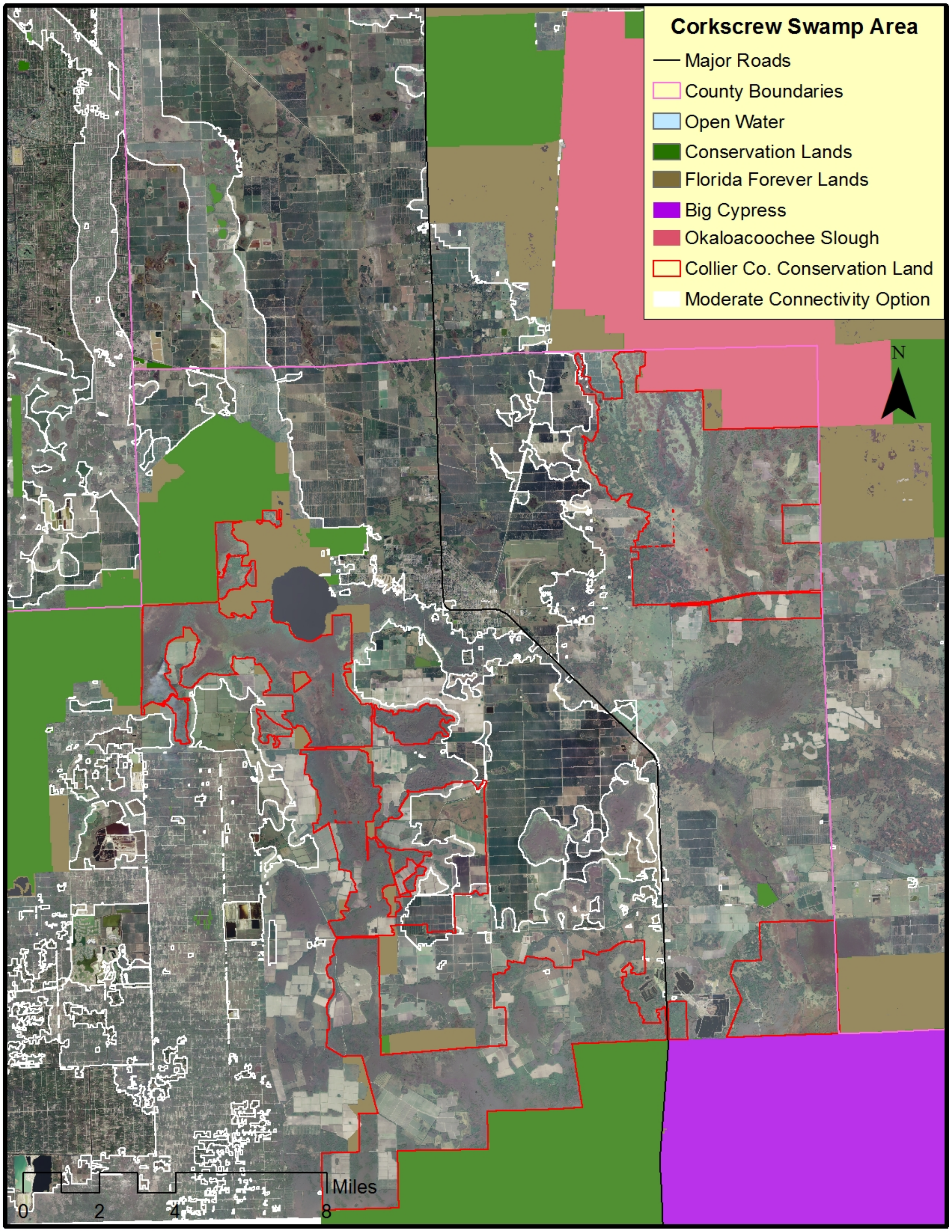


Figure 43. Overlay of the moderate habitat connectivity scenario onto 1-meter resolution Digital Ortho Quarter Quads for the Corkscrew Swamp region of the Babcock study area.

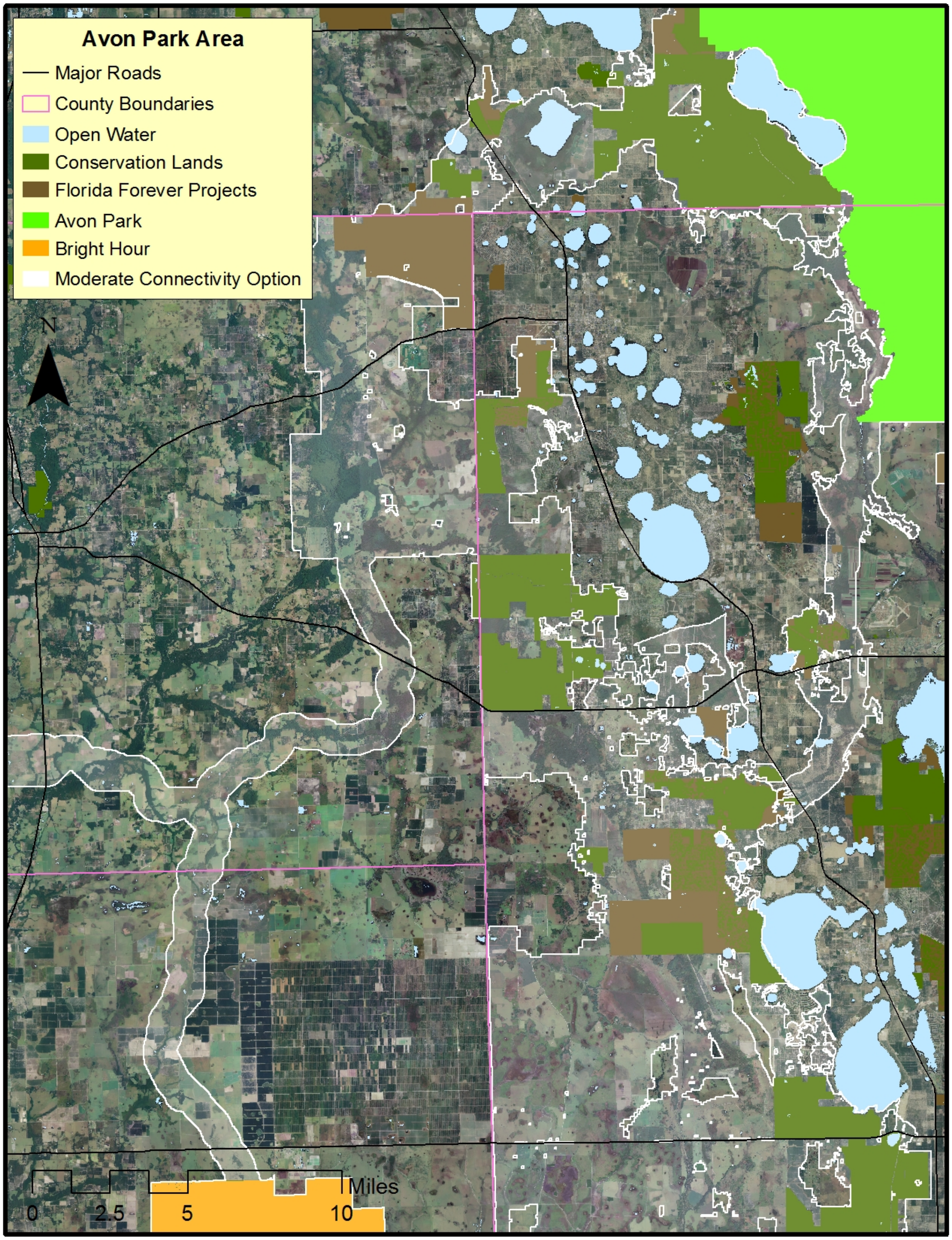


Figure 44. Overlay of the moderate habitat connectivity scenario onto 1-meter resolution Digital Ortho Quarter Quads for the Avon Park-Lake Wales Ridge region of the Babcock study area.

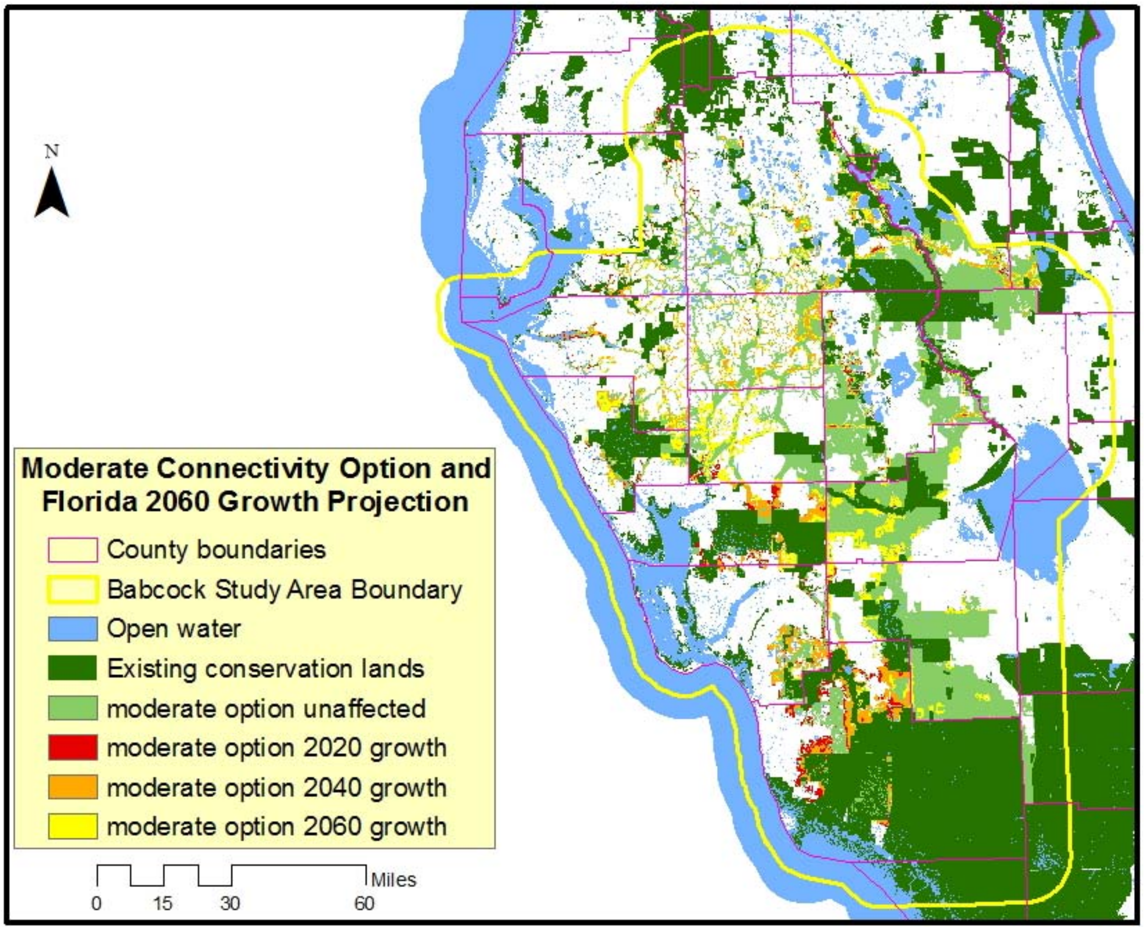


Figure 45. Comparison of the moderate connectivity option with the Florida 2060 growth projection model.

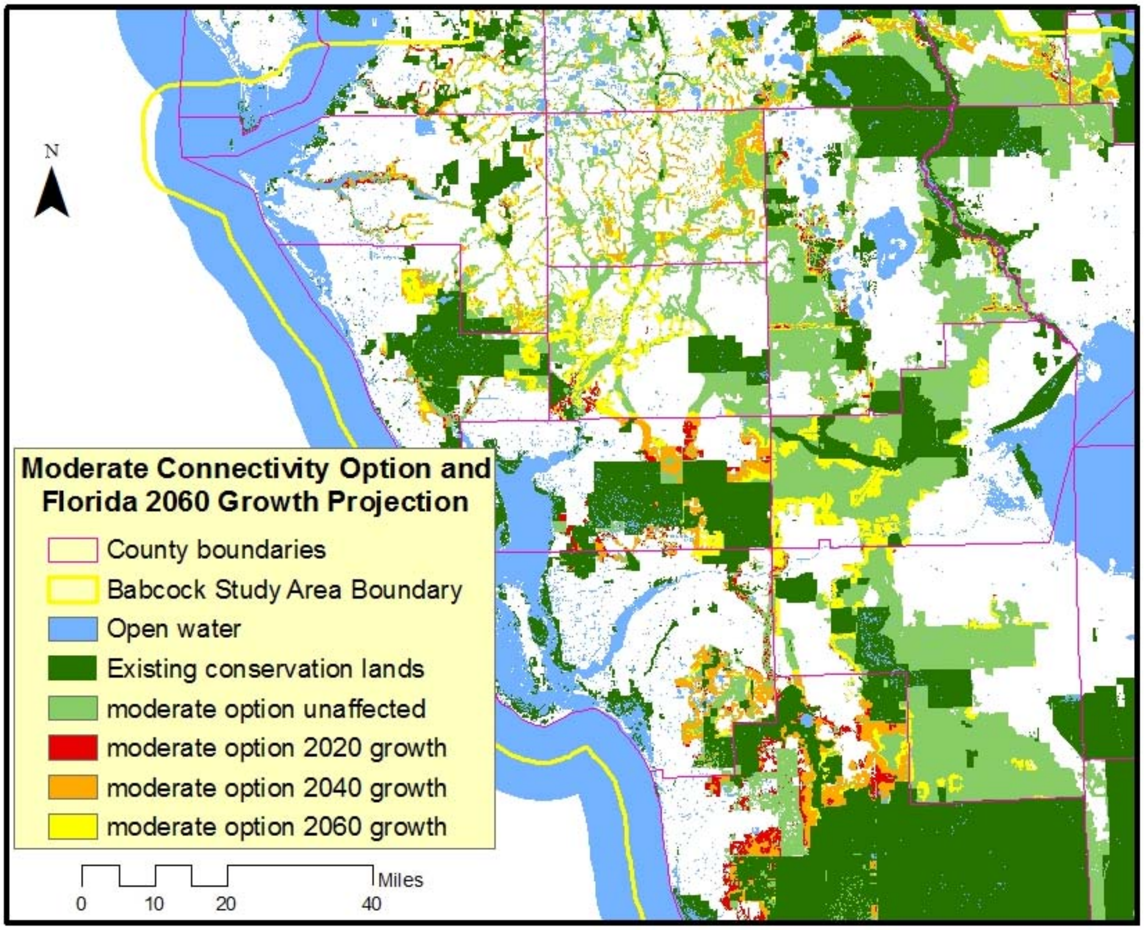


Figure 46. Comparison of the moderate connectivity option with the Florida 2060 growth projection model.

Connectivity Options in the Face of Projected Regional Urban Growth and Sea-Level Rise

Future residential, commercial, and industrial development could preclude protection of any of the connectivity options without appropriate planning. To indicate the potential conflict between ecological connectivity and future growth, we compared the moderate connectivity option to the Florida 2060 growth projection. The results of the comparison suggest that there is significant potential for conflict with future growth (Figs. 45-46). The two areas that might be affected the most are within Collier County and between Babcock Ranch and Myakka.

Sea level rise (SLR) may also have significant negative impacts on conservation efforts in the study area. These impacts could include the loss of core habitat for all three focal species on conservation lands in the southernmost part of the study area (Fig. 47). In addition, SLR could degrade or fragment corridors across the lower Peace River (Fig. 48) and the Caloosahatchee River (Fig. 49).

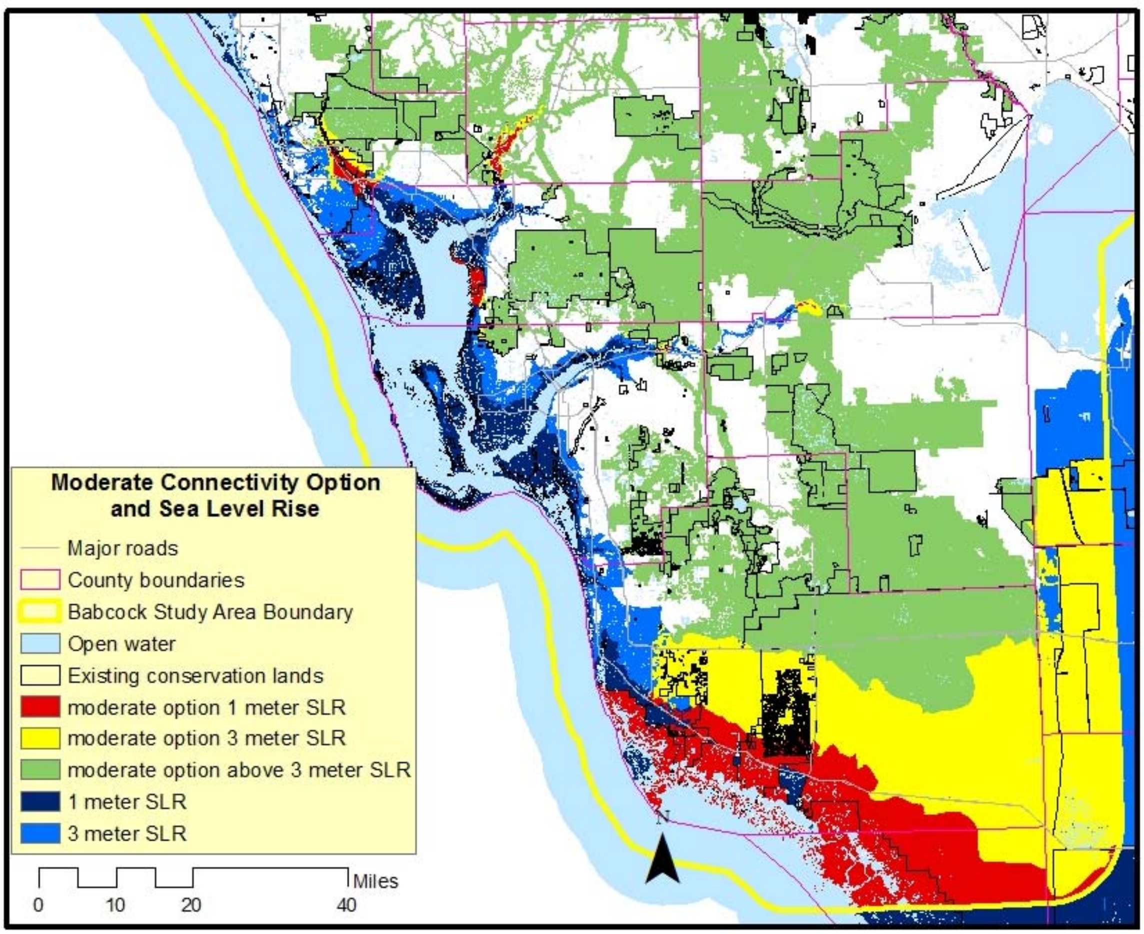


Figure 47. Comparison of the moderate connectivity option with Sea Level Rise projections.

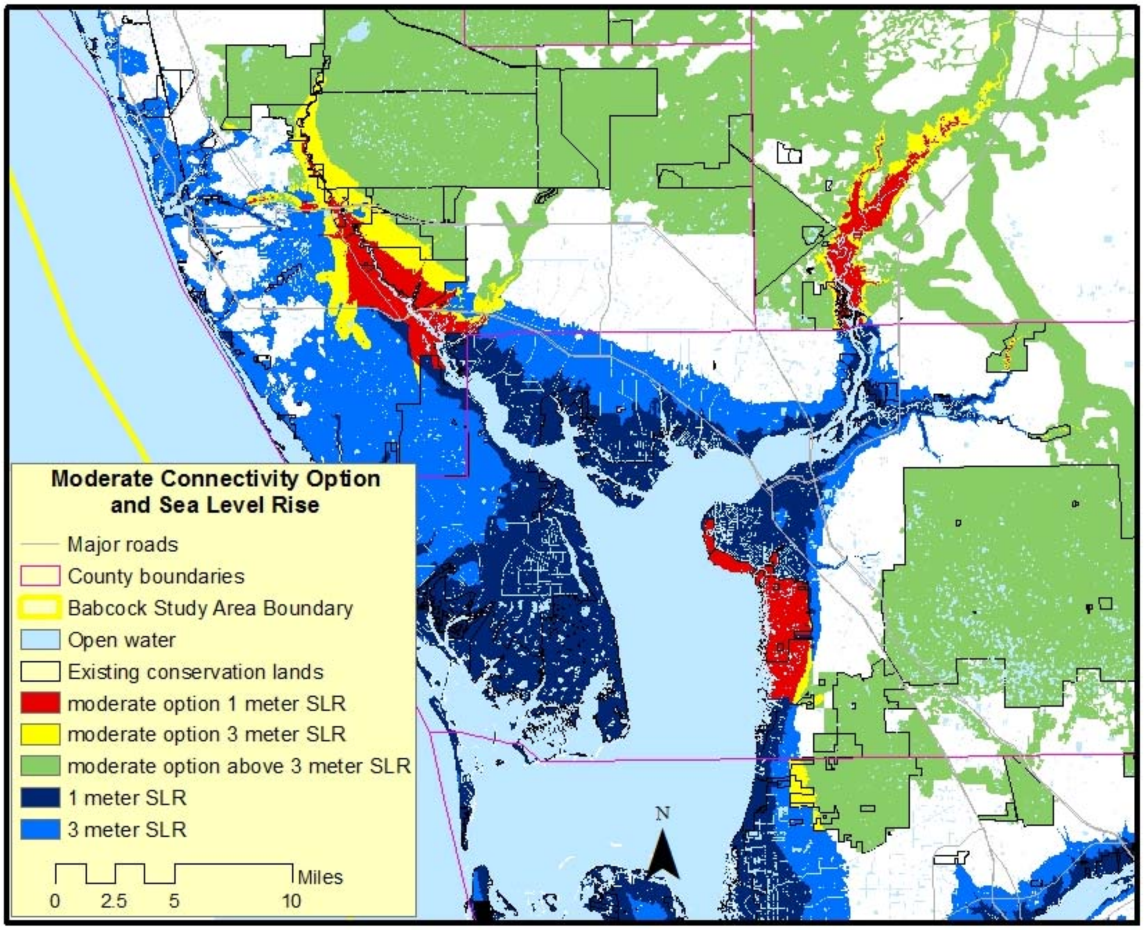


Figure 48. Comparison of the moderate connectivity option with Sea Level Rise projections for the lower Peace and Myakka Rivers.

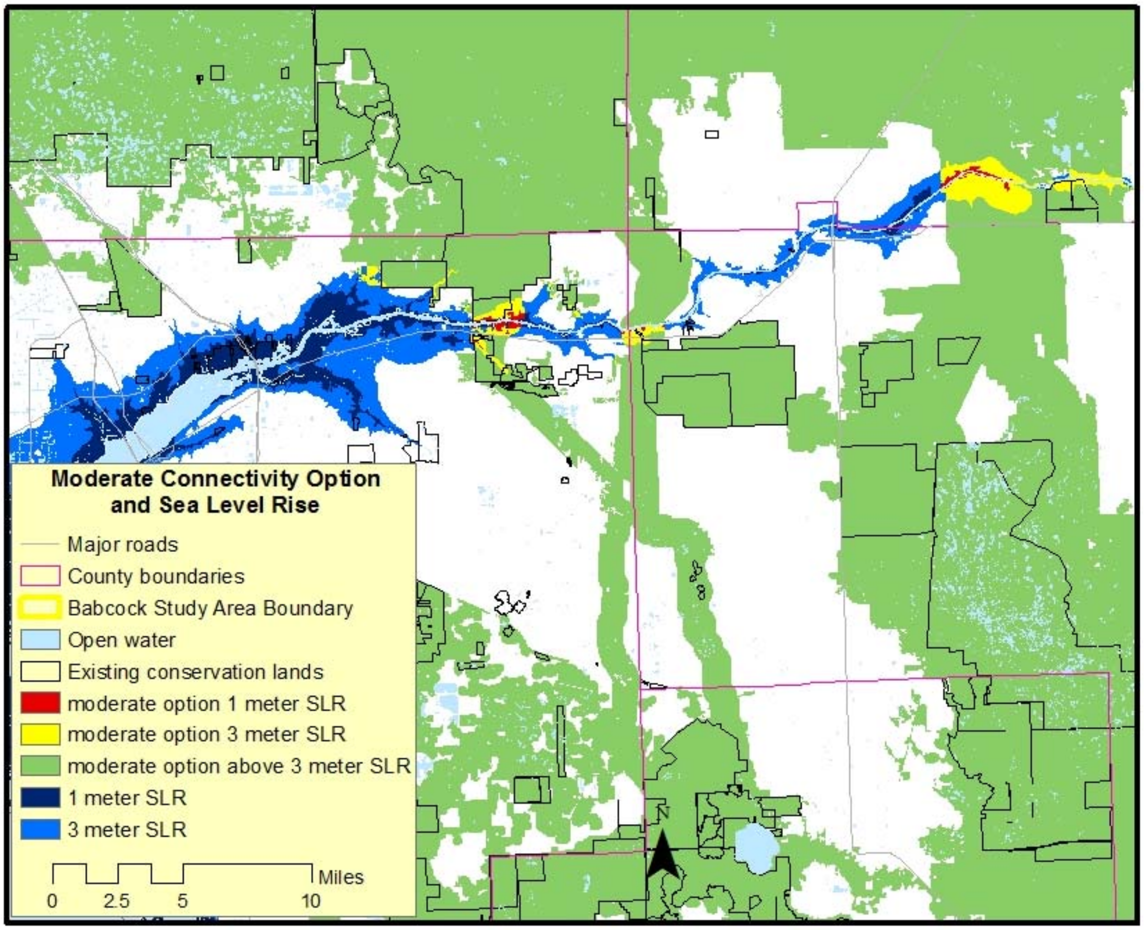


Figure 49. Comparison of the moderate connectivity option with Sea Level Rise projections for the Caloosahatchee River.

Discussion and Recommendations

A distinct and reassuring finding from this study is that options for maintaining connectivity for three focal species – Florida panther, Florida black bear, and Sherman's fox squirrel – between Babcock Ranch and other existing and potential conservation areas within the regional landscape are still relatively abundant and intact. Quite extensive areas of potentially suitable habitat are available for the black bear and panther, but somewhat less for the fox squirrel. We must issue the reminder, however, that occupied habitat is a generally unknown but consistently smaller subset of the potential habitat identified in habitat models, either because the habitat models fail to identify all potential limiting factors to a species' distribution, or because potentially suitable habitat is unoccupied today due to past or current human pressures, including hunting, poaching, and road impacts.

A less optimistic finding from our study is that several problematic corridor bottlenecks are present already in the region and will constrain animal movement unless remedied by increased land protection and mitigation of impacts from roads and development. Most worrisome, unless potential conservation areas (e.g., Florida Forever projects) are protected quite soon, connectivity for our focal species and many other animals will be significantly diminished, especially if human population growth and development continue in the study region and if road impacts (increased traffic volume, road widening, etc.) are not reduced by properly located and designed wildlife crossings and associated barrier fencing. Sea-level rise is also a threat. Impacts of sea-level rise in the immediate vicinity of Babcock Ranch, and on corridors to the east and northeast, are expected to be relatively minor – certainly much less severe than in areas closer to the coast, especially in low-lying areas of extreme South Florida, e.g., the lower Everglades and the Florida Keys (Noss et al. in preparation). On the other hand, the southern and western portions of our study area could experience extreme impacts of even a 1-meter rise in sea level, as will the Lower Peace and Myakka River areas to the northwest of Babcock Ranch, where some of our identified LCPs would be severed by rising waters. Moreover, even inland areas substantially above 3 meters in elevation will be at high risk as displaced people potentially move inland from the coasts over the coming decades. This phenomenon underscores the need to protect key core areas and landscape linkages in advance of this displacement of people and other species from low-lying coastal areas (Noss et al. in preparation).

Although we made the best use we could of available data within the short time span and limited budget of this study, we acknowledge several limitations of our research that should be addressed through further studies. Most importantly, we were not able to assess population viability directly for the three focal species, but rather could only estimate population sizes and viability based on habitat conditions and knowledge of home range sizes and life histories. Such estimates make the implicit assumption that the size and configuration of individual habitat patches are unimportant and that individual animals can move freely through the corridors identified in each connectivity option. Hence, static habitat and corridor models typically produce an optimistic portrayal of potential population size and viability in comparison with dynamic models.

Assessment of population viability is best accomplished through spatially explicit population modeling (Dunning et al. 1995, Carroll et al. 2003, Akcakaya et al. 2004). In these dynamic models, information on demography (age-specific birth and death rates, dispersal, etc.) for a species is integrated with GIS-based information on habitat quality (e.g., from habitat models of the type developed in our study) and spatial configuration to simulate births, dispersal, reproduction, and deaths of individuals across a study landscape. Output from these models includes predictions of source (recruitment > mortality) vs. sink (mortality > recruitment) status of specific habitat patches, dispersal and other movements among patches, and probabilities of extinction vs. recovery under alternative future scenarios of land cover, land use, and even climate change (Carroll 2007). Surprisingly, although our focal species have been relatively well studied, no spatially explicit population models have been produced for these species in Florida, other than the work of the USFWS Panther Subteam for panthers in south Florida.. We view this as a high priority for future research, and should include modeling of alternative future scenarios of landscape conditions.

Another caveat concerns our modeling of movement paths among habitat blocks. Least-cost path modeling, though widely used and found acceptable in many conservation plans, has limitations. The logic of least-cost path modeling is sound: Intelligent animals will try to follow a path of least resistance through a landscape, minimizing energy expenditure and maintaining adequate security. However, the resistance of each class of land use, vegetation, topography, or human disturbance is usually based on expert opinion and/or literature review on habitat suitability. Expert opinion performs poorly if not combined with literature review. The assumption in LCP analysis that animals choose travel routes on the basis of the same factors they use to choose habitat (e.g., for home ranges) is not always valid. In the case of this study, however, we made intensive use of the literature; moreover, our three focal species have been well enough studied that estimation of least cost paths can be considered reasonably accurate.

The three connectivity options that we developed from the habitat and LCP models applied in this study represent a political or economic feasibility gradient from highly to minimally constrained. All options would require addition of lands to Florida's conservation area network. For example, approximately 130,000 acres of private land is included in the low connectivity option, with approximately 43,000 of those acres within Florida Forever projects, as well as 26,000 acres of wetlands; approximately 1.7 million acres of private land is included in the moderate connectivity option, with approximately 500,000 of those acres within Florida Forever projects, as well as 400,000 acres of wetlands; and approximately 3.9 million acres of private land is included in the high connectivity option, with approximately 700,000 of those acres within Florida Forever projects, as well as 900,000 acres of wetlands.

Assuming that all potential habitat is suitable habitat and that individual animals can move freely through the corridor network, which as noted above is unreasonable, we made crude estimates of potential population sizes for the three focal species under the three connectivity options. To partially correct for biases, we provided population estimates based on the unrealistic assumption that all potential habitat is suitable and compared these with estimates based on an assumption that only 75% (for panthers and bears) or 50% (for fox squirrels) of the potential habitat in each connectivity option is suitable. Although these percentage estimates are arbitrary, they are likely more realistic than estimates based on the assumption that all potential habitat is suitable. Applying the moderate connectivity option, the 75% suitable habitat assumption, and population densities obtained from a study in Ocala National Forest, for example, the study region could support 1582 to 2331 bears. Under the same option and 75% suitable habitat assumption, and using population densities calculated by Maehr et al. (1991), the study region could support 65 to 89 panthers. And under the same option, a 50% suitable habitat assumption, and density estimates from two studies of fox squirrels, the study region could support 4,609 to 13,829 fox squirrels. Nevertheless, these revised estimates are still highly optimistic, especially so for the fox squirrel, for which, as noted earlier and is discussed further below, so little of the potential habitat is suitable today due to inappropriate management.

Especially for habitat specialist species such as the fox squirrel, protection of large habitat blocks and connections among blocks is not enough to assure persistence. Ecological management to maintain suitable habitat – both within Babcock Ranch and within other existing and potential conservation areas within the study region – is essential to assure population viability. Fox squirrels are associated primarily with open, mature pinelands, but also are found in open cypress stands and in oak hammocks, bottomland hardwood areas, and tropical hardwood hammocks. As noted, the squirrels make high use of ecotones between hammocks and pine savannas (Weigl et al. 1989, Kantola and Humphrey 1990). The seeds of longleaf pine and slash pine, as well as acorns from oaks, are the staple food items for fox squirrels in Florida (Wooding 1997). Pine seeds are often more dependable than acorns from oaks, which sometimes (e.g., for turkey oak) are available only in occasional mast years (Kantola and Humphrey 1990). On the other hand, acorns are more storable (although not highly so) than pine seeds, which are available for only about 4 months of the year and do not store well (Wooding 1997). Squirrels eat many other food items, but probably do not depend on them to the extent that they depend on pine seeds and acorns (Koprowski 1994, Kantola and Humphrey 1990). A scarcity of suitable, storable food in large quantities may explain the low densities of fox squirrels in the southeastern coastal plain compared to the Midwest (Wooding 1997). One common, potentially important and interesting food item is fungi. It appears likely that the fox squirrel serves as a keystone species by consuming and dispersing the spores of hypogeous mycorrrhizal fungi, which develop symbiotic relationships with the roots of pines and other trees. Pines may depend on this symbiosis to obtain essential soil nutrients and water (Weigl et al. 1989, Earley 2004).

Probably the most frequently cited habitat feature essential for southeastern fox squirrels is an open understory, which under natural conditions is usually maintained by frequent, low-severity fires during the early growing season and are typical of pine savanna ecosystems (Kiltie 1989, Wooding 1997, Earley 2004). Brown (1978) observed that "complete fire protection in pine woodlands has resulted in the growth of dense understory vegetation which is not suitable as fox squirrel habitat." Ironically, because of past fire exclusion, many conservation areas that once were excellent habitat now have few fox squirrels. Extensive surveys for Big Cypress fox squirrels in the Big Cypress National Preserve and other natural areas yielded few fox squirrels (Jodice and Humphrey 1992, Ditgen et al. 2007, Eisenberg et al. in review). Instead, the squirrels are mostly found today in residential areas, golf courses, and pastures with artificially maintained open understories. Importantly, however, these anthropogenic habitats will not remain suitable for fox squirrels indefinitely due to lack of recruitment of new pines and oaks to the overstory (Wooding 1997, Eisenberg et al. in review). When the present overstory trees die, these habitats will no longer be suitable for fox squirrels.

Besides fire exclusion, another problem that makes many natural areas unsuitable for fox squirrels is a history of management burning during the dormant season rather than during the growing season, when virtually all lightning-ignited fires occur. Fires during the dormant season favor dense saw palmetto and other shrubs (Tanner et al. 1999), which repel fox squirrels, presumably because the squirrels favor open understories in order to travel quickly between trees and remain vigilant for predators. In areas of Babcock Ranch where the flatwoods have developed dense palmetto understories due to a history of fire exclusion or winter burning, restoration will be needed to restore the open understory conditions essential for fox squirrels. A return to a natural growing season fire regime often will not suffice to restore understory quality. Instead, studies (primarily in dry prairie) show that a mix of roller chopping and fire works better to reduce palmetto and other shrub cover, and allow recovery of essential warm-season grasses and native forbs, than either practice alone (Watts et al. 2006). On the other hand, heavy treatment to maintain and open understory, to the extent that oaks and other hardwoods are strongly diminished, could be harmful to fox squirrels. Perkins et al. (2008) observed that the highest quality habitat for Sherman's fox squirrel is comprised of 88.2% mature pine savanna to 11.8% hardwood cover. These authors expressed concern that the restoration and management model for longleaf pine savannas is almost exclusively longleaf in the overstory and midstory with virtually no hardwoods, a condition that is far from optimal for fox squirrels.

Unfortunately, suitable habitat for fox squirrels is difficult to model because their presence and abundance are closely tied to habitat structural and compositional features, as described above, that are essentially impossible to evaluate accurately from aerial photographs, satellite imagery, or available GIS maps of land use and land cover. Existing habitat models, including the one produced in this study (See Figs. 11 and 12) necessarily carry the assumption that primary, secondary, and matrix habitat are not necessarily in suitable condition that today, but might become suitable if restored and managed in such a way as to maintain the large pines, hardwoods, and open understory essential to fox squirrels.

To summarize, we conclude that the moderate connectivity option, especially when augmented by the integrated habitat network focused on riparian areas, would provide a reasonably high probability of protecting the Florida panther, Florida black bear, and Sherman's and Big Cypress Fox Squirrel within the study region including and surrounding Babcock Ranch. This hypothesis should be tested through further field research and modeling (especially spatially explicit population modeling for the focal species), but provides a good working hypothesis for planning. Our recommendations for implementing this option and serving the broader goal of maintaining biodiversity include:

- Seek increased land acquisition and conservation easements in high-priority areas identified through this study and through other credible science-based planning.
- Corridors should be as wide as feasible. Although corridor design questions such as width, width to length ratio, and optimal structure are landscape- and species-specific issues that should be investigated empirically, in the absence of case-specific data we suggest that, at the landscape scale, corridors at least 3 times the width of edge effects (which commonly extend 100 m) should be protected. At the regional scale (> ca. 10 miles long) corridors should average 1 mile wide, and that a 1 to 10 rule for width to distance should be applied as distance increases.
- Multiple corridors (networks) and other pathways for animal movement are preferred over single corridors between core areas.
- Planners should use the best available science for "conservation development" through the Rural Land Stewardship program or other programs. Mitigation banking sites should be selected through defensible conservation prioritization methods and managed to maintain habitat for focal species and communities.
- Further empirical study is needed to determine hotspots of wildlife mortality on roads in the region, and to determine where and how to construct wildlife crossings, barrier fencing, and other options such as wildlife movement detectors to reduce roadkill.
- Habitat within core areas (i.e., conservation areas) and corridors should be actively managed to maintain required habitat structure for the focal species of interest. For animals such as fox squirrels, which depend on open habitats with minimal understory, frequent fire during the early growing season (April-June) at intervals of 2-3 years is optimal. If habitats have gone a long time without fire or with dormant season burning only, mechanical treatments such as roller chopping, in addition to fire, may be necessary to reduce palmetto or other shrub cover.
- Due to threats related to human population growth, development, and sea-level rise within the study region, there is some urgency in implementing the conservation actions suggested here.

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Literature Cited

Akcakaya, H.R., V.C. Radeloff, D.J. Mladenoff, and H.S. He. 2004. Integrating landscape and metapopulation modeling approaches: viability of the sharp-tailed grouse in a dynamic landscape. Conservation Biology 18:526-537.

Allendorf, F. W. 1983. Isolation, gene flow, and genetic differentiation among populations. Pages 51-65 in C. M. Schonewald¬Cox, S.M. Chambers, B. MacBryde, and W.L. Thomas, eds., Genetics and conservation. Benjamin/Cummings, Menlo Park, CA.

Beier, P. 1995. Dispersal of juvenile cougars in fragmented habitat. Journal of Wildlife Management 59:228-237.

Beier, P. 1996. Metapopulation models, tenacious tracking, and cougar conservation. Pages 293-324 in D.R. McCullough, editor. Metapopulations and wildlife conservation. Island Press, Washington, D.C.

Beier, P., and R.F. Noss. 1998. Do habitat corridors provide connectivity? Conservation Biology 12:1241-1252.

Bennett, A.F. 1999. Linkages in the Landscape: the role of corridors and connectivity in wildlife conservation. IUCN, Gland, Switzerland and Cambridge, UK.

Brown, J.H., and M.V. Lomolino. 1998. Biogeography. 2nd edition. Sinauer, Sunderland, MA.

Brown, L.N. 1978. Mangrove fox squirrel. Pages 5-6 in J.N. Layne, editor. Rare and Endangered Biota of Florida. Volume 1, Mammals. University Presses of Florida, Gainesville.

Bullock, J.M., R.E. Kenward, and R.S. Hails, editors. 2002. Dispersal ecology. Blackwell Science, Oxford, U.K.

Carroll, C. 2007. Interacting effect of climate change, landscape conversion, and harvest on carnivore populations at the range margin: marten and lynx in the northern Appalachians. Conservation Biology 21:1092-1104.

Carroll, C., R.F. Noss, and P.C. Paquet. 2001. Carnivores as focal species for conservation planning in the Rocky Mountain region. Ecological Applications 11:961-980.

Carroll, C., R.F. Noss, P.C. Paquet, and N.H. Schumaker. 2003. Integrating population viability analysis and reserve selection algorithms into regional conservation plans. Ecological Applications 13:1773-1789.

Cox, J., R. Kautz, M. MacLaughlin, and T. Gilbert. 1994. Closing the gaps in Florida's wildlife habitat conservation system: recommendations to meet minimum conservation goals for declining wildlife species and rare plant and animal communities. Florida Game and Fresh Water Fish Commission, Tallahassee Florida.

Damschen, E.I., N.M. Haddad, J.L. Orrock, J.J. Tewksbury, and D.J. Levey. 2006. Corridors increase plant species richness at large scales. Science 313:1284-1286.

Davis, M.B. 1981. Quaternary history and the stability of for¬est communities. Pages 132-53 in D.C. West, H.H. Shugart, and D.B. Botkin, eds., Forest succession. Springer-Verlag, New York.

Ditgen, R.S., J.D. Shepherd, and S.R. Humphrey. 2007. Big Cypress fox squirrel (Sciurus niger avicennia) diet, activity, and habitat use on a golf course in southwest Florida. American Midland Naturalist 158:403-414.

Dixon, J. D., M. K. Oli, M. C. Wooten, T. H. Eason, J. W. McCown, and D. Paetkau. 2006. Effectiveness of a regional corridor in connecting two Florida black bear populations. Conservation Biology 20:155-162.

Dixon, J. D., M. K. Oli, M. C. Wooten, T. H. Eason, J. W. McCown, and M. W. Cunningham. 2007. Genetic consequences of habitat fragmentation and loss: the case of the Florida black bear (*Ursus americanus floridanus*). Conservation Genetics 8:455–464.

Dunning, J.B., Jr., D. J. Stewart, B. J. Danielson, B.R. Noon, T.L. Root, R.H. Lamberson, E.E. Stevens.1995. Spatially explicit population models: current forms and future uses.Ecological Applications 5:3-11.

Earley, L.S. 2004. Looking for Longleaf: The Fall and Rise of an American Forest. University of North Carolina Press, Chapel Hill.

Eisenberg, D.A., R.F. Noss, J.M. Waterman, and M.B. Main. In review. The distribution, abundance, and habitat use of the Big Cypress fox squirrel. American Midland Naturalist.

Florida Panther Subteam. 2002. Landscape Conservation Strategy for the Florida Panther in South Florida. Prepared for the U.S. Fish and Wildlife Service South Florida Ecological Services Office, Vero Beach, Florida.

Foster, M.L. and S.R. Humphrey. 1995. Use of highway underpasses by Florida panthers and other wildlife. Wildlife Society Bulletin 23:95-100.

Hanski, I. 1999. Metapopulation ecology. Oxford University Press, Oxford, UK.

Harris, L. D. 1985. Conservation corridors: A highway system for wildlife. ENFO Report 85-5. Florida Conservation Foundation, Winter Park.

Harris, L.D., and K. Atkins. 1991. Faunal movement corri¬dors, with emphasis on Florida. Pages 117-134 in W. Hudson, ed., Landscape linkages and biodiversity: a strategy for survival. Island Press, Washington, D.C.

Harris, L.D., and P.B. Gallagher. 1989. New initiatives for wildlife conservation: The need for movement corridors. Pages 11-34 in G. Mackintosh, ed., Preserving communities and corridors. Defenders of Wildlife, Washington, D.C.

Harris, L.D., and J. Scheck. 1991. From implications to applications: The dispersal corridor principle applied to the conservation of biological diversity. Pages 189-200 in D. A. Saunders and R. J. Hobbs, eds., Nature conservation: the role of corridors. Surrey Beatty and Sons, Chipping Norton, NSW, Australia.

Harrison, S. 1994. Metapopulations and conservation. Pages 111-128 in P.J. Edwards, R.M. May, and N.R. Webb, eds. Large-scale ecology and conservation biology. Blackwell Science, Oxford, UK.

Hellgren, E. C., and D. S. Maehr. 1992. Habitat fragmentation and black bears in the eastern United States. Proceedings of the Eastern Black Bear Workshop on Management and Research 11:154-165.

Hobbs, R.J., and A.J.M. Hopkins. 1991. The role of conservation corridors in a changing climate. Pages 281-90 in D. A. Saunders and R. J. Hobbs, eds., Nature conservation: the role of corridors. Surrey Beatty and Sons, Chipping Norton, NSW, Aus¬tralia.

Hoctor. T. S. 2003. Regional landscape analysis and reserve design to conserve Florida's biodiversity. Ph.D. dissertation. University of Florida, Gainesville.

Hoctor, T.S., M.H. Carr, and P.D. Zwick. 2000. Identifying a linked reserve system using a regional landscape approach: the Florida ecological network. Conservation Biology 14:984-1000.

Hoctor, T. S., W. L. Allen, III, M. H. Carr, P. D. Zwick, E. Huntley, D. J. Smith, D. S. Maehr, R. Buch, and R. Hilsenbeck. 2008. Land corridors in the Southeast USA: connectivity to protect biodiversity and ecosystem services. Journal of Conservation Planning 4:90-122.

Hoctor, T.S., J. Oetting, and S. Beyeler. 2008. Critical Lands and Waters Identification Project: Report on completion of the CLIP Version 1.0 Database. Report for the Century Commission for a Sustainable Florida, Tallahassee.

Jodice, P.G., and S.R. Humphrey. 1992. Activity and diet of an urban population of Big Cypress fox squirrels. Journal of Wildlife Management 56:685-692.

Kantola, A.T., and S.R. Humphrey. 1990. Habitat use by Sherman's fox squirrel (Sciurus niger shermani) in Florida. Journal of Mammalogy 71:411-419.

Kautz, R., Kawula, R., Hoctor, T., Comiskey, J., Jansen, D., Jennings, D., Kasbohm, J., Mazzotti, F., McBride, R., Richardson, L., and Root, K. 2006. How much is enough? Landscape-scale conservation for the Florida panther. Biological Conservation 130:118-133.

Keller, L.F., and D.M. Waller. 2002. Inbreeding effects in wild populations. Trends in Ecology and Evolution 17:230-241.

Kiltie, R.A. 1989. Wildfire and the evolution of dorsal melanism in fox squirrels, Sciurus niger. Journal of Mammalogy 70:726-739.

Koprowski, J.L. 1994. Sciurus niger. Mammalian Species 479:1-9.

Lambeck, R.J. 1997. Focal species: a multi-species umbrella for nature conservation. Conservation Biology 11:849-856.

Land, D., Cunningham, M., Lotz, M., Shindle, D., 2004. Florida panther genetic restoration and management Annual report 2003–2004. Florida Fish and Wildlife Conservation Commission, Tallahassee, FL, USA.

Land, E. D, D. B. Shindle, R. J. Kawula, J. F. Bensona, M. A. Lotz, and D. P. Onorato. 2008. Florida panther habitat selection analysis of concurrent GPS and VHF telemetry data. Journal of Wildlife Management 72(3):633-639.

Larkin, J. L., D. S. Maehr, T. S. Hoctor, M. A. Orlando, and K. Whitney. 2004. Landscape linkages and conservation planning for the black bear in west-central Florida. Animal Conservation 7:23-34.

Little, S.J., R.G. Harcourt, and A.P. Clevenger. 2002. Do wildlife passages act as prey-traps? Biological Conservation 107:135-145.

Lovejoy, T. E. and L. Hannah, editors. 2004. Climate change and biodiversity. Yale University Press, New Haven, Connecticut.

Maehr, D. S., T. S. Hoctor, L. J. Quinn, and J. S. Smith. 2001a. Black bear habitat management guidelines for Florida. Florida Fish and Wildlife Conservation Commission, Tallahassee, Florida.

Maehr, D. S., T. S. Hoctor, and L. D. Harris. 2001b. The Florida panther: a flagship for regional restoration. Pages 293-312 in D. S. Maehr, R. F. Noss, and J. L. Larkin, editors. Large mammal restoration: ecological and sociological challenges in the 21st century. Island Press, Washington, D.C.

Maehr, D.S., E.D. Land, D.B. Shindle, O.L. Bass, and T.S. Hoctor. 2002. Florida panther dispersal and conservation. Biological Conservation 106:187-197.

Maehr, D.S. 1997. The comparative ecology of bobcat, black bear, and Florida panther in south Florida. Bulletin of the Florida Museum of Natural History 40:1-176.

Maehr, D.S., and J.T. DeFazio. 1985. Foods of black bears in Florida. Florida Field Naturalist 13: 8-12.

Merriam, G. 1988. Landscape dynamics in farmland. *Trends in Ecology and Evolution* 3:16-20.

Noss, R.F. 1987. Corridors in real landscapes: A reply to Simberloff and Cox. Conservation Biology 1:159-164.

Noss, R.F. 2001. Beyond Kyoto: forest management in a time of rapid climate change. Conservation Biology 15:578-590.

Noss, R.F., and L.D. Harris. 1986. Nodes, networks, and MUMs: Preserving diversity at all scales. Environmental Management 10:299-309.

Noss, R.F., C. Carroll, K. Vance-Borland, and G. Wuerthner. 2002. A multicriteria assessment of the irreplaceability and vulnerability of sites in the Greater Yellowstone Ecosystem. Conservation Biology 16:895-908.

Noss, R.F., and A. Cooperrider. 1994. Saving Nature's legacy: protecting and restoring biodiversity. Defenders of Wildlife and Island Press, Washington, D.C.

Orlando, M.A. 2003. The ecology and behavior of an isolated black bear population in west-central Florida. M.S. thesis. University of Kentucky, Lexington, Kentucky, USA.

Pederson, R. J., and A W. Adams. 1976. Rocky Mountain elk research project progress report. Project No. W-70-R-6. Oregon Department ofFish and Wildlife, Portland.

Peters, R.L. 1988. Effects of global warming on species and habitats: An overview. Endangered Species Update 5 (7):1-8.

Peters, R.L., and J.D.S. Darling. 1985. The greenhouse effect and nature reserves. BioScience 35:707-717.

Perkins, M.W., L.M. Conner, and M.B. Howze. 2008. The importance of hardwood trees in the longleaf pine forest ecosystem for Sherman's fox squirrels. Forest Ecology and Management 255:1618-1625.

Pilkey, O.H., and R. Young. 2009. The rising sea. Island Press/Shearwater Books, Washington, D.C.

Ross, M.S., J.J. O'Brien, R.G. Ford, K. Zhang, and A. Morkill. 2009. Disturbance and the rising tide: the challenge of biodiversity management on low-island ecosystems. Frontiers in Ecology and Evolution in press.

Simberloff, D., and J. Cox. 1987. Consequences and costs of conservation corridors. Conservation Biology 1:63-71.

Tanner, G.W., J.J. Mullahey, and D. Maehr. 1999. Saw palmetto: an ecologically and economically important native palm. WEC-109, IFAS, University of Florida, Gainesville.

Tewksbury, J.J., D.J. Levey, N.M. Haddad, S. Sargent, et al. 2002. Corridors affect plants, animals, and their interactions in fragmented landscapes. Proceedings of the National Academy of Sciences 99:12923-12926.

Tischendorf, L., and L. Fahrig. 2000. On the usage and measurement of landscape connectivity. Oikos 90:7-19.

Trombulak, S.C., and C.A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14:18-30.

Trauth, S.E., and D.H. Jamieson. 1997. Swimming behavior in the fox squirrel, Sciurus niger (Rodentia: Sciuridae), from northeastern Arkansas. Journal of the Arkansas Academy of Science 51:213-214.

Ulrey, W.A. 2008. Home range, habitat use, and food habits of the black bear in south-central Florida. M.S. Thesis. University of Kentucky, Lexington. 117 pp.

U.S. Census Bureau. 2002. Highlands County, Florida. United States Department of Commerce. http://quickfacts.census.gov/qfd/states/12/12055.html. Accessed 24 January 2003.

U.S. Fish and Wildlife Service 2008. Florida Panther Recovery Plan, third revision. Atlanta, GA.

Watts, A., G. Tanner, and R. Dye. 2006. Restoration of dry prairie using fire and roller chopping. Pages 225-230 in R.F. Noss, editor. Land of Fire and Water: The Florida Dry Prairie Ecosystem. Proceedings of the Florida Dry Prairie Conference. E.O. Painter, De Leon Springs, FL.

Webb, T., III. 1987. The appearance and disappearance of major vegetational assemblages: long-term vegetational dynamics in eastern North America. Vegetatio 69:177-187.

Weigl, P.D., M.A. Steele, L.J. Sherman, J.C. Ha, and T.S. Sharpe. 1989. The ecology of the fox squirrel in North Carolina: implications for survival in the Southeast. Tall Timbers Research Bulletin 24:1-93.

Williams, L.E., Jr. 1978. Florida panther. Pages 13-15 in J.N. Layne, editor. Rare and Endangered Biota of Florida. Volume 1, Mammals. University Presses of Florida, Gainesville.

Winn, D. S. 1976. Terrestrial vertebrate fauna and selected coniferous habitat types on the north slope of the Uinta Mountains. Wasatch National Forest Special Report. USDA Forest Service, Salt Lake City, Utah.

Wooding, J.B. 1997. Distribution and population ecology of the fox squirrel in Florida. Ph.D. dissertation, University of Florida, Gainesville.