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Species at Risk on Department of Defense Installations in the Carolinas Final Report

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Species at Risk on Department of Defense Installations in the Carolinas

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Draft Report and Documentation

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Executive Summary

In March 2008, the US Fish and Wildlife Service (FWS), with funding from the Department of Defense Legacy Program (Legacy), contracted with NatureServe to identify priority habitat areas for Species at Risk (SAR) likely to be found on military reservations in the Carolinas. Specifically, NatureServe was tasked with:

(1) determining a list of target SAR species for the study area
(2) creating habitat models to map probable locations of target species
(3) developing natural resource management guidelines for habitats occupied by target species
(4) identifying priority habitat areas and determining ownership for those areas

In joint meetings between NatureServe, FWS, the Department of Defense, and state wildlife officials, we identified thirteen species at risk for evaluation. These species occur in and around military installations on Onslow Bight in North Carolina and/or in the vicinity of Fort Jackson in South Carolina. Three of the thirteen species were targeted for habitat modeling. These include the mimic glass lizard (*Ophisaurus mimicus*), northern pine snake (*Pituophis melanoleucus*), and the southern hognose snake (*Heterodon simus*). Basic habitat and threat information, resource management guidelines, and recommendations for future modeling were made for the remaining SAR.

Habitat modeling consisted of refining vertebrate habitat models previously created by the Southeast Gap Analysis program to areas with the sandy soils characteristic of the sandhills environments the three target species favor. Following the model refinements, habitat for each species was grouped into distinct patches by using minimum size thresholds. Patches greater than the minimum size were then ranked by area, shape, connectivity, and road density to identify those patches that were most likely to contain the highest quality habitat. Ownership information for each of the top ranked patches was then determined, and is summarized in this report.

The modeling and prioritization efforts show that within the sandhills region, both military installations (Camp Lejeune, Fort Jackson, and the U.S. Air Force Gunnery Range in particular) and private lands (especially timber lands) provide good candidate locations for conservation efforts aimed at bolstering the viability of these species.

The identification of likely high quality habitat patches provides a good starting place for conservation efforts for these species at risk in the Carolinas. While it is our hope that conservation measures can be enacted at many of the areas highlighted in this report, it is important to note that the areas identified as likely to contain high quality habitat have not been validated on-the-ground. Thus, before conservation action is planned, we highly recommend survey and inventory to verify the presence of the species of interest at any candidate site and delineate the best areas for conservation action.

1. Introduction

In March 2008, the US Fish and Wildlife Service (FWS) contracted with NatureServe to identify priority habitat areas for Species at Risk (SAR) likely to be found on military reservations in the Carolinas. Specifically, NatureServe was tasked with:

(1) determining a list of target SAR species for the study area
(2) creating habitat models to map probable locations of target species
(3) developing natural resource management guidelines for habitats occupied by target species
(4) identifying priority habitat areas and determining ownership for those areas

The original scope of work also called for a field inventory of mapped populations of SAR. However, once the list of target species was finalized, it became apparent that the effort necessary to survey for these species (mostly reptiles) was beyond the resources allocated for the project as originally planned (when it was assumed that target species would largely be plants). With approval from FWS, plans for a species inventory under the current contract were withdrawn. The project was consequently re-scoped in January 2009, with NatureServe and FWS agreeing upon the following deliverables:

a. Range, rarity, and resource management guidelines for 13 species at risk
b. A ranked modeling priority for each of those species
c. Habitat models for three Priority A species, including the mimic glass lizard, northern pine snake, and southern hognose snake, including:
    i. Maps of predicted habitat within the project area
    ii. Likely high quality habitat areas suitable for inventory and survey
    iii. Land ownership information for those high quality habitat areas
d. Supplemental information for all Priority B and C species, including:
    i. A recommended approach for future modeling efforts
    ii. A summary of existing information on habitat distribution and known occurrences

This information is provided in full in this report.

1.1. Study Area

The study area consists of selected military reservations in the Carolinas and surrounding lands that likely support species found on the reservations. In meetings with FWS and representatives of the Department of Defense (DoD), it was decided that the area for assessment should consist of two distinct areas that contain a mix on DoD and non-DoD owned land: Onslow Bight, North Carolina and the Midlands Area Joint Installation Consortium (MAJIC) area in South Carolina.

Onslow Bight comprises approximately 14,800 square kilometers (~3,650,000 acres) stretching from the lower Cape Fear River to the Pamlico River and from offshore waters to approximately 30 miles inland. The Onslow Bight landscape includes large areas managed for military training, conservation, and other uses as well as smaller conservation sites and other privately owned or otherwise unprotected parcels containing significant natural heritage areas. Camp Lejeune, the Military Ocean Terminal at Sunny Point, and the Marine Corps Air Station at Cherry Point are all located in this area.

The MAJIC area is part of the Army Compatible Use Program (ACUB). The goal of this program is to protect land surrounding military installations from development that is incompatible with the goals of those installations. The significant military areas included in MAJIC include Fort Jackson, Shaw Air Force Base, McEntire Joint National Guard Station, and Poinsett Range. The land between installations is targeted as the Joint Compatible Use Buffer program focus area. For this project, the MAJIC area was buffered by 10 miles to include additional area surrounding the bases and is 1,866 square kilometers (461,000 acres) in size.

1.2. Species at Risk

An initial list of SAR on or near military installations in the Carolinas was provided to NatureServe from FWS based on a database developed by NatureServe in 2002. Following a review of species ranges, rarity, habitat, presence of military lands, and vulnerability to impacts from military activity, a final list of SAR taxa was developed. This review involved input between FWS, NatureServe, DOD representatives, and state wildlife experts. The final SAR list is provided on Table 1.

A modeling priority was assigned to each species based on the probability of modeling success, as well as the perceived importance of these species. The modeling priority for each species is included on Table 1. Priority A species include reptile species endemic to the sandhills environment: the mimic glass lizard (*Ophisaurus mimicus*), northern pine snake (*Pituophis melanoleucus*), and southern hognose snake (*Heterodon simus*). It should be noted that while LeBlond's goldenrod (*Solidago villosicarpa)* is also listed as a species at risk for the project area, it is not assigned a modeling priority, as habitat mapping has previously been completed for this very rare species.

The majority of this report focuses on the methods and results of mapping efforts for these three Priority A species. However, additional information on all target SAR taxa is provided in Appendix A, including a full species and habitat description, conservation status and trend details, and natural resource management guidelines. Modeling recommendations for Priority B and C species are provided in the conclusions and recommendations section of this report.

Table 1. List of Target Species at Risk

Common Name	Scientific Name	Modeling Priority	Conservation Status		
			Global*	NC*	SC*
Bachman's Sparrow	*Aimophila aestivalis*	B	G3	S3B, S2N	S3
Henslow's Sparrow	*Ammodramus henslowii*	C	G4	S2B, S1N	SNA
Red Knot	*Calidris canutus*	C	G4	S3N	SNRN
Carolina Gopher Frog	*Rana capito*	B	G3	S2	S1
E. Diamondback Rattlesnake	*Crotalus adamanteus*	B	G4	S1	S3
Mimic Glass Lizard	*Ophisaurus mimicus*	A	G3	S2	SNR
Northern Pine Snake	*Pituophis melanoleucus*	A	G4	S3	S3S4
Southern Hognose Snake	*Heterodon simus*	A	G2	S2	SNR
Boykin's Lobelia	*Lobelia boykinii*	B	G2G3	S2	S3
Coastal Beaksedge	*Rhynchospora pleiantha*	B	G2G3	S2	S1
LeBlond's Goldenrod	*Solidago villosicarpa*	previously completed	G1	S1	n/a
Many-flowered Grass-pink	*Calopogon multiflorus*	B	G2G3	S1	S1
Fitzgerald's Sphagnum	*Sphagnum fitzgeraldii*	C	G3	S2S3	SNR

* Full rank definitions are provided in Appendix A for each species, but in general:
1 = critically imperiled, 2 = imperiled, 3 = vulnerable, 4 = apparently secure, 5 = secure
For birds, "B" indicates breeding populations, "N" indicates non-breeding
SNR = unranked by the state

Priority A Species

The three Priority A species are three of the primary species that constitute the longleaf pine reptile guild (Bennett and Buhlman, undated). All of these species are associated with the longleaf pine ecosystem that was extensive across the southeastern United States at the time of European settlement. The northern pine snake and the southern hognose snake are typically associated with the more xeric longleaf communities. The mimic glass lizard is commonly associated with the mesic longleaf communities, including longleaf pine flatwoods. All species show some overlap in their particular habitat preferences and can be found in habitats other than longleaf. All members of this guild spend some portion of their life using underground shelters, such as stump holes, rodent burrows, root channels, or gopher tortoise burrows (Bennett and Buhlman, undated).

The primary challenge confronting members of this guild is habitat loss. Longleaf pine habitat has been greatly reduced in extent and in quality. The large snakes are particularly vulnerable to habitat fragmentation and an increasing road network. The northern pine snake in particular is a long-lived animal with a large home range. Maintaining viable populations becomes more difficult when mortality from automobiles further reduces the number of individuals in the population.

These species are endemic to the sandhills ecoregions: the inland portion of the coastal plain that borders the fall line. This region is sometimes incorporated within a broader area known as the inner coastal plain. Pliocene and Pleistocene sands deposited up to ten million years ago by strong southwest prevailing winds forms the top layer of the sandhills. These deep sands have created a xeric environment that supports a distinctive type of vegetation dominated by longleaf pines and turkey oaks. This fire-adapted community type burns with a frequency interval of 5 to 10 years and may be one of the oldest communities of this type in the southeast. This sandhills pine woodland is the characteristic vegetation on the sandy soils that define the region. On deep well-drained sands a longleaf pine (*Pinus palustris*) canopy with a subcanopy of turkey oak (*Quercus laevis*) and other scrub oak species prevails. (SC DNR 2010)

Priority B & C Species

Priority B species include a diverse assortment of animals and plants found in the varied environments of the sandhills and coastal plain. Bachman's sparrow (*Aimophila aestivalis)*, the Carolina gopher frog (*Rana capito*), the Eastern diamondback rattlesnake (*Crotalus adamanteus)*, Boykin's lobelia (*Lobelia boykinii)*, coastal beaksedge (*Rhynchospora pleiantha),* and the many-flowered grass-pink (*Calopogon multiflorus)*. For all Priority B animals, Southeast Gap vertebrate models exist that provide a starting point for the development of refined models more appropriate for use at fine scales. For all Priority B plants, at least preliminary data exists that can serve as the basis for building predictive statistical models.

Priority C species include Henslow's sparrow (*Ammodramus henslowii*), the red knot (*Calidris canutus*), and Fitzgerald's sphagnum (*Sphagnum fitzgeraldii*). These have been assigned the lowest modeling priority due to the anticipated difficulty in creating reliable models. Both

Henslow's sparrow and the red knot only winter in the study area, and data for them is limited. Fitzgerald's sphagnum is a rare moss with limited occurrence data and narrow habitat specificities that are not easily captured by the relatively coarse-scale spatial environmental data most often used for predictive modeling.

Table 2 provides a summary of documented occurrences of Priority B and C species, both within the study areas and within the Carolinas. The element occurrence records referenced here are maintained by the North Carolina Natural Heritage Program and South Carolina Department of Natural Resources and are current as of May 2010.

Table 2. Existing Element Occurrence Records for Priority B & C Species

	Number of EOs on Record			
Common Name	Onslow Bight	All of NC	MAJIC + buffer	All of SC
Bachman's Sparrow	59	161	0	4
Henslow's Sparrow	9	24	0	0
Red Knot	0	0	0	0
Carolina Gopher Frog	25	48	0	21
E. Diamondback Rattlesnake	19	35	0	7
Boykin's Lobelia	2	10	5	40
Coastal Beaksedge	15	18	0	1
LeBlond's Goldenrod	28	29	0	0
Many-flowered Grass-pink	5	5	0	1
Fitzgerald's Sphagnum	0	0	0	0

2. Methods

Maps of predicted habitat for the three Priority A species were developed by obtaining vertebrate habitat models from the Southeast Gap Analysis program and then refining those models using detailed soils data.

Areas most likely to contain the highest quality habitat were then identified by (1) partitioning the modeled area into distinct habitat patches, (2) retaining only those patches above a pre-determined size threshold, and (3) ranking the remaining sites based on area, shape, connectivity to adjacent sites, and road density.

Ownership information was then sought for the highest ranked sites of each species.

2.1. Mapping Predicted Habitat

Habitat models were obtained from the Biodiversity and Spatial Information Center at NC State University (www.basic.ncsu.edu/segap/Vertebrate.html) for the three reptile species of interest. These models, developed as a component of the Southeast Gap Analysis program, use a combination of landcover data and satellite imagery to predict species presence across a landscape. Based on existing literature and expert review, the Gap program identified the ecological systems known to support the target species and then created spatial data of species distributions based on a map of ecological systems map previously created by the Program. Table 3 lists the systems identified as supporting each of our target species within the study area. The resulting habitat models are binary, meaning that areas are either assigned a "1" (habitat) or a "0" (non-habitat).

Because sandy soils are an important aspect of these reptiles' habitats, we further refined the Southeast Gap models for these species by restricting areas designated as habitat to those with sandy soils. Sandy soils were queried from the Natural Resources Conservation Services (NRCS) SSURGO soils database (http://soils.usda.gov/survey/geography/ssurgo/) based on a list of sandhills soils provided to NatureServe by the Southeast Gap program (pers. comm. with Alexa McKerrow 2009). Soil moisture and soil texture were used to identify appropriate SSURGO soil types as "sandy soils" indicative of longleaf pine habitat in the Carolinas (Peet 2006).Once those areas were identified, we used the "clip" function in ArcGIS 9.3 (ESRI, Redlands, California) to restrict the modeled area for each species to only those areas overlapping sandy soils.

Table 3. Ecological Systems Mapped as Habitat for Target Species

Mimic Glass Lizard
Atlantic Coastal Plain Fall-Line Sandhills Longleaf Pine Woodland – Loblolly Modifier
Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Open Understory Modifier
Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Scrub/Shrub Understory Modifier
Atlantic Coastal Plain Southern Wet Pine Savanna and Flatwoods
Atlantic Coastal Plain Upland Longleaf Pine Woodland
Northern Pine Snake
Atlantic Coastal Plain Fall-Line Sandhills Longleaf Pine Woodland - Loblolly Modifier
Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Open Understory Modifier
Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Scrub/Shrub Understory Modifier
Atlantic Coastal Plain Upland Longleaf Pine Woodland
Bare Sand
Northeastern Interior Dry Oak Forest - Mixed Modifier
Southern Piedmont Dry Oak-(Pine) Forest - Loblolly Pine Modifier
Southern Hognose Snake
Atlantic Coastal Plain Fall-Line Sandhills Longleaf Pine Woodland - Loblolly Modifier
Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Open Understory Modifier
Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Scrub/Shrub Understory Modifier
Atlantic Coastal Plain Upland Longleaf Pine Woodland
Atlantic Coastal Plain Central Maritime Forest
Bare Sand
Pasture / Hay

2.2. *Translating Modeled Areas into Distinct Habitat Patches*

To identify which areas were most likely to contain the highest quality habitat and would thus be the best candidates for survey, inventory, and ultimately conservation measures, we then used the region group function in ArcGIS 9.3 to group contiguous modeled areas into distinct habitat patches. This function assigns a unique identification value to each patch of contiguous habitat. These patches in turn were converted to polygons and ranked based on ecologically meaningful characteristics such as area, contiguity, and presence of disturbances (i.e. roads). The region group function requires the user to define the number of neighboring cells for use in evaluating connectivity between cells. For this project, connectivity was assumed between cells of the same value if they were within the immediate eight-cell neighborhood (eight nearest neighbors) of each other. This includes to the right or left, above or below, or diagonal to each other.

Once the raster map of habitat was translated into distinct patches using the region group function, but before those patches were ranked, we applied an area threshold to eliminate very small patches of habitat that would be unlikely to support viable populations. A critical threshold was estimated for each of the three reptiles species based on expert input and review (pers. comm. with Steve Bennett and David Woodward 2010). Critical patch sizes for viability were estimated as follows: southern hognose snake = 750 acres (with smaller patches also utilized), northern pinesnake = 15000 acres, and mimic glass lizard = 600 acres (with smaller patches also utilized).

Few patches within the study area approached those viability thresholds, yet many patches were located in close proximity to other patches and thus were likely, in combination, to provide adequate habitat. For this reason, the area threshold we used to eliminate small patches were set lower than the threshold area requirements provided by expert review (see results).

2.3. Prioritizing Patches for Survey and Inventory

Priority habitat areas for inventory and/or conservation action were identified from the modeled results based on patch-level metrics designed to characterize the spatial character and context of the habitat patches, and thus identify those likely to contain high quality habitat.

Generalizations can be made with regard to fragmentation and species' viability. As habitat decreases, population survival decreases. Increasing habitat clumping increases survival. There are several components of landscape pattern, all of which affect species viability. They include: amount of habitat, mean size of habitat patches, mean inter-patch distance, variance in patch sizes, variance in inter-patch distances, and landscape connectivity. Commonly used fragmentation metrics include total area, average patch area, number of patches, edge-to-interior ratio, total perimeter, inter-patch distance (proximity), connectivity, and contagion or clumpiness (McGarigal et al. 2002).

Derivation of Ecologically Meaningful Habitat Metrics for Patches

Metrics were derived to characterize the habitat patches across the study areas. Fragstats (McGarigal et al. 2002) was used to derive several of the metrics for use in the prioritization. Fragstats is a stand-alone program that performs spatial pattern analysis for quantifying landscape structure and offers a comprehensive choice of landscape metrics. Many metrics were produced but only the most ecologically meaningful metrics were used in the prioritization. In addition to Fragstats, we used ArcGIS 9.3 to perform spatial analyses for additional patch metrics. The following metrics were derived for the habitat patches in the study areas and used to rank the most important sites.

Area – The area of the patch in hectares. The area of each patch comprising a landscape is probably the single most important and useful piece of information contained in the landscape. Not only is this information the basis for many other indices, but patch area also has a great deal of ecological utility in its own right.

Patch Extent/Shape –Called the "radius of gyration" in Fragstats, this is a measure of patch extent, and is thus effected by both patch size and patch compaction. It is the mean distance (in meters) between each cell in the patch and the patch centroid. It is a value ≥ 0 without limit. The metric equals 0 when the patch consists of a single cell and increases without limit as the patch increases in extent. The metric achieves its maximum value when the patch comprises the entire landscape. Compact patches are less fragmented and thus likely to provide better habitat.

Contiguous Area – This metric measured a type of connectivity by assessing the amount of modeled habitat in a 1609 meter (1 mile) buffer surrounding the habitat patch of interest. Area was calculated for all habitat within the buffer surrounding and including the habitat patch of interest. The area of the patch itself was then subtracted to obtain an area measure of relatively contiguous habitat surrounding the patch through which the species could possibly traverse. This is an important measure because it emphasizes and values patches that are closer to other patches over those patches that might be large but isolated.

Average Road Density –NatureServe contracted with Dr. Ron Sutherland at Duke University to analyze the response of the Priority A species to measures of urbanization including road density and the percent of impervious surfaces (see Appendix B). A strong response between species and road presence was documented, and critical thresholds for each of the three reptile species were generated. Road densities within the study area were generally below this critical threshold; however, recognizing the important relationship between high quality habitat and low road density, we used road density as one of our metrics for ranking patches. A mean road density value was calculated for each patch using a 1 kilometer radius, and patches with the lowest densities were ranked highest.

Area, radius of gyration, contiguous area, and average road density were calculated for all patches larger than the aforementioned size threshold. The patches were ranked on each metric and the ranks were summed to produce an overall ranking for all patches. Multipliers were applied to the metrics so that the area metric was most influential in the ranking scheme, and road density was the least influential (reflecting the fact that all patches in the study area had road densities below the critical threshold). The importance weighting for area was set at 5, the importance weightings for patch extent and contiguous area were set at 2, and the importance weighting for average road density was 1. The ranks were summed and ordered from smallest value (highest rank or best patch) to highest value (lowest rank or worst patch). If there were two patches with identical ranks, rank order was determined based on the area metric, with the larger of the two area measures receiving the higher rank.

2.4. Analysis of Ownership

The ownership of the top 15 ranked habitat patches for each species was queried and is presented in the results section. Parcel data were acquired for as many counties as possible within the Onslow Bight and MAJIC study area. Parcel data were acquired for all counties comprising Onslow Bight and for Sumter County in the MAJIC study area. In general, digital parcel data was not readily available for most counties in South Carolina. When parcel data were lacking, the Protected Areas Database (USGS 2010) was used to generate information on ownership for the habitat patches. If detailed ownership information is desired for any patches located on private property in areas where the Protected Areas Database was used, it will be necessary to contact county officials. Contact information for each county is provided in the results section.

3. Results

3.1. Critical Area Thresholds for Viability

Applying area thresholds reflects the fact that animals are unlikely to successfully utilize very small habitat patches while decreasing the number of patches used in analysis to a manageable number. Critical area thresholds obtained by consulting reptile experts in the Carolinas served as the basis for our area thresholds. However, recognizing that few patches in the study area met the critical area thresholds these experts provided, and recognizing that collections of patches in close proximity to one another may together provide adequate area, the size thresholds we applied were often less than the provided critical sizes for population viability. Cut-offs used for each species, and the number of patches they generated, are provided below.

<u>*Mimic Glass Lizard*</u>

According to expert review, the patch size critical threshold for the mimic glass lizard is ~300 hectares (750 acres), with the understanding that smaller patches are still utilized by the lizard as well. In both study areas, this threshold produced very few viable patches for the mimic glass lizard so a lower threshold 1/5 the size of the original (60 hectares; 150 acres) was applied to incorporate smaller patches as well. In the Onslow Bight area, this threshold produced 52 viable patches with only 2 patches greater than 300 hectares. In the MAJIC area; the threshold produced 9 total patches, none of which were above the 300 hectare threshold. Although very few patches were 300 hectares or larger, it is important to note that expert review suggested that patches of at least that size are ideal, but that smaller patches could be viable for the mimic glass lizard as well.

<u>*Northern Pine Snake*</u>

Individual northern pine snakes have relatively large home ranges: ~40 hectares (100 acres) for females and ~60 hectares (150 acres) for males (personal comm. with David Woodward 2010). Critical size thresholds for this species are thus large (~600 hectares; 1500 acres) (personal comm. with Steve Bennett and David Woodward 2010) and important when considering habitat viability. In the Onslow Bight study area, no viable patches existed above the 1500 acre threshold so a threshold ¼ the size (150 hectares; 375 acres) was used and produced 4 viable patches. In the MAJIC study area, this threshold produced 30 patches, 3 of which were greater than 600 hectares in area.

<u>*Southern Hognose Snake*</u>

The patch size critical threshold for the southern hognose snake is ~300 hectares (750 acres), with smaller patches supporting habitat for the hognose as well (personal comm. with Steve Bennet 2010). The southern hognose snake has a smaller home range (4-8 hectares; 10 -20 acres) (personal comm. with David Woodward 2010) than the northern pine snake and thus, the critical threshold can be used more flexibly. In the MAJIC study area, we adhered strictly to the 300 hectare (750 acre) threshold because it produced a manageable number of viable patches (30 patches). In the Onslow Bight study area, a threshold 1/5 the size of the recommended threshold was used (60 hectares; 150 acres) and produced 82 patches, with only 4 patches greater than 300 hectares.

3.2. Results for Onslow Bight

Habitat patches were prioritized within the Onslow Bight study area for the mimic glass lizard, the northern pine snake, and the southern hognose snake. Results suggest that many of the top-ranked habitat patches for the three species are shared, due to these species' affinities for similar habitat types. This can make conservation planning and action more efficient. The mimic glass lizard had 52 total viable habitat patches on Onslow Bight with the top 15 listed on Table 4. The northern pine snake had 4 viable patches identified on Onslow Bight, which are listed on Table 5. The southern hognose snake had 82 viable patches as well with the top 15 listed on Table 6. Many of the highest ranked patches for the mimic glass lizard and southern hognose snake occur on the U.S. Marine Corps Base at Camp Lejeune, although numerous other high quality patches are located on privately owned timber lands. The best candidates for further habitat evaluation for the northern pine snake are all located on these timber lands.

Table 4. High Quality Habitat Patches for the Mimic Glass Lizard, Onslow Bight

Patch ID	Overall Rank	Area (ha)	County	Ownership
17388	1	119	Onslow	USMCB Camp Lejeune
31100	2	132	Brunswick	Parcel ID 14400001 – Orton Plantation LLC
16414	3	141	Onslow	USMCB Camp Lejeune
20404	4	165	Onslow	USMCB Camp Lejeune
29049	5	137	Brunswick	Parcel ID 4500001 – Sustainable Forests LLC/ Parcel ID 05500001 – Sustainable Forests LLC
18937	6	131	Onslow	USMCB Camp Lejeune
20738	7	112	Onslow	USMCB Camp Lejeune
14852	8	337	Onslow	City of Jacksonville
19964	9	141	Onslow	USMCB Camp Lejeune
19749	10	116	Onslow	USMCB Camp Lejeune
18360	11	90.00	Onslow	USMCB Camp Lejeune
21700	12	259	Onslow	USMCB Camp Lejeune
28993	13	139	Brunswick	Parcel ID 4500001 – Sustainable Forests LLC/ Parcel ID 05500001 – Eady Edward
18869	14	95	Onslow	USMCB Camp Lejeune
34329	15	330	Brunswick	Parcel ID 2180000101 – MAS Properties LLC/Parcel ID 21800001 – DWE III LLC & Ladane Enterprises LLC

Table 5. Hiqh Quality Habitat Patches for the Northern Pine Snake, Onslow Bight

Patch ID	Overall Rank	Area (ha)	County	Ownership
7728	1	330	Brunswick	Parcel ID 2180000101 – MAS Properties LLC/Parcel ID 21800001 – DWE III LLC & Ladane Enterprises LLC
3344	2	213	Brunswick	Parcel ID 10100001 – Town Creek Timber Co
2343	3	153	Brunswick	Parcel ID 05800007 – Funston Land & Timber LLC
4435	4	178	Brunswick	Parcel ID 14400001 – Orton Plantation LLC

Table 6. High Quality Habitat Patches for the Southern Hognose Snake, Onslow Bight

Patch ID	Overall Rank	Area (hectares)	County	Ownership
39146	1	185	Brunswick	Parcel ID 14400001 – Orton Plantation LLC
25668	2	125	Onslow	USMCB Camp Lejeune
38977	3	139	Brunswick	Parcel ID 14400001 – Orton Plantation LLC
24473	4	163	Onslow	USMCB Camp Lejeune
28915	5	202	Onslow	USMCB Camp Lejeune
41741	6	144	Brunswick	Parcel ID 2020000101 – Sunset Harbor Investment LLC ETAL/ Parcel ID 2020000104 Mary Kocur & Thomas A Zimmerman TR/ Parcel ID 20200022 MAS Properties LLC
27489	7	141	Onslow	USMCB Camp Lejeune
37345	8	136	Brunswick	Parcel ID 05500001 – Eady Edward/Sustainable Forests LLC
42207	9	450	Brunswick	Parcel ID 2180000101 – MAS Properties LLC/Parcel ID 21800001 – DWE III LLC & Ladane Enterprises LLC
37088	10	239	Brunswick	Parcel ID 4500001 – Sustainable Forests LLC/ Parcel ID 05500001 – Eady Edward/Sustainable forest LLC
34393	11	526	Pender	Corbett Industries Inc/Corbett Package Company
29195	12	140	Onslow	USMCB Camp Lejeune
34960	13	196	Brunswick	Parcel ID 01000003 - Butler Ira D JR ETALS/ Parcel ID 0100000308 - Merrywoods Inc/ Parcel ID 0100002101 – Corbett Industries/ Parcel ID 00600011 – Corbett Industries
26856	14	322	Onslow	USMCB Camp Lejeune
28793	15	134	Onslow	USMCB Camp Lejeune

The ranks displayed on tables 4-6 are based on a combination of area, patch extent, contiguous area, and average road density. It is important to note, that though the area metric was weighted to strongly influence the overall rank, there are still cases where the largest patch was not the top ranked site because other habitat patches may have had better combinations of all four metrics. A full listing of all ranked patches, metric values, and metric rankings, is provided in Appendix C.

Figures 1-2 show the results for the mimic glass lizard for the northern and southern portions of the Onslow Bight study area respectively. These maps display all modeled area for the species, with ranked patches labeled. Figure 3 displays the results for the northern pine snake for all of Onslow Bight. Figures 4 and 5 display the results for the southern hognose snake for the northern and southern portions of Onslow Bight respectively.

3.3. Results for the MAJIC Study Area

Habitat patches were prioritized within the MAJIC study area for the mimic glass lizard, the northern pine snake, and the southern hognose snake. Results suggest that many of the top-ranked habitat patches for the three species are shared, due to these species' affinities for similar habitat types. This can make conservation planning and action more efficient. The mimic glass lizard had 9 total viable habitat patches (Table 7), the northern pine snake had 30 viable patches, with the top 15 reported in Table 8, and the southern hognose had 30 viable patches as well, with the top 15 reported in Table 9. Many of these patches occur either on Fort Jackson or on the U.S. Air Force Gunnery Range. Outside of the military installations, important habitat patches were found in state forest land and on timber plantations. Ownership information for each of the top ranked sites is provided on Tables 7–9.

Table 7. Hiqh Quality Habitat Patches for the Mimic Glass Lizard, MAJIC

Patch ID	Overall Rank	Area (hectares)	County	Ownership
3173	1	143	Calhoun	Private Land[1]
1341	2	95	Calhoun	Private Land[1]
1696	3	236	Calhoun	Private Land[1]
5014	4	63	Calhoun	Private Land[1]
2877	5	62	Calhoun	Private Land[1]
3	6	123	Sumter	U.S. Air Force Gunnery Range
231	7	84	Sumter	Parcel ID – 1069001003 Milford LLC/ Santee Cooper Hydroelectric Project: Public Service Authority
8860	8	87	Orangeburg	Private Land[2]
4719	9	74	Calhoun	Private Land[1]

[1] Contact Steven Hamilton at ccassessor@sc.rr.com for additional information.

[2] Contact Patrick Bresnahan at GISWEB@Richlandonline.com for additional information.

[3] Contact Jack Maquire at jmaguire@lex-co.com for additional information.

Table 8. High Quality Habitat Patches for the Northern Pine Snake, MAJIC

Patch ID	Overall Rank	Area (hectares)	County	Ownership
15824	1	1633	Richland	Fort Jackson Army Training Center
41288	2	492	Calhoun	Private Land[1]
35818	3	591	Lexington	Private Land[2]
41301	4	931	Calhoun/ Lexington	Private Land[1,2]
19771	5	475	Richland	Fort Jackson Army Training Center
15748	6	216	Richland	Fort Jackson Army Training Center
36977	7	320	Calhoun	Private Land[1]
4499	8	858	Kershaw	Private Land[3]
33930	9	596	Sumter	U.S. Air Force Gunnery Range
37264	10	351	Calhoun/Lexington	Private Land[1,2]
18610	11	209	Richland	Fort Jackson Army Training Center
43545	12	225	Calhoun	Private Land[1]
21044	13	225	Richland	Private Land[4]
45836	14	176	Calhoun	Private Land[1]
17596	15	167	Richland	Fort Jackson Army Training Center

Table 9. High Quality Habitat Patches for the Southern Hognose Snake, MAJIC

Patch ID	Overall Rank	Area (hectares)	County	Ownership
13309	1	2561	Richland	Fort Jackson Army Training Center
35476	2	1003	Calhoun	Private Land[1]
35170	3	932	Calhoun	Private Land[1]
12166	4	475	Richland	Fort Jackson Army Training Center
34994	5	1139	Lexington	Private Land[2]
16506	6	613	Calhoun	Private Land[1]
23242	7	1001	Richland	Fort Jackson Army Training Center
3418	8	1047	Sumter	U.S. Air Force Gunnery Range/ Manchester State Forest SC Forestry Commission/ Parcel ID 1019001001 Ruffield Timber LTD PART
22739	9	414	Kershaw	Private Land[3]
29007	10	827	Richland	Adjacent (easterly direction) to U.S. Air Force McEntire Air National Guard Base.
44065	11	397	Sumter	U.S. Air Force Gunnery Range
31573	12	448	Lexington/Calhoun	Private Land
31327	13	387	Calhoun	Private Land
36723	14	437	Lexington	Private Land
30283	15	624	Calhoun	Private Land

[1] Contact Steven Hamilton at ccassessor@sc.rr.com for additional information.
[2] Contact Jack Maquire at jmaguire@lex-co.com for additional information.
[3] Contact Cathy Norris at cathy.norris@kershaw.sc.gov for additional information.
[4] Contact Patrick Bresnahan at GISWEB@Richlandonline.com for additional information.

The ranks displayed on tables 7-9 are based on a combination of area, patch extent, contiguous area, and average road density. It is important to note, that though the area metric was weighted to strongly influence the overall rank, there are still cases where the largest patch was not the top ranked site because other habitat patches may have had better combinations of all four metrics. A full listing of all ranked patches, metric values, and metric rankings, is provided in Appendix C.

Figures 6, 7 and 8 show the results for the mimic glass lizard, northern pine snake, and southern hognose snake in the MAJIC study area. These maps display all modeled area for the species, with ranked patches distinctly labeled.

4.4 Overlapping Habitat

In both the MAJIC and Onslow Bight study areas, there were particular habitat patches suitable for all three reptile species. Though not always the top ranked habitat patches for all three species, it may be advantageous to consider these areas first for prioritizing inventory and/or conservation efforts because of the possibility of conserving area for all three reptile species in a single patch. These patches are listed on Tables 10 for both study areas.

Table 10. High Ranked Habitat Patches Supporting Multiple Species

Mimic Glass Lizard ID	Southern Hognose Snake ID	Northern Pine Snake ID	Area (ha)	County	Ownership
Onslow Bight Study Area					
7728	42207	34329	330	Brunswick	Parcel ID 2180000101 – MAS Properties LLC/Parcel ID 21800001 – DWE III LLC & Ladane Enterprises LLC
3344	38935	31053	213	Brunswick	Parcel ID 10100001 – Town Creek Timber Co
4435	37914	29962	153	Brunswick	Parcel ID 05800007 – Funston Land & Timber LLC
4435	37034	28961	178	Brunswick	Parcel ID 14400001 – Orton Plantation LLC
MAJIC Study Area					
1696	39576	35960	236	Calhoun	Private Land
3	29007	46353	123	Sumter	U.S. Air Force Gunnery Range

4. Conclusion and Recommendations

The identification of likely high quality habitat patches for the mimic glass lizard, northern pine snake, and southern hognose snake, provides a good starting place for conservation efforts for these species at risk in the Carolinas. The modeling and prioritization efforts show that within the sandhills region, both military installations and private lands provide good candidate locations for conservation efforts aimed at bolstering the viability of these species.

While it is our hope that conservation measures can be enacted at many of the areas highlighted in this report, it is important to note that the areas identified as likely to contain high quality habitat have not been validated on-the-ground. The modeling and ranking of sites was conducted using remotely sensed data. This provides an efficient means to identify probable candidate sites, but models are only as good as the data on which they are built, and even the best models cannot guarantee that the species of interest will occupy a given area. Thus, before conservation action is planned, we highly recommend survey and inventory to verify the presence of the species of interest at any candidate site and delineate the best areas for conservation action. These surveys will require the oversight of a herpetologist experienced with trapping or otherwise detecting these very secretive species.

When selecting exact locations for survey, we recommend verifying the patch extent using the most recent available satellite imagery before beginning field work. The Southeast Gap vertebrate models we used are derived from 2001 satellite imagery and thus changes in the landscape that have occurred since 2001 will not be reflected in the models.

Recommended conservation measures for a given location will be highly dependent upon the species that occur their and legal and logistical management opportunities. To aid in the development of conservation strategies, we have provided natural resource management guidelines for each species (including Priority B and C species) in Appendix A. Our recommendations for habitat modeling for all Priority B and C species are provided below.

<u>*Carolina Gopher Frog*</u>

The predicted distribution map created by the Southeast Gap Analysis Project provides a good overview of the range of this species. However, additional refinement will be necessary to create habitat maps specific enough to be used for land protection undertakings. Refining the mapped distribution of this species will require gaining more specific information about species/habitat relationships either through expert interviews or predictive modeling using known species occurrences and statistical methods such as classification and regression trees (CART, Random Forests), logistic regression, or maximum entropy (MaxEnt). Identifying breeding ponds should be a focus of any modeling effort; review of aerial or satellite imagery from appropriate seasons could aid in this endeavor, as could the use of LIDAR data.

Before predictive models can be created for this species, it will be necessary to locate data on known locations of occurrence, since currently there are no element occurrence records for this the Carolina gopher frog within the study area (see Table 2).

Eastern Diamondback Rattlesnake

The predicted distribution map created by the Southeast Gap Analysis Project provides a good overview of the range of this snake. However, additional refinement will be necessary to create habitat maps specific enough to be used for land protection undertakings. Using soils data to further refine the predictive model is a recommended first step, although to do so, it will be necessary to first gain better information about the soil affinities of this species. Some uncertainties also exist as the true range of this species; for example, Conant and Collins (1991) do not show the range of the Eastern diamondback rattlesnake fully extending into the study area.

The most useful models will require gaining more specific information about species/habitat relationships either through expert interviews or predictive modeling using known species occurrences and statistical methods such as classification and regression trees (CART, Random Forests), logistic regression, or maximum entropy (MaxEnt).

Bachman's Sparrow

Within the project area, the Southeast Gap predicted distribution model ties Bachman's sparrow to Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodlands and Southern Wet Pine Savannas and Flatwoods, as well as several successional grassland/herbaceous habitat types. The modeling algorithms include open areas only when located in proximity to forested areas of the appropriate habitat types, and when those forested areas are of sufficient size (> 3 hectares).

In order to narrow the modeled area to those areas best suited for Bachman's sparrow, incorporating more up-to-date information on vegetation cover via more recent satellite imagery is recommended. Incorporating data on burn zones could also improve the model, with a one to three year burn interval yielding the best habitat. While challenging to incorporate into modeling exercises, the spatial and temporal dynamics of early sucessional landscapes should be considered in any effort to identify areas best suited to this species.

As the Southeast Gap models for birds are for breeding habitat only, maps that include non-breeding habitat will need to be derived from other sources. This will require gaining better information on species/habitat relationships either through expert interviews or predictive modeling using known species occurrences and statistical methods such as classification and regression trees (CART, Random Forests), logistic regression, or maximum entropy (MaxEnt). As with other avian species, data from the North American Breeding Bird Survey or Christmas Bird Counts could be incorporated into predictive distribution models.

Henslow's Sparrow

The Southeast Gap model for Henslow's sparrow is for breeding habitat only; if information is desired for all occupied areas, extensive additional modeling will be necessary. As it stands, the Southeast Gap model does not contain any modeled habitat within the MAJIC area, although there are large tracts of modeled breeding habitat on Onslow Bight.

As the Southeast Gap model is for breeding habitat only, maps that include non-breeding habitat will need to be derived from other sources. This will require gaining better information on species/habitat relationships either through expert interviews or predictive modeling using known species occurrences and statistical methods such as classification and regression trees (CART, Random Forests), logistic regression, or maximum entropy (MaxEnt). State element occurrence records will not be adequate to carry out modeling for this species as they are rare to non-existent in the project area. The North American Breeding Bird Survey or Christmas Bird Counts should be considered as additional sources of occurrence data.

Because of the large area requirements of this species, measures of patch size and habitat contiguity should either be including in modeling efforts, or used after-the-fact to identify the most important habitat patches on the landscape.

Red Knot

The Southeast Gap model for the red knot is for breeding habitat only; if information is desired for all occupied areas, extensive additional modeling will be necessary. As it stands, the Southeast Gap model does not contain any modeled habitat that overlaps the project area, as this is exclusively stopover habitat.

Mapping habitat within the project area will require gaining better information on species/habitat relationships either through expert interviews or predictive modeling using known species occurrences and statistical methods such as classification and regression trees (CART, Random Forests), logistic regression, or maximum entropy (MaxEnt). State element occurrence records will not be adequate to carry out modeling for this species as they are rare to non-existent in the project area. Finding adequate data to allow predictive modeling will likely be a challenge.

Boykin's Lobelia

Boykin's lobelia is known to occur near depression ponds, Carolina bays, and cypress savannas. The success of modeling efforts for this species will depend highly on the ability of the modelers to obtaining data that enables these features to successfully be identified on the landscape. Existing shapefiles of the location of Carolina bays and cypress savannahs in North Carolina will provide a good start, although analogous data will need to be obtained for South Carolina. LIDAR data may provide a good means for identifying these features in the future.

Statistical methods for predictive modeling such as classification and regression trees (CART, Random Forests), logistic regression, or maximum entropy (MaxEnt) also require data on known species occurrences. State element occurrence records for the Carolinas are often one of the best sources of this data; however, or the 10 element occurrence records in North Carolina and the 40 records in South Carolina, only two are located on Onslow Bight and only one is located in the MAJIC area. It will therefore likely be necessary to seek additional occurrence data from other sources, or refine any models in an iterative fashion, using the model results to find new populations and entering that information back in the model to generate refined results.

Coastal Beaksedge

The success of modeling efforts for coastal beaksedge will be very dependent on the incorporation of high quality data to represent the exposed sandy shores of freshwater "sinkhole" ponds and lakes where this species occurs. This will likely require data layers representing soil type, canopy cover, and high resolution digital elevation data such as LIDAR to capture these sinkhole features.

The North Carolina Natural Heritage Program maintains element occurrence records for 18 occurrences of this species in the state, 16 of which are located on Onslow Bight. This is a relatively high number of occurrence records for rare plant modeling, and if suitable data for environmental variables can be obtained, any of a variety of modeling approaches could be employed with meaningful results. These include classification and regression trees (CART, Random Forests), logistic regression, and maximum entropy (MaxEnt). Because coastal beaksedge is confined to the outer coastal plain, it is not expected to occur within the MAJIC area.

Many-flowered Grass-pink

Limited occurrence data are available for use in predictive modeling efforts. State element occurrence records for many-flowered grass-pink include one record from South Carolina that is not near the MAJIC area, and four records for North Carolina which are all located on Onslow Bight. This data is probably adequate to build coarse predictive models using method that can handle low sample sizes, such as maximum entropy (MaxEnt). However, any model will be greatly improved by including additional data on known locations if they are available from other sources. Another option would be to approach modeling in an iterative fashion, using the model results to find new populations and entering that information back in the model to generate refined results.

Because this species occurs on open, damp sandy pinelands and meadows, as well as on the edge of hammocks and in swampy fields and savannahs, environmental data that represent those conditions well will be key to modeling success. Vegetation maps for the Southeast will be a good place to start. Data on canopy cover and moisture indices may also prove useful, as could detailed elevation data such as that provided by LIDAR.

Fitzgerald's Sphagnum

Creating a reliable model for Fitzgerald's sphagnum will be very difficult. It is not well understood why this rare moss occurs where it occurs, there is little occurrence data available with which to create a model, and few environmental data sets capture the narrow environmental conditions in which Fitzgerald's sphagnum exists. At this time, predictive modeling efforts are unlikely to be successful.

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Figures

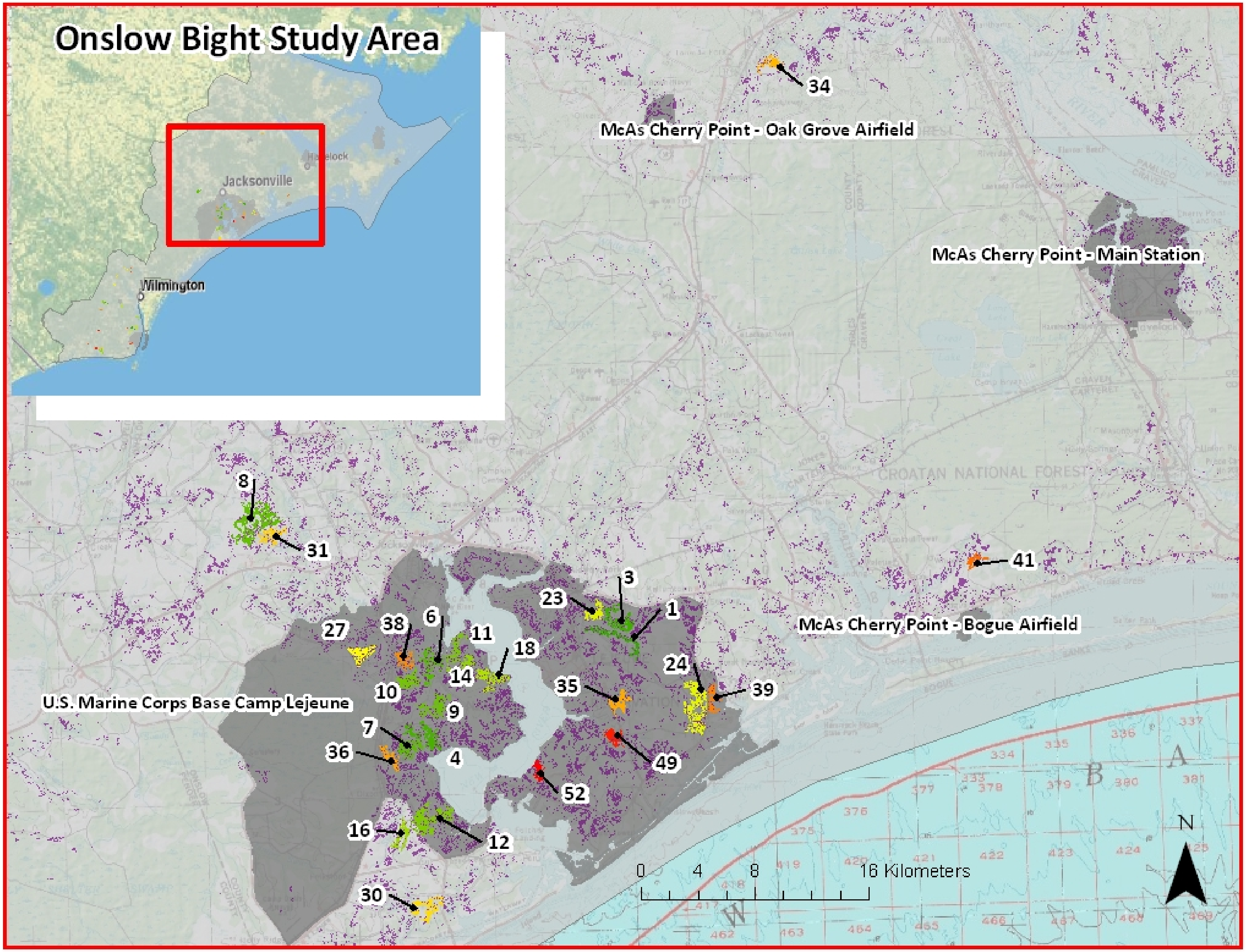

Figure 1. Habitat map and top ranked patches for the mimic glass lizard, Onslow Bight North.
A green-to-red color scheme has been applied to the ranked patches with greener patches indicating those with the highest ranks and red patches indicating those with the lowest. All modeled habitat below our minimum size threshhold (150 acres) is shown in purple.

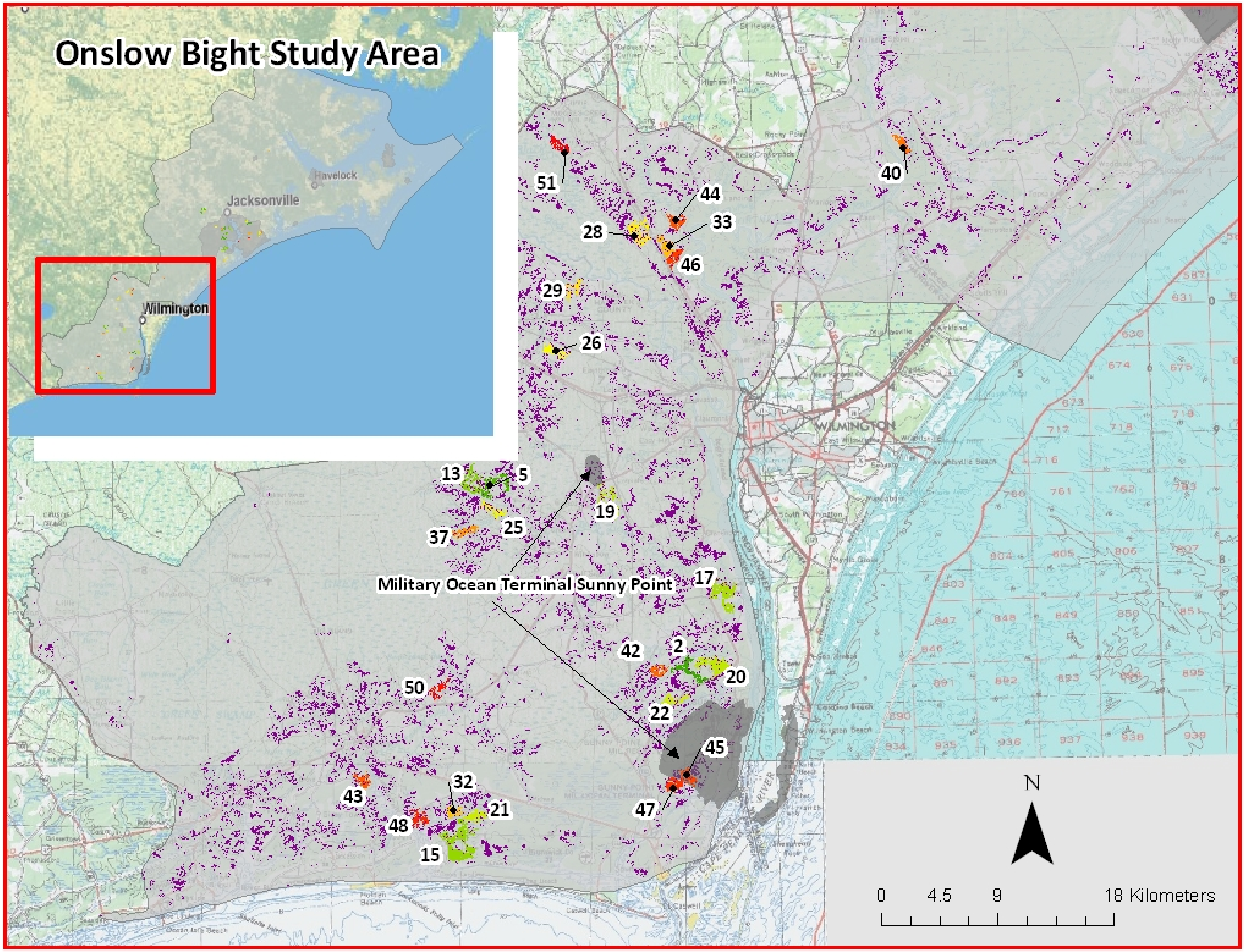

Figure 2. Habitat map and top ranked patches for the mimic glass lizard, Onslow Bight South.

A green-to-red color scheme has been applied to the ranked patches with greener patches indicating those with the highest ranks and red patches indicating those with the lowest. All modeled habitat below our minimum size threshold (150 acres) is shown in purple.

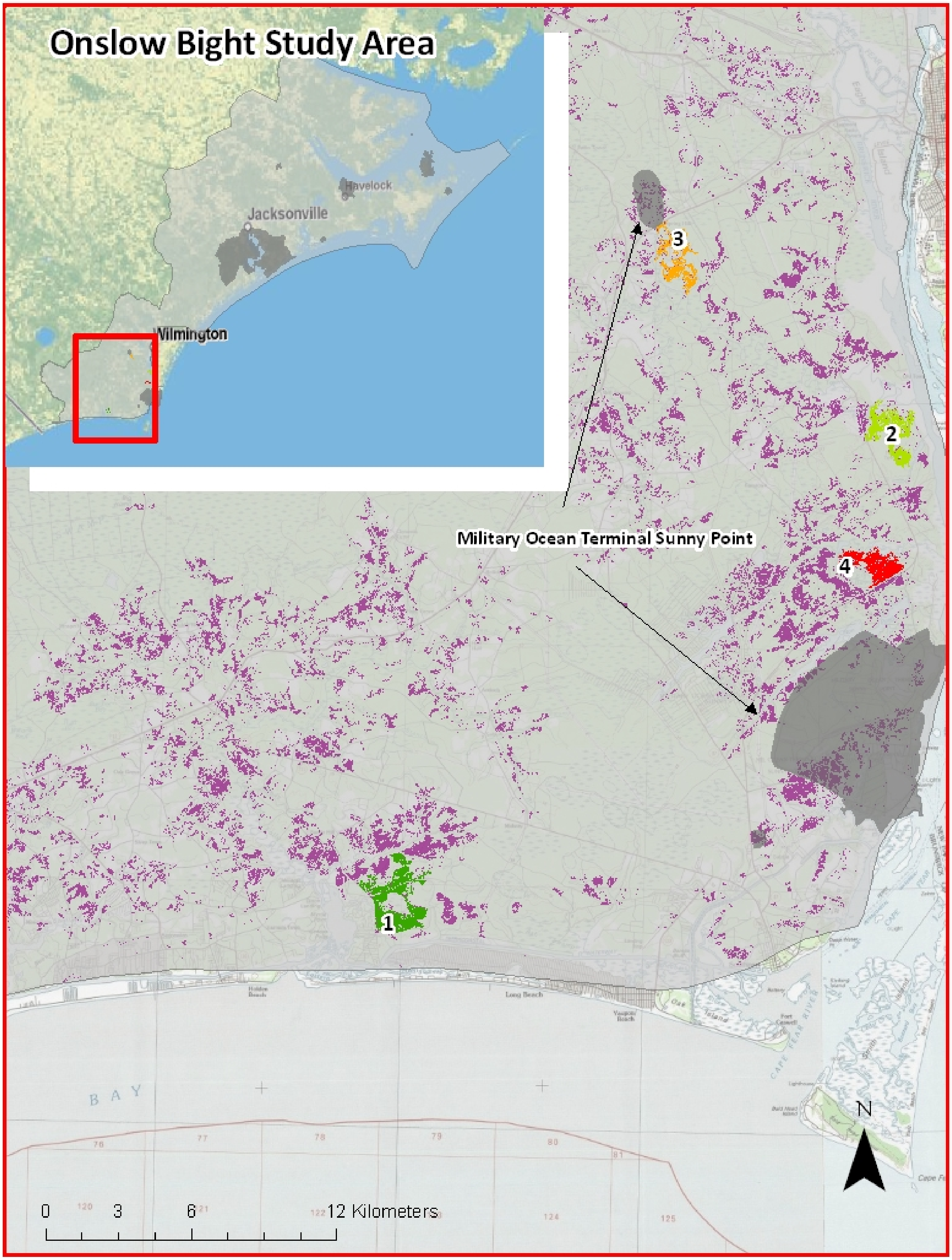

Figure 3. Habitat map and top ranked patches for the northern pine snake, Onslow Bight. A green-to-red color scheme has been applied to the ranked patches with greener patches indicating those with the highest ranks and red patches indicating those with the lowest. All modeled habitat below our minimum size threshold (375 acres) is shown in purple.

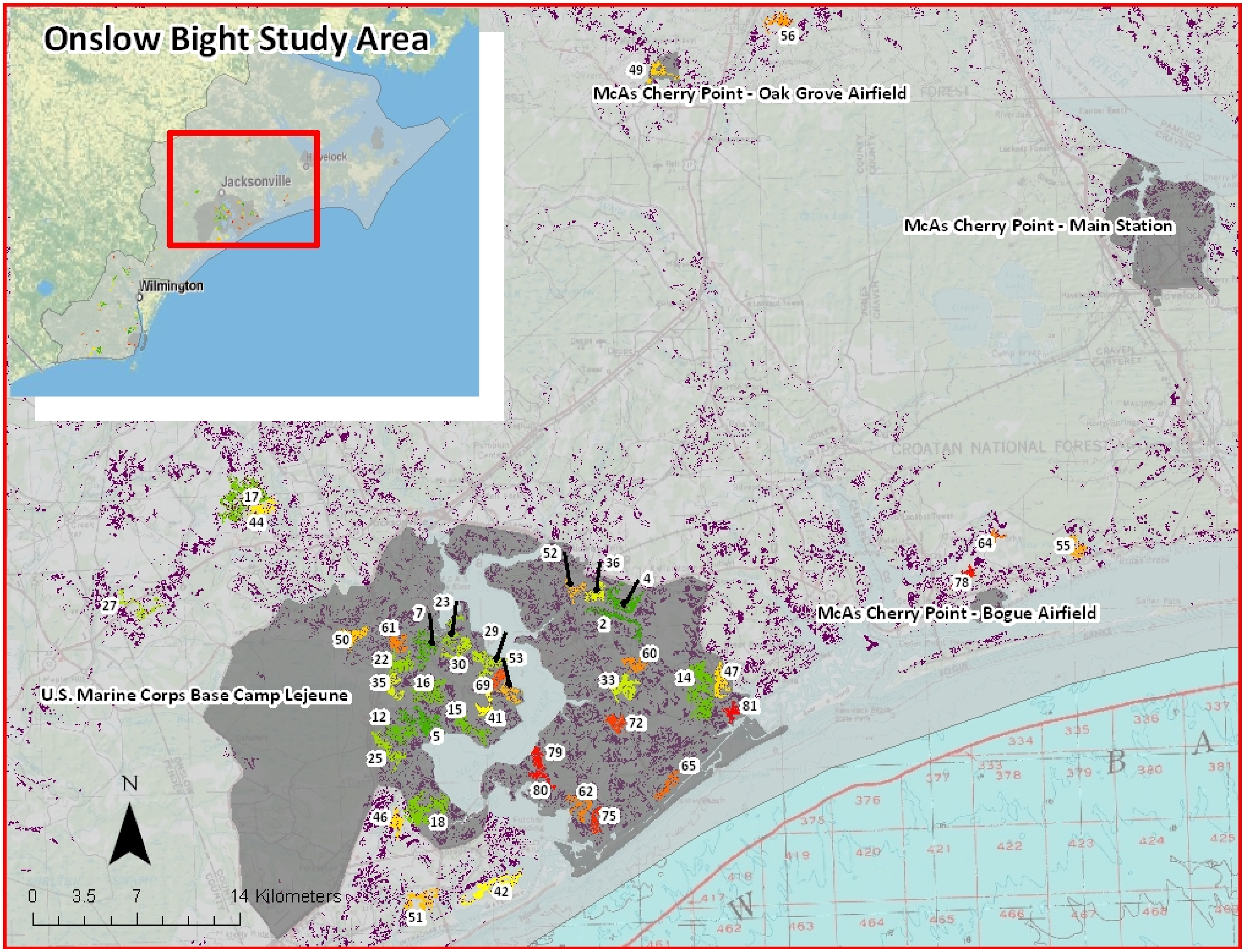

Figure 4. Habitat map and top ranked patches for the southern hognose snake, Onslow Bight North.

A green-to-red color scheme has been applied to the ranked patches with greener patches indicating those with the highest ranks and red patches indicating those with the lowest. All modeled habitat below our minimum size threshold (150 acres) is shown in purple.

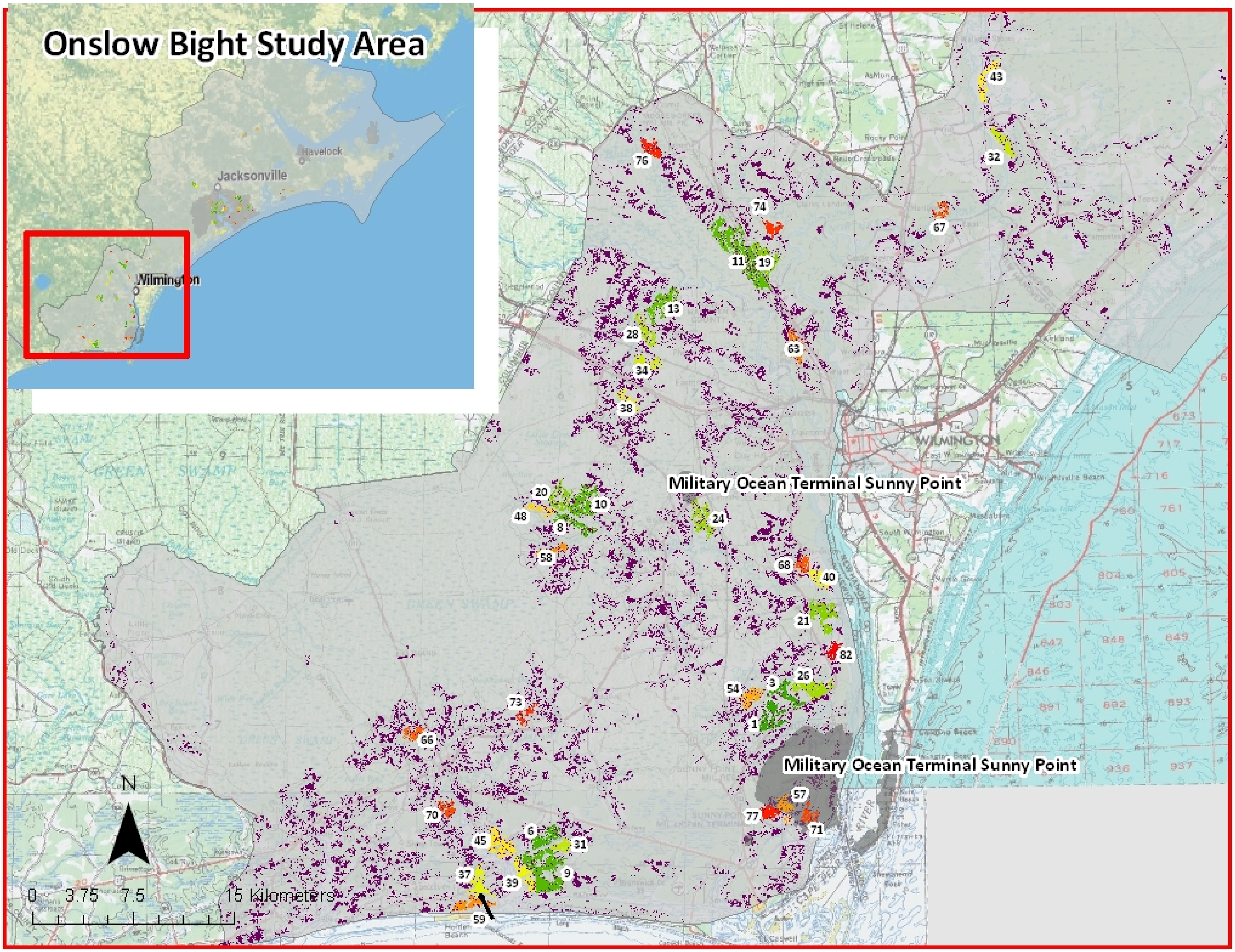

Figure 5. Habitat map and top ranked patches for the southern hognose snake, Onslow Bight South.

A green-to-red color scheme has been applied to the ranked patches with greener patches indicating those with the highest ranks and red patches indicating those with the lowest. All modeled habitat below our minimum size threshold (150 acres) is shown in purple.

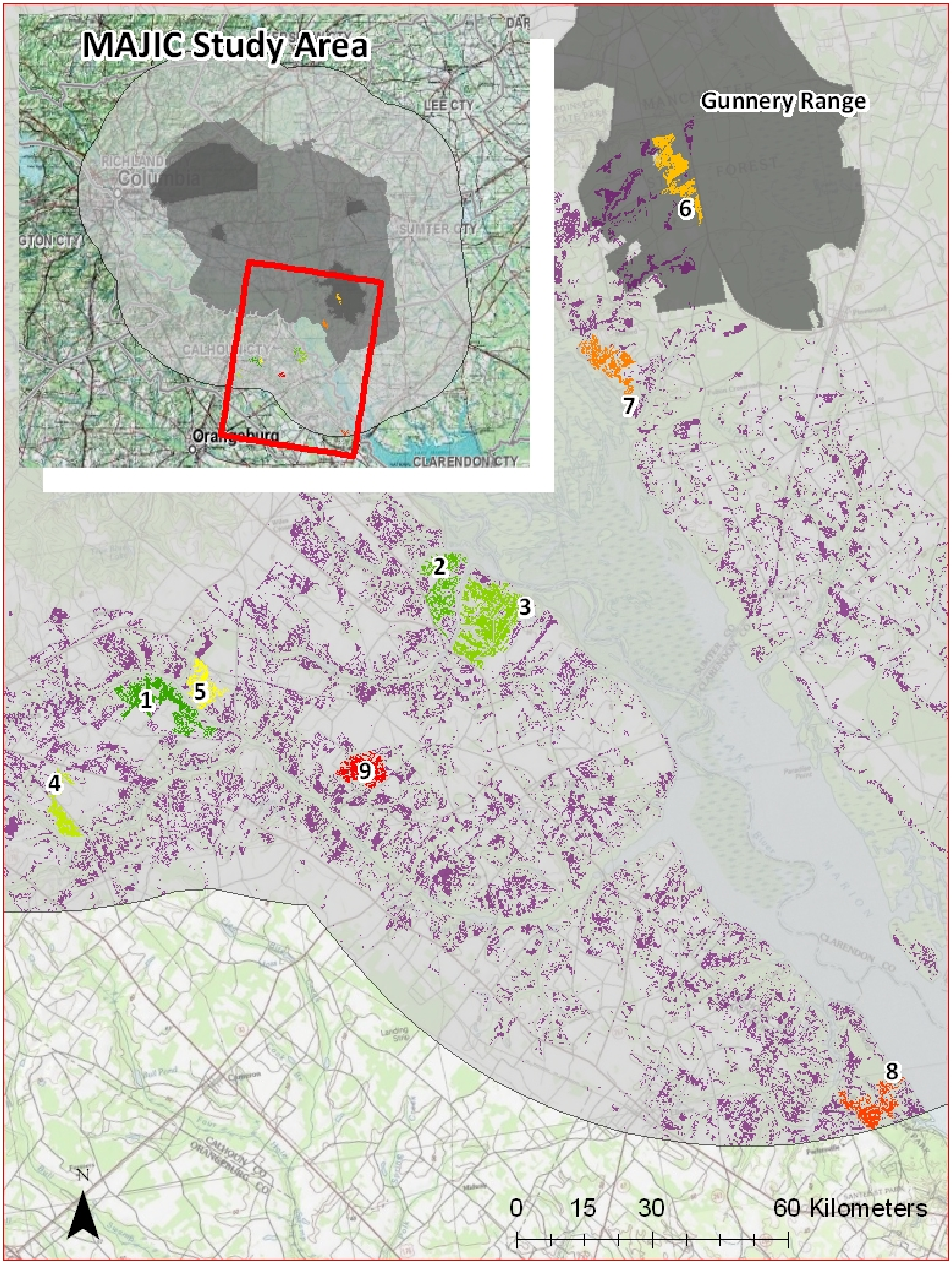

Figure 6. Habitat map and top ranked patches for the mimic glass lizard, MAJIC area.
A green-to-red color scheme has been applied to the ranked patches with greener patches indicating those with the highest ranks and red patches indicating those with the lowest. All modeled habitat below our minimum size threshold (150 acres) is shown in purple.

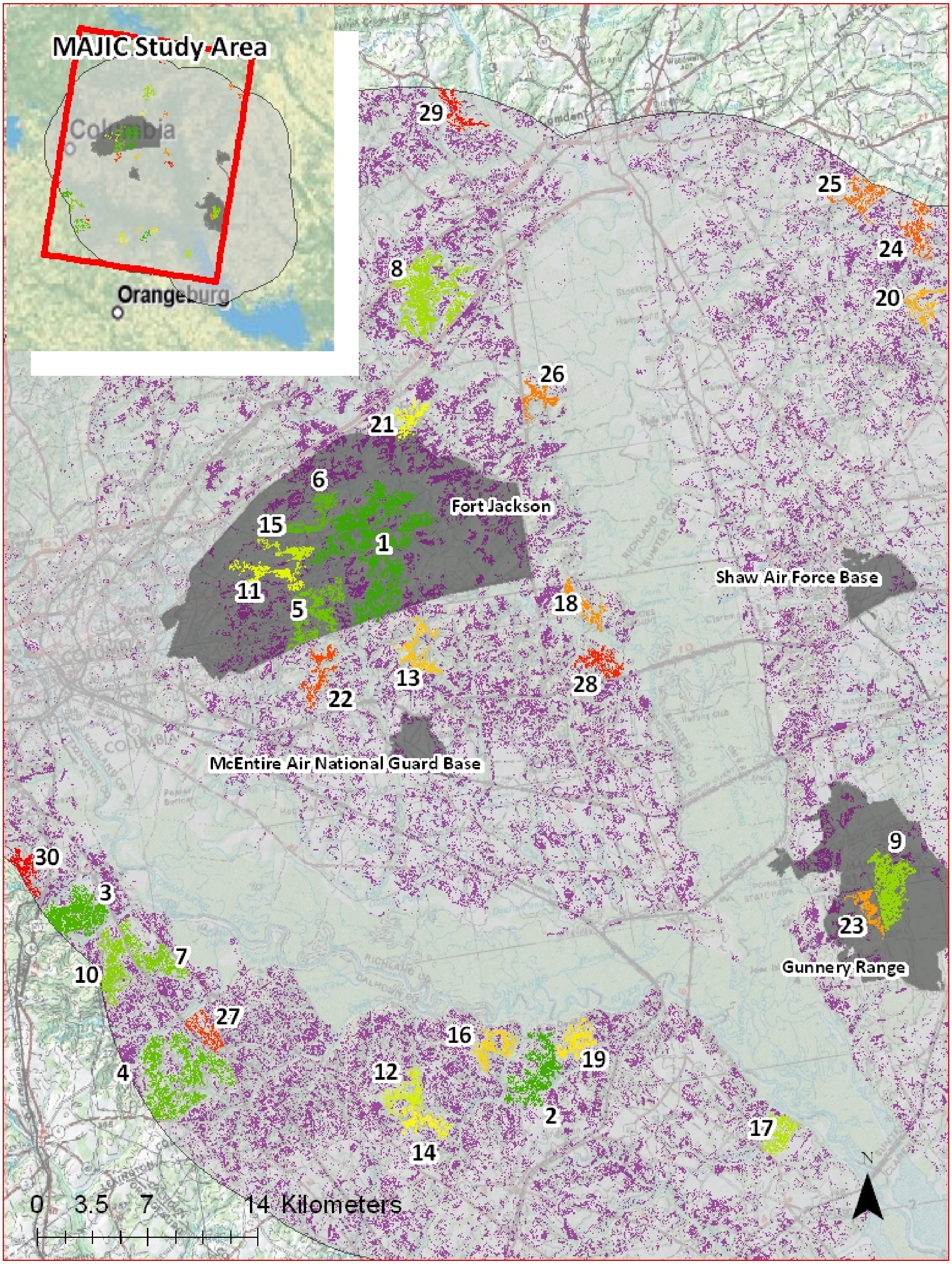

Figure 7. Habitat map and top ranked patches for the northern pine snake, MAJIC area.
A green-to-red color scheme has been applied to the ranked patches with greener patches indicating those with the highest ranks and red patches indicating those with the lowest. All modeled habitat below our minimum size threshold (375 acres) is shown in purple.

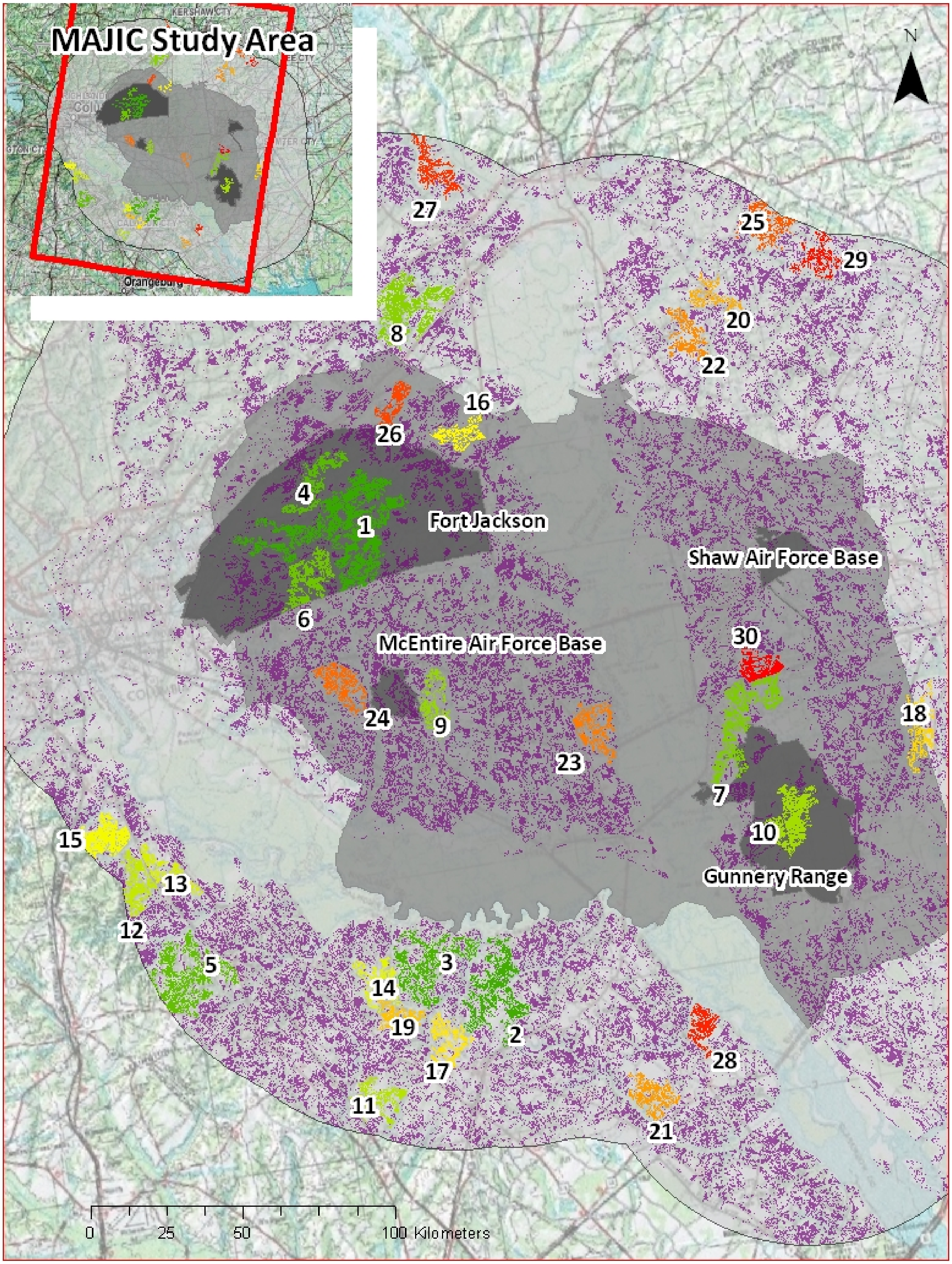

Figure 8. Habitat map and top ranked patches for the southern hognose snake, MAJIC area. A green-to-red color scheme has been applied to the ranked patches with greener patches indicating those with the highest ranks and red patches indicating those with the lowest. All modeled habitat below our minimum size threshold (150 acres) is shown in purple.

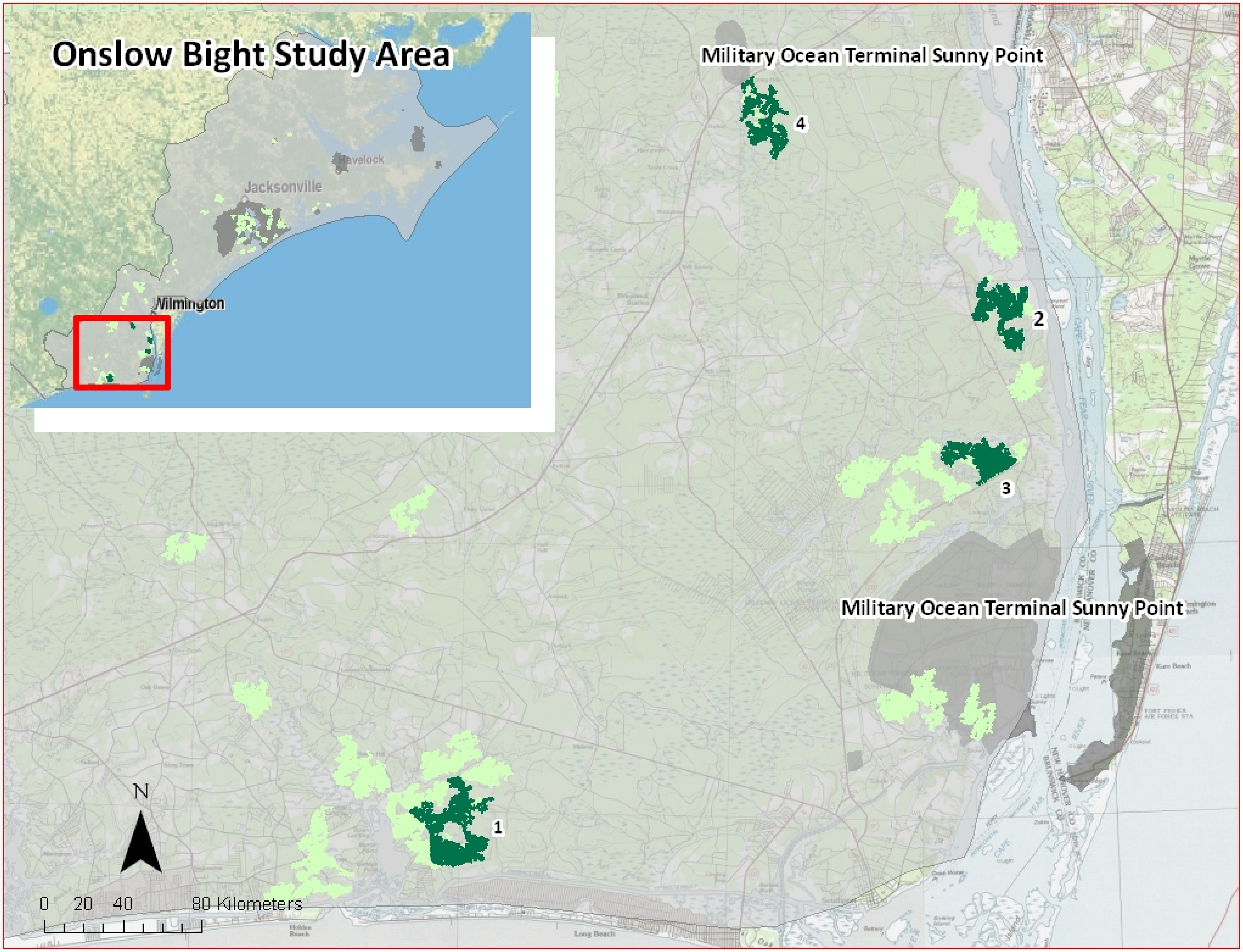

Figure 9. Best candidates for protection of multiple species, Onslow Bight.
Habitat area that overlaps for all three reptile species is shown in dark green. The patches are ranked based on area. Lighter green patches show those patches that don't overlap for all three reptile species.

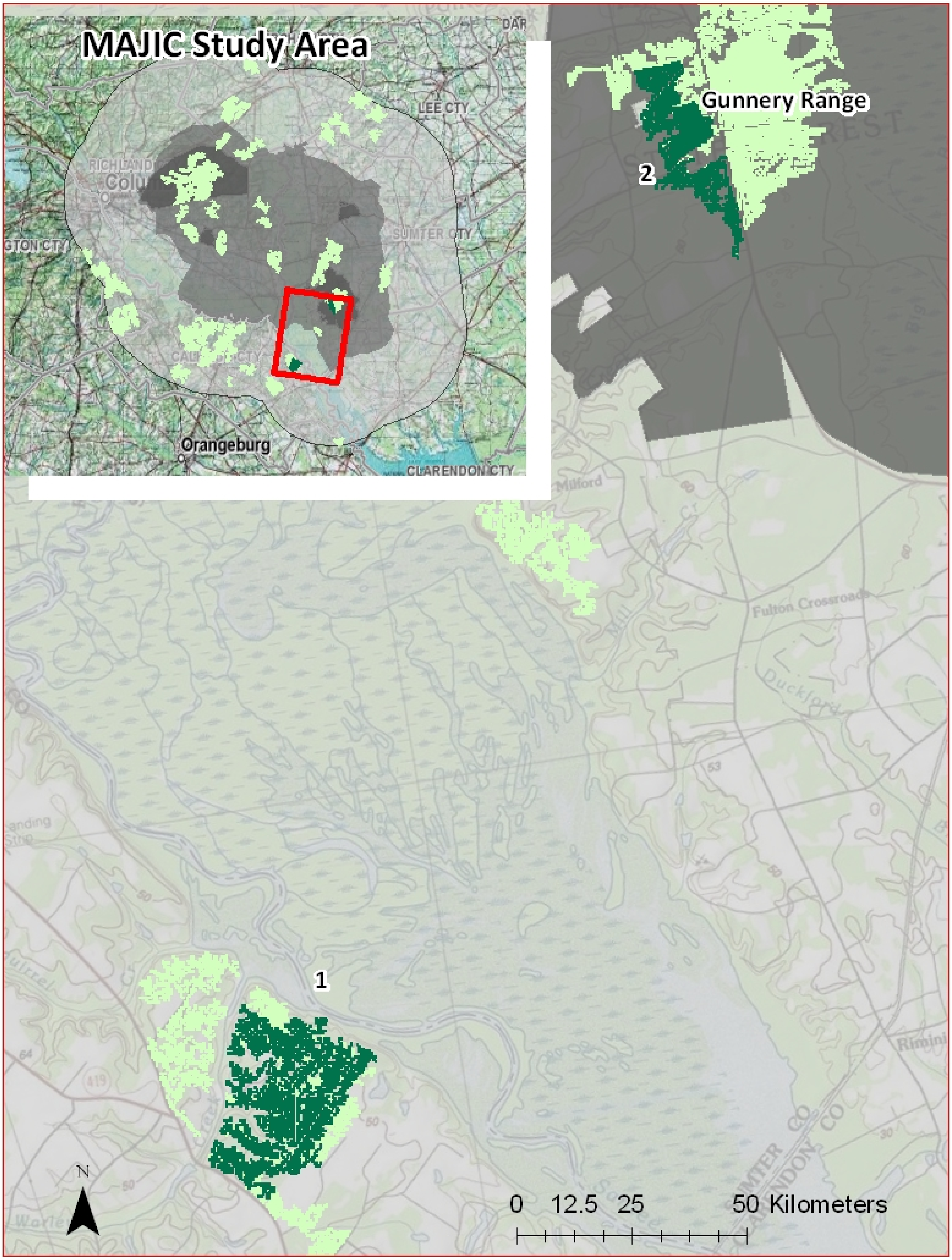

Figure 10. Best candidates for protection of multiple species, MAJIC.
Habitat area that overlaps for all three reptile species is shown in dark green. The patches are ranked based on area. Lighter green patches show those patches that aren't shared by all three species

Appendix A:
Species Information and Management Guidelines

Mimic Glass Lizard

(*Ophisaurus mimicus*)

Species Information

A limbless lizard with external ear openings, movable eyelids, a dark brown or black mid-dorsal stripe and three or four dark stripes or rows of spots, separated by pale stripes. Total length of adults generally is 38-66 cm, maximum head-body length is 18.3 cm (Conant and Collins 1991). Habitat typically is dominated by pines and includes sandy flatwoods and hillsides with longleaf pine, scattered oaks, ericaceous shrubs, and wiregrass (Palmer 1987; P. Moler, pers. comm., 1998). Longleaf pine savanna constitutes an important part of this species' habitat. In areas of suitable habitat, this lizard can be found in early morning hours along roadways that have wide grassy berms. Mimic glass lizards eat crickets, other orthopterans, and other insects (Ashton and Ashton 1991). Usually observed in daytime, especially in morning and early evening, but also on roads at night (Palmer 1987).

Conservation Status

Global Status: G3 - Vulnerable
Global Status Last Reviewed: 13 May 2005
Global Status Last Changed: 23 Oct 1996

Reasons: Spotty distribution in a portion of the southeastern U.S.; threatened in some areas by habitat loss to development and conversion to pine plantations; conservation status is poorly known.

State Status, North Carolina: S2—Imperiled

State Status, South Carolina: SNR—Not Ranked

Degree of Threat: Moderate and imminent threat
Threat Scope: Moderate
Threat Severity: Moderate
Threat Immediacy: High
Threats: Threats include habitat loss to development, conversion of habitat to pine plantations, and road mortality (M. Bailey, J. Jensen, and H. LeGrand, pers. comm., 1997). Moderately threatened in North Carolina (M. Bailey and H. LeGrand, pers. comm., 1997).

Fragility: Narrow, elongate distribution along the Atlantic and Gulf coastal plains of the southeastern United States, from southeastern North Carolina to northern Florida.

Trend: Global Short Term Trend: Declining to stable (+/-10% fluctuation to 30% decline); Global Long Term Trend: Moderate decline to relatively stable (25% change to 50% decline).

Natural Resource Management Guidelines

Relatively little is known regarding best practices for management to protect and restore populations of the mimic glass lizard. Given the current lack of information, protection strategies should focus on protection and/or restoration of longleaf pine savanna, sandy flatwoods and hillsides with longleaf pine, scattered oaks, ericaceous shrubs, and wiregrass via (a) maintenance of natural fire regimes, (b) avoidance of non-compatible timber practices and especially the wholesale conversion to pine plantations, and (c) minimizing habitat loss to development and habitat fragmentation by road networks.

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All personal communications were between the stated individual and G. Hammerson and/or M.K. Clausen.

Additional information can be found at www.natureserve.org/explorer

Northern Pine Snake

(*Pituophis melanoleucus melanoleucus*)

Species Information

The northern pine snake (subspecies *melanoleucus*) is white to pinkish-cream with distinct black body blotches that become somewhat less distinct and brown toward the tail. Body is large and moderately stout with a head that appears small for its body size. The pinesnake's mating period extends from April to early June (Ernst and Barbour 1989), with eggs being laid primarily from late May to July. Clutch size is often 4-12 eggs, but may be larger (up to 24 or more) in the largest females (Burger and Zappalorti 1991). Generally, individual females produce one clutch per year, with incubation typically lasting 50-100 days (70-75 days most common) (Parker and Brown 1980, Ernst and Barbour 1989). Hatchlings emerge in August and September with a total body length of about 22-26 cm; hatchlings are dull in color at emergence, but brighten noticeably after shedding. Pinesnakes are not aggressive but can be impressively defensive when threatened. Defensive displays are loud hissing, inflating the body, vibrating the tail, raising the front part of the body, and striking (may be accompanied by a grunting sound) (Ernst and Barbour 1989). This snake is terrestrial, arboreal, and fossorial--it remains underground in cold weather and during the hot midday period in summer (Fitch 1956, Zappalorti et al. 1983, Burger et al. 1988). Good quality pinesnake habitat appears to be characterized by xeric, pine-dominated or pine-oak (50 to 80% pine) woodland with an open, low understory established on sandy soils (Ernst and Barbour 1989). Longleaf pine sandhills comprise a habitat of special importance for this species.

In general, the ecology of pine snakes is poorly known, except in the New Jersey Pine Barrens (see Zappalorti et al. 1983; Zappalorti and Burger 1985; Burger and Zappalorti 1986; Burger et al. 1988; Burger 1989, 1990).

Conservation Status

Global Status: G4T4 – Apparently Secure
Global Status Last Reviewed: 23 Sep 1997
Global Status Last Changed: 23 Sep 1997
Reasons: Patchy range from New Jersey to Kentucky, Tennessee, Alabama, and Georgia; many occurrences and relatively common (for a predator) in some areas, but probably declining due mainly to habitat alteration/fragmentation and direct mortality from humans, but population data are lacking.

State Status, North Carolina: S3—Vulnerable
State Status, South Carolina: S3s4—Vulnerable

Degree of Threat: Localized substantial threat
Threat Scope: Unknown
Threat Severity: Moderate
Threat Immediacy: High

Threats: Pine snakes are large, conspicuous, and relatively slow and are thus an easy mark for people who kill snakes on sight. Despite apparently low population densities and fossorial habits, several authors have reported numerous encounters with pine snakes on relatively open habitats and roadways (Burger and Zappalorti 1988, Gibbons and Semlitsch 1991). Other threats to pine snakes include excessive collecting, road mortality, habitat alteration, and pesticide use (Ernst and Barbour 1989; Franz 1992; Zappalorti, pers. comm., 1994). Commercial logging of longleaf pine habitat probably has caused declines. As with many sandhills-dependent organisms, outright loss of habitat occurs when land is converted to agriculture, housing, or single-species pine plantations. Remaining areas are degraded so that their suitability for pine snakes is greatly diminished. Exclusion of fire leads to the oak component becoming too dominant, and densely stocked stands may not provide adequate openings for nesting or hibernacula. Zappalorti (1994, pers. comm.) listed habitat fragmentation as the primary threat to pine snake survival in New Jersey. Increasing human development of the New Jersey Pinelands has led to increased human access to previously remote areas, greater off-road recreational use, and ultimately increased paved roadways and traffic. The presence of humans can cause the abandonment of potential nest sites (Burger and Zappalorti 1986).

Fragility: Vulnerable throughout its range, which includes southern and eastern North Carolina, and all of South Carolina.

Trend: Global Short Term Trend: Declining (decline of 10-30%).

Natural Resource Management Guidelines

Effective natural resource management for the northern pine snake is largely dependent on the maintenance and restoration of the large tracts of suitable habitat for this wide-ranging snake. Recommended approaches include:

- Protection of large, contiguous areas of mature pine and pine-oak forest habitats via management of public lands, including national forests and military installations; management plans for the red-cockaded woodpecker could be adapted to take into account the requirements of the pine snake, particularly when the needs of the two species do not conflict.
- Land protection through acquisition, easement, and registry programs to ensure that large tracts of suitable habitat are preserved and that fragmentation is minimized.
- Active management to restore degraded pine-oak forests, including maintenance of natural fire regimes to prevent oak dominance and provide adequate openings for nesting and hibernacula.
- Population monitoring to better determine the status of the pine name in the Southeast and whether reported low densities are a reflection of rarity or of its secretive nature.
- Avoidance of heavy pesticide use in important habitat areas.

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All personal communications were between the stated individual and G. Hammerson and/or M.K. Clausen.

Additional information can be found at www.natureserve.org/explorer

Southern Hog-nosed Snake
(*Heterodon simus*)

Species Information
A stocky, dark-blotched snake with a sharply upturned snout; belly unpatterned or mottled with grayish brown; length usually 36-51 cm (up to 61 cm) (Conant and Collins 1991). Clutches likely include 6-10 eggs. Based on *Heterodon nasicus* (Western Hog-nosed snake), females probably mature at 2-3 years, and some individuals likely live well into their second decade, hence generation length may be 5-10 years. This snake inhabits open, xeric habitats with well-drained, sandy or sandy-loam soils such as sand ridges, stabilized coastal sand dunes, pine flatwoods, mixed oak-pine woodlands and forests, scrub oak woods, and oak hammocks; also old fields and river floodplains (Ashton and Ashton 1981, Palmer and Braswell 1995, Tennant 1997, Ernst and Ernst 2003). Southern hog-nosed snakes spend considerable time burrowed in the soil. Eats mainly frogs and toads, sometimes lizards and small mammals (Ernst and Barbour 1989); may use snout to excavate buried toads.

Conservation Status
Global Status: G2 - Imperiled
Global Status Last Reviewed: 1 Sep 2006
Global Status Last Changed: 9 Apr 1998
Reasons: Relatively small range on the Coastal Plain of the southeastern United States; possibly extirpated from Mississippi and Alabama, apparently now rare and declining throughout most of the range, but still locally common in some areas; research on the threat posed by imported fire ants is needed.

State Status, North Carolina: S2—Imperiled
State Status, South Carolina: SNR—Not Ranked

Degree of Threat: Moderate and imminent threat
Threat Scope: Moderate
Threat Severity: Moderate
Threat Immediacy: High
Threats: Significant threats remain poorly understood but are here estimated to be of at least moderate scope and severity. Predation of eggs and hatchlings by red imported fire ants (IFA) may be a factor in the decline (Tuberville et al. 2000). The snake's disappearance from certain areas is associated with heavy red IFA infestations. Other factors suggested to be of potential importance include loss of habitat to intensive agricultural/silvicultural activities, widespread pesticide application, road mortality, and the general persecution of snakes by humans. This species apparently can persist in areas of fragmented and altered upland habitats, although cumulative road mortality may be a significant factor, especially for hatchlings (Enge and Wood 2003).

Fragility: The Southern hog-nosed snake occurs on the Coastal Plain from eastern North Carolina to southern Florida, west to southeastern Mississippi, though it has already possibly been extirpated from the westernmost portions of its range.

Trend: Global Short Term Trend: Declining (decline of 10-30%); Global Long Term Trend: Substantial to moderate decline (decline of 25-75%).

Natural Resource Management Guidelines

More research is needed to determine the factor or combination of factors responsible for the this species' precipitous decline. Until the causes of decline are better understood, management efforts should focus on habitat preservation, including:

- Protection of longleaf pine habitats
- Implementing/continuing seasonally appropriate burning programs in pyric communities
- Efforts to minimize road construction and high traffic volumes in important habitat areas
- Environmentally benign fire ant control in areas at the edge of within the belt of fire ant expansion.

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All personal communications were between the stated individual and G. Hammerson, T.M. Mann, and L. Glass-Godwin.

Additional information can be found at www.natureserve.org/explorer

Carolina Gopher Frog

(*Rana capito)*

Species Information

A stubby frog with short limbs, a large head, and dorsolateral ridges; adults generally are 6-9 cm in snout-vent length (maximum 112 mm) (Conant and Collins 1991). The skin ranges in texture from smooth to warty, and from creamy-white to gray or brown in color. Breeding typically occurs between mid-January and April in North and South Carolina (Semlitsch et al. 1995), but calling has been heard in every month of the year in South Carolina (A. Braswell, pers. comm.; S. Bennett, pers. comm.). The call is a loud snore that lasts up to two seconds and carries nearly 0.4 km (Wright and Wright 1933); however, gopher frogs may also call while submerged beneath the water's surface, which significantly mutes the call (Jensen et al. 1995). The reproductive habitat is best described as a circular or near- circular depression marsh, ranging from 0.1 ha to 33 ha (Palis and Jensen 1995). Breeding events last only a short period of less than two weeks, and local breeding populations are very small (Semlitsch et al. 1995). Eggs are 1.7-2.7 mm in diameter; the egg mass is a fist-sized glob, oval to nearly circular in shape, and containing up to 6000 eggs (Volpe 1958). Gopher frog tadpoles are yellowish-green to olive-green or gray with scattered, relatively large, diffuse black spots on the upper body, tail musculature, and fin. They attain a length of 84 mm before transformation (Wright and Wright 1933) (although they may reach well over 90mm in parts of North Carolina (A. Braswell, pers. comm.)). In South Carolina the larval period was estimated to last 87-113 days (Semlitsch et al. 1995); metamorphosing and emigrating juveniles were found from late May to late July. Two years are required for gopher frogs to attain the minimum size of sexual maturity (Franz, unpubl. data). Egg predators include caddisfly larvae and turtles; predators on larvae include dragonfly nymphs, diving beetles, introduced game fishes, and undoubtedly many other species (Cronin and Travis 1986, Travis et al. 1985). Among years and ponds, juvenile recruitment is highly variable (Greenberg 2001), but successful recruitment of metamorphs into the adult population at a particular site occurred only rarely. Metamorphosed frogs eat various invertebrates and occasionally small anurans (Godley 1992). According to Wright and Wright (1949), gopher frogs range "some distance from their burrows in foraging at night." Larvae eat suspended matter, organic debris, algae, minute organisms, and plant tissue. Caroline Gopher Frogs are mainly nocturnal but sometimes active on the surface in daylight, and are inactive during cold weather (Einem and Ober 1956).

Conservation Status

Global Status: G3 - vulnerable
Global Status Last Reviewed: 17 April 2002
Global Status Last Changed: 15 November 2001
Reasons: Restricted to a portion of the southeastern U.S., where distribution and abundance are reduced from historical levels, probably due mainly to loss and degradation of habitat caused by silvicultural practices and fire suppression, combined with reduced gopher tortoise populations; population estimates are not precise but there may be fewer than 10,000 individuals remaining.

State Status, North Carolina: S2 – Imperiled
State Status, South Carolina: S1 – Critically Imperiled

Degree of Threat: Moderate and imminent threat
Threat Scope: Moderate

Threat Severity: Moderate
Threat Immediacy: High
Threats: Threats are many and include loss of longleaf pine habitat through maximum-yield timber management (e.g., establishment of pine monocultures) and/or decreased frequency of fire; introduction of predatory fishes into breeding ponds; road construction near breeding sites; and declining populations of gopher tortoises, whose burrows are used extensively by gopher frogs (Bailey 1991, Godley 1992). Mechanical site preparation (e.g., roller chopping) destroys burrow openings which may result in entrapment of inhabitants. Routine pine straw harvest and associated removal of herbaceous vegetation degrades habitat quality of the gopher frog (A. Braswell, pers. comm.). Introduction of predatory game fishes (LEPOMIS spp. and MICROPTERUS spp.) is detrimental as these species feed upon gopher frog tadpoles. In some instances, introduction of GAMBUSIA can be detrimental to gopher frogs and other larval amphibians (A. Braswell, pers. comm.). Gopher frog breeding sites are often degraded by off-road recreational vehicle (ORV) use or by sand roads that pass through or adjacent to the ponds (J. Palis, pers. comm.). Vehicular traffic disrupts pond floor micro-topography and eliminates herbaceous vegetation (J. Palis, pers. comm.). Large tires of ORVs may break the organic hardpan that lies below the pond floor. This hardpan prevents water from draining into the sand below the wetland (LaClaire and Franz 1991). Breaking the hardpan could result in a shorter hydroperiod and thus make some wetlands unsuitable for gopher frog reproduction. Loss of herbaceous vegetation from ORV use could also discourage gopher frog reproduction since egg masses are attached to stems of herbaceous vegetation (Bailey 1990; J. Palis, pers. comm.). Erosion of unpaved roads lying adjacent to breeding sites may result in sedimentation into the ponds. Introduction of sediment is exacerbated by emplacement of wing ditches that divert water from roads into ponds. Heavy grazing by cattle in summer in dried pond basins may reduce or eliminate frog oviposition sites and/or alter pond nutrient cycling.
Fragility: Environmental Specificity: Very narrow to narrow.

Trend: Global Short Term Trend: Declining (decline of 10-30%).

Natural Resource Management Guidelines
Suggested measures to mitigate threats to this species include:

- Protection of longleaf pine habitat via (1) maintaining natural fire regimes, (2) avoiding non-compatible timber practices (such as roller chopping), and (3) barring routine pine straw harvest.
- Protection of breeding sites by (1) avoiding road construction and other manual disturbances in close proximity, (2) preventing ORV use in the vicinity of breeding ponds, (3) preventing the introduction of predatory fishes including Lepomis spp., Micropterus spp. And Gambusia spp., and (4) preventing heavy grazing by cattle in summer in dried pond basins.
- Efforts to preserve gopher tortoise populations (whose burrows are used extensively by gopher frogs).

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Additional information can be found at www.natureserve.org/explorer

Eastern Diamond-backed Rattlesnake

(*Crotalus adamanteus*)

Species Information

This is the largest venomous snake in the United States and Canada, recognized by its large size, dorsal pattern of diamonds, yellowish unpatterned belly, black tail, infrared-sensitive pit between the eye and nostril, and rattle at the tip of the tail. Males and females both probably participate in courtship and mating every August and September after reaching sexual maturity, but females usually reproduce every two or possibly three years after giving birth to their first clutch (Means, unpublished manuscript). Mating takes place in August and September. Females store sperm until the following April when ovulation and fertilization take place. Gestation requires about 120 days. Females give live birth in August and September to an average of about 14 young. Females may remain in the vicinity of the newborn for several days. At birth, young average 14 inches (36 cm) total length (Means 1995) and grow rapidly to adult size (39-59 inches, 100-150 cm in total length) (Ernst and Barbour 1989, Berish 1992). Maximum size is about 96 inches or 244 cm). Males may reach sexual maturity by the time of their second birthday; females at year three (Means, unpublished manuscript). Males average larger than females and grow larger (Timmerman 1989, Berish 1992, Means 1995). The principal predators and enemies are other snakes, including the indigo snake (*Drymarchon corais couperi),* which feeds upon diamondbacks, and the eastern kingsnake (*Lampropeltis getulus*), which takes young rattlesnakes occasionally. The red-tailed hawk is a known predator and several other birds of prey are suspected of feeding on medium- and small-sized rattlesnakes. Feral hogs have been reported to kill and feed on small rattlesnakes and white-tailed deer have been reported to stamp rattlesnakes to death (Timmerman 1989; Means, unpublished manuscript). No doubt humans are presently the most serious source of direct mortality (roadkilling, clubbing, shooting, and collecting for sale of skins or for rattlesnake roundup competitions) (Means, unpublished manuscript). Habitats include pine and wiregrass flatwoods, pine-palmetto flatwoods, longleaf pine-turkey oak hills, rosemary scrub, mesophytic and coastal maritime hammocks, xeric hammocks, barrier islands and coastal scrub habitats, vicinity of wet savannas, wet prairies (during dry periods), mixed pine-hardwood successional woodland, and abandoned farms and fields (especially near pine-dominated habitats), particularly areas with abundant cover (Mount 1975, Dundee and Rossman 1989, Palmer and Braswell 1995, Tennant 1997, Ernst and Ernst 2003, Campbell and Lamar 2004). Large tracts of habitat are most suitable. Eastern diamondbacks are basically terrestrial and rarely climb into vegetation. Prey is principally rodents and lagomorphs, including the eastern cottontail (*Sylvilagus floridanus*), marsh rabbit (*Sylvilagus palustris*), cotton rat (*Sigmodon hispidus*), cotton mouse (*Peromyscus floridanus*), grey squirrel (*Sciurus carolinensis*), fox squirrel (*Sciurus niger*), and other rodents. Activity occurs mainly in early morning, evening, and at night. A very small number of eastern diamondback snakebites impact human beings every year (less than about 10), and many of these are delivered to people deliberately handling the animals (snake fanciers, roundup yahoos, researchers).

Conservation Status

Global Status: G4 – Apparently Secure
Global Status Last Reviewed: 8 Sep 2006
Global Status Last Changed: 31 Oct 1996
Reasons: The original range has been reduced and fragmented by agriculture, forestry practices, urbanization, and plant succession resulting from fire suppression (Martin and Means 2000).

State Status, North Carolina: S1—Critically Imperiled
State Status, South Carolina: S3—Vulnerable

Degree of Threat: Moderate and imminent threat
Threat Scope: Moderate
Threat Severity: High
Threat Immediacy: High
Threats: Current threats to local populations include conversion of native habitat to planted slash or loblolly pine silvicultural plantations, agricultural fields, and urban and suburban uses. More than anything else, human alteration of native longleaf pine upland ecosystems (including fire suppression) is shrinking and fragmenting the suitable habitat base for this species. Another direct threat is the collecting of rattlesnakes for the skin trade and in some areas (notably Alabama and Georgia) for competition for prizes in rattlesnake roundups. While probably not a serious threat in itself, when coupled with habitat loss, this sort of collecting is additive. Rattlesnake roundups, themselves, account for only about 2,000 snakes per year. The skin trade is more insidious. Skin dealers have a huge network of pick-up stations where they advertise for people to bring in killed snakes to be frozen until the dealers can make the rounds and pick up the carcasses. Rangewide, this sort of activity probably accounts for at least ten times (20,000) the number of rattlesnake deaths caused by roundups (Means, unpublished manuscript).
Fragility: The Eastern Diamond-backed Rattlesnake occupies a restricted range along the coastal plain, and its specific ecological requirements define a fairly limited suitable habitat even without considering the constraints placed on that habitat by land development and other degradation.
Trend: Global Short Term Trend: Declining (decline of 10-30%). This species has been declining over its geographic range in several ways. First, the northern perimeter of the range has been shrinking southward. Second, the western and northeastern ends of the distribution are shrinking toward the middle of the range. Third, throughout the range, the habitat and thus the opportunity for a globally panmictic population has been severely fragmented by humans.

Natural Resource Management Guidelines

The best way to arrest the trend of decline is to manage occupied habitat in ways that promote the preservation and/or maintenance of the full complement of native ecosystems originally thought to have occurred naturally on each site. Usually this is longleaf pine forest on the uplands and wetland habitats naturally adjacent to them.

Measures to protect Eastern Diamond-backed Rattlesnake should include:

- Protection of longleaf pine upland ecosystems
- Maintaining natural fire regimes in longleaf and adjacent habitats, ideally a 1-5 year burn interval with burns occurring May-July
- Preserving the native complement of other animals co-located with viable populations (food species and the gopher tortoise, where present).

Additional research on the life history and ecology of the species should inform future management practices. Research is needed to better understand (1) minimum viable population size and the area required to maintain a minimum viable population; (2) the role food supply plays in the reproductive health of females, and whether females could reproduce annually or shorten their ages to maturity by access to unlimited food supply; (3) morbidity and mortality in the first two years of life, when individuals are less than 1.0 meters long.

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Additional information can be found at www.natureserve.org/explorer

Bachman's Sparrow

(*Aimophila aestivalis*)

Species Information

A large sparrow with a large bill, fairly flat forehead, long dark rounded tail, gray upperparts heavily streaked with chestnut or dark brown, buff or gray sides and breast, and whitish belly (NGS 1983). Overall length is about 14-16 cm. In the southeastern U.S., may begin singing as early as mid-February, two months before breeding (Burleigh 1958, Sprunt and Chamberlain 1970). Nests on the ground in dense cover, against/under grass tuft or under low shrub (Harrison 1978), in grassy opening, field, or area with scattered trees. Open, domed nests are built by the female and consist of coarse dry grasses and weed stems lined with finer materials (Blincoe 1921, Ganier 1921, Brooks 1938). Eggs are laid from late April through July or August (mostly May-June) (Burleigh 1958, Oberholser 1974, Bent 1968). Clutch size 3-5, typically 4; eggs are entirely white and average 19.3 mm by 15.3 mm. Often two, sometimes 3 broods per year (Sprunt and Chamberlain 1970). Incubation, by the female, lasts 12-14 days. Young are tended by both parents (Brooks 1938), leave nest at about 9-10 days while unable to fly, continue to be fed by parents for about 25 days, during which time the female may initiate another nest and the male may assume most of the feeding responsibilities. Habitat specialist: historically, found in mature to old growth southern pine woodland subject to frequent growing-season fires; a fugitive species, breeding wherever fires created suitable conditions. Requires well-developed grass and herb layer with limited shrub and hardwood midstory components. Ideal habitat was originally the extensive longleaf pine woodlands of the south. Able to colonize recent clearcuts and early seral stages of old field succession but such habitat remains suitable only for a short time. In the southeastern U.S., Coastal Plain breeding habitat usually is open pine woods with thick cover of grasses or saw palmetto. In South Carolina, higher densities were recorded in mature (more than 80 years old) pine stands than in young stands (Dunning and Watts 1990). Eats insects, other invertebrates, and seeds of herbaceous plants and pines (Meanley 1959, Sprunt and Chamberlain 1970, Oberholser 1974, Allaire and Fisher 1975).

Conservation Status

Global Status: G3 - Vulnerable
Global Status Last Reviewed: 14 Sep 2007
Global Status Last Changed: 4 Dec 1996
Reasons: Significant recent contraction of northern edge of range; local reduction in abundance or local extinctions noted in center of range. Habitat specialist; can be severely affected by habitat modification.

State Status, North Carolina: S3B, S2N – Vulnerable (Breeding), Imperiled (Non-breeding)
State Status, South Carolina: S3—Vulnerable

Degree of Threat: B
Threats: Conversion of longleaf pine stands to plantations of fast-growing pines, shortage of newly abandoned farmland, and urbanization are apparently important factors in the population decline (Dunning 1993). At least 90% of original habitat (mature pine forests in South) has been severely altered by conversion of natural forest to pine plantation or other forms of alternative land use. Isolated patches of habitat are less likely to support populations. This species is negatively affected by fire suppression which increases understory and its shrubby components;

also affected by harvest rotations that maintain unsuitable timber age classes (i.e. 15-70 years old). Nestlings and eggs are frequently eaten by snakes or mammals but no records of adult mortality (Dunning 1993).

Fragility: While the Bachman's Sparrow occupies a larger native range than many of the species in this report, the specificity of its habitat requirements puts the species at risk across this range.

Trend: Global Short Term Trend: Declining (decline of 10-30%).

Natural Resource Management Guidelines

The primary management concern for Bachman's sparrow is the provision of adequate habitat, which is ephemeral and often declines as a result of natural vegetation succession. Because this species often inhabits early successional habitats that require ongoing management (and an ongoing financial commitment), land protection through acquisition may not always be a suitable or feasible method of protection. Given those considerations, the following two-prong approach to conservation is recommended (LeGrand and Schneider 1992):
First Priority: Protection of sites (via acquisition or other stewardship) that can be maintained through natural processes, particularly fire. A 3 year burn interval is ideal (Johnson and Landers 1982, Dunning and Watts 1990, Gobris 1992, Shriver and Vickery 2001, Tucker et al. 2005) and the timing of burns has not been shown to be important (King et al. 1998, Tucker 2002).

Second Priority: Protection of sites where existing management practices can be modified to accommodate the birds' needs for nesting habitat; this may include timber of agricultural lands that can be managed to provide a minimum of 75 ha of suitable habitat in any one breeding season. A mosaic of sites in different stages of vegetation succession is ideal, as a single area generally cannot provide continuously favorable habitat. Protection of areas that are compact in shape is preferred to those that are long and narrow, as powerlines and other narrow clearing do not seem to be suitable (LeGrand and Schneider 1992).

Areas managed for red-cockaded woodpeckers generally provide habitat for Bachman's sparrows (Dunning and Watts 1990) if those areas contain adequate grass cover for foraging and nest placement. Clearcuts may also provide habitat, but burning should follow timber removal to ensure dense grass cover.

Most of the stewardship information contained above is based on a article by Harry E. LeGrand, Jr., and Kathryn J. Schneider (1992) and on a draft ESA completed by R. L. Henson

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Henslow's Sparrow
(*Ammodramus henslowii*)

Species Characteristics

Characterized by large flat head, large gray bill, and short tail. The head, nape, and most of the central crown stripe are olive-colored, with the wings extensively dark chestnut. The sexes have similar appearances. The song is distinctive and diagnostic: a short, quiet "see-lick," accented on the second syllable (Peterson 1980, National Geographic Society 1987). Sometimes sings on quiet nights. Nests can be either open or domed and they are located from 0-50 cm above the litter (Hyde 1939, Robins 1971, Flanigan 1975). Those nests that are off the ground are attached to grass or forb stalks. The nest is loosely woven with dead grass and lined with finer grasses and hair. Two broods of young per breeding season (Hyde 1939), perhaps three (Robins 1971), are raised. Clutch size is from three to five eggs. The eggs are approximately 18.3 x 14.4 mm in size (Graber 1968) and are white with spots or blotches of brown, mostly at the larger end. The incubation period lasts about 11 days and the young stay in the nest nine to ten days. Young are tended by both parents, leaving the nest at 9-10 days. Potentially important predators include mammals, snakes, and birds of prey. Eats crickets, grasshoppers, beetles, caterpillars, and other insects, spiders, and seeds of herbaceous plants; forages on the ground (Terres 1980). Territory boundaries not well-defined (Ehrlich et al. 1992), but Robins (1971) found that the average territory size was smallest and the population density highest in areas with the tallest and densest vegetation. Found in a variety of habitats that contain tall, dense grass and herbaceous vegetation (Smith 1968, 1992). Hyde (1939) describes a variety of preferred habitats: upland weedy hayfields or pastures without shrubs, wet meadows, drier areas of saltmarshes, grassy fields, and sedgy hillsides with recently planted pine seedlings (*Pinus* spp.). Several authors have commented that local populations tend to be unstable from year to year (Hyde 1939, Wiens 1969, Robins 1971). On the other hand, birds are reported to have bred consistently in some undisturbed, protected areas (Ennis 1959, Birkenholz 1983).

Conservation Status

Global Status: G4
Global Status Last Reviewed: 11 Jan 2008
Global Status Last Changed: 4 Dec 1996
Reasons: Has a spotty distribution, and has experienced population and range reductions due to habitat alteration. Requires a successionally transitory habitat, particularly in the eastern portion of its range.

State Status, North Carolina: S2B, S1N – Imperiled (Breeding), Critically Imperiled (Non-breeding)
State Status, South Carolina: SNA – Not Applicable (*note, South Carolina does not track this species, although it is known to be a non-breeding resident of the state)*

Degree of Threat: B
Threats: Decline apparently is related to loss of habitat due to encroaching urbanization, successional change to shrubland or forest, and use for row-crop agriculture. Habitat is ephemeral and also often not available due to heavy human use (not allowed to lie idle; Robbins et al. 1986). In the East, increasing urbanization and encroachment of woody species have been

major factors. Fragmentation of suitable habitat into small widely scattered plots is another serious threat. Rarely encountered on grassland fragments less than 100 hectares (Herkert 1994). Normal annual population fluctuations can be more dramatic on smaller preserves, reducing local populations to levels where random events could lead to local extirpation. Conflicts may occur between timing of nesting and cutting of hay (Bollinger 1988). Highly productive hayfields may attract sparrows (as well as other grassland species) to establish territories and start nesting early in the breeding season; when the hayfields are then cut, the losses of nests, eggs and nestlings may lead to a decline in local productivity (Best 1986, Temple 1990). Fire and grazing management with short-term rotations can be too frequent to allow for sufficient litter buildup and a high density of standing dead vegetation (Fleckenstein, pers. comm.; Herkert 1994; Skinner 1975). Nest predation by snakes and small mammals likely.

Fragility: This species occurs in most of the Eastern United States, but researchers have observed a disturbing decline in populations across its range. In North Carolina, it only occurs in the southernmost portion of the Coastal Plain. While its range is large elsewhere in the country, its habitat requirements are narrow, making it particularly vulnerable.

Trends: Global Short Term Trend: Severely declining to declining (decline of 10% to >70%).

Natural Resource Management Guidelines

Because Henslow’s sparrow requires unfragmented grasslands of 30+ hectares in area, successful resource management for this species is highly dependent on the maintenance of large, well-connected habitat patches. The following guidelines are provided for land protection for these birds:

- A minimum area of 30 ha or more of contiguous grassland habitat should be preserved at any site (Smith and Smith 1990, Zimmerman 1988).
- If contiguous management units are not available, provide a complex of smaller units located near enough to one another to facilitate colonization from adjacent territories in available habitat (Mazur 1996).
- Breeding populations should be monitored annually in localized areas that are inhabited.
- Management activities that enhance grassland productivity such as mowing, burning, and grazing should be encouraged, but units subject to these management efforts should not be disturbed from mid-May through August (when the birds are nesting).
- Never burn, mow, or otherwise disturb an entire area in one breeding season because disturbance reduces available habitat for one or two growing seasons (Herkert et al. 1993, Hanson 1994, Melde and Koford 1996).
- Management regimes that produce dense and moderately tall grassy vegetation (> 30 cm) from mid-May through mid-August should be considered.

Additional studies are necessary to determine the impacts of various frequencies and timings of burning, mowing and grazing on existing, stable populations. Zimmerman (pers. comm. 1994) commented on unpublished data that demonstrates that Henslow's sparrows do not show site fidelity or even philopatry. Annual population fluctuations should be investigated (Fleckenstein pers. comm. 1994).

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Additional information can be found at www.natureserve.org/explorer

Red Knot

(*Calidris canutus*)

Species Characteristics

A large sandpiper approximately 27cm long and weighing 148 grams. Red knots migrate long distances between nesting areas in mid- and high arctic latitudes and southern nonbreeding habitats as far north as the coastal United States (low numbers) and southward to southern South America. Red knots migrate in large flocks northward through the contiguous United States mainly April-June, southward July-October (Bent 1927). Arrival in breeding areas occurs in late May or early June; most have departed breeding areas by mid-August. Nests on ground in barren or stony tundra and in well-vegetated moist tundra. Lays clutch of usually 4 eggs, June-July. Incubation lasts about 20-25 days, by both sexes. Young are tended mostly by male (female leaves before fledging), leave nest soon after hatching, can fly at about 18 days (Terres 1980). Preferred habitat includes: primarily seacoasts on tidal flats and beaches, less frequently in marshes and flooded fields (AOU 1983). On sandy or pebbly beaches, especially at river mouths; feeds on mudflats, loafs and sleeps on salinas and salt-pond dikes (Costa Rica, Stiles and Skutch 1989). Eats mainly mollusks, eggs of crab and horseshoe crab, insects, some seeds and small fishes; pecks and snatches at sand or mud, or probes.

Conservation Status

Global Status: G4 – Apparently Secure
Global Status Last Reviewed: 4 Oct 2005
Global Status Last Changed: 4 Oct 2005

State Status, North Carolina: S3N—Vulnerable (Non-breeding)
State Status, South Carolina: SNRN – Unranked (Non-breeding)

Degree of Threat: Moderate and imminent threat
Threat Scope: Moderate
Threat Severity: Moderate
Threat Immediacy: High
Threats: Increased commercial harvest of horseshoe crabs (for use as bait in eel and conch fisheries; especially in the Delaware Bay region in the 1990s; Walls et al. 2002, Morrison et al. 2004), a reduction in horseshoe crab populations, and a consequent reduction in red knot food resources (horseshoe crab eggs), body condition during spring migration, and annual survival (Baker et al. 2004) are major concerns for population that migrate along the U.S. Atlantic coast (González et al. 2006, Niles et al. 2007).

Actions to conserve horseshoe crabs have included reduced harvest quotas, more efficient use of crabs as bait, closure of the harvest in certain seasons and places, and the designation of a sanctuary off the mouth of Delaware Bay (Niles et al. 2007). The latest information is that the crab population may have stabilized, but there is no evidence of recovery (Niles et al. 2007).

Fragility: In North and South Carolina, the red knot only occupies limited coastal areas as seasonal stopovers on its long migration. Because these areas are so limited, protection is extremely important to prevent the decline of this species.

Trends: Global Short Term Trend: Declining to stable (+/-10% fluctuation to 30% decline); Global Long Term Trend: Moderate decline to relatively stable (25% change to 50% decline).

Natural Resource Management Guidelines

Conservation of this species ultimately depends on effective natural resource management of adequate breeding areas wintering areas, and stopovers along the Flyway (Niles et al. 2007). A necessary first step is better surveillance of birds as they migrate to identify important stopovers and key wintering grounds.

In North Carolina, red knots are known to forage in shore areas and coastal mudflats during spring and fall migrations (Niles et al 2007). Controlling the impact of disturbances in these areas during peak migration times is important. However, more research is necessary to pinpoint exactly when and where minimizing disturbances will be most beneficial.

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Additional information can be found at www.natureserve.org/explorer

Boykin's Lobelia

(*Lobelia boykinii*)

Species Information

A perennial herb, 40-80 cm tall, with inconspicuous bract-like leaves. Leaves sessile, subulate or narrowly linear, to 2.5 cm long and 0.5 mm wide. Flowers are blue with a white eye at the throat, and the lower lip bearded at base (Gleason and Cronquist 1991). Blooms mostly from May into August, with flowering apparently dependent on fluctuating water levels. Habitat: cypress-gum depressions or ponds, wet pine savannahs and flatwoods. Some sites have continuous, shallow standing water; others are only seasonally very moist or inundated. *Lobelia boykinii* is an obligate outcrosser.

Conservation Status

Global Status: G2G3 - Imperiled
Global Status Last Reviewed: 9 Mar 2009
Global Status Last Changed: 6 May 1996
Reasons: Restricted to scattered populations in the southeastern Coastal Plain with a few disjunct occurrences in New Jersey and Delaware. Approximately 70 occurrences are believed extant, mostly in South Carolina and Georgia; the total remaining population is probably less than 10,000 plants. The species' wetland habitats were once common in the southeast but are now limited in number due to drainage for agriculture and development. In addition, many southeastern wetlands are threatened by a drawdown in the regional water table, a result of intense development over the last 10-20 years. Lack of disturbance, leading to succession, is also a threat. Populations in New Jersey have declined for unknown reasons.

State Status, North Carolina: S2—Imperiled
State Status, South Carolina: S3—Vulnerable

Degree of Threat: Moderate, non-imminent threat
Threat Scope: Moderate
Threat Severity: Moderate
Threats: Sites vulnerable to drainage (many populations have been lost to drainage), and conversion of habitat to tree farms or agriculture. Also threatened by lack of disturbance leading to succession (Southern Appalachian Species Viability Project 2002).
Fragility: *Lobelia boykinii* is an obligate outcrosser. This type of breeding system may limit seed production in small populations, as small populations typically have a reduced number of genotypes available for cross-pollination (reviewed by Ellstrand and Elam 1993). Also, inbreeding depression effects (e.g., lower seed set, reduced germination) are typically more severe in small populations of self-incompatible species, such as *L. boykinii* (Bates 1996, Royo et al. 2008, Moreno 2003). This problem is exacerbated by this species' confined home range, which consists of isolated populations in only eight states.

Trend: Global Long Term Trend: Substantial decline (decline of 50-75%).

Natural Resource Management Guidelines

Preventing drainage of cypress-gum depressions or ponds, wet pine savannas, and flatwoods that supporting existing populations of *Lobelia boykinii* should be the first priority for conservation action. However, because this species is an obligate outcrosser, merely conserving the habitat surrounding small, isolated populations will not ensure survival. Conservation measures for this species should include focus on:

- Careful monitoring and census-taking of existing populations.
- Conservation of the largest, most genetically viable populations (as identified via monitoring), through preventing drainage of suitable habitats.
-

A secondary priority should be the protection of smaller existing populations, including:

- Conservation of suitable habitats nearby large *Lobelia boykinii* populations to allow for natural recruitment and population expansion.
- Protection of habitat supporting smaller populations.
- Possibly, introduction of genetically dissimilar individuals into smaller existing populations to bolster their genetic health.

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Additional information can be found at www.natureserve.org/explorer

Coastal Beaksedge

(*Rhynchospora pleiantha*)

Species Information

Strongly clonal perennial sedge with abundant basal leaves 10-20 cm long and less than 1 mm wide; many very slender flowering stems reach up to 0.4 m tall, each with 1-3 groups of spikelets (flowering/fruiting structures) near the tips of stems. Rhizomes pale, slender, and easily broken during excavation. Found on exposed sandy shores of freshwater ponds and lakes, where the water level fluctuates naturally from rainfall cycles (e.g., from local water table rise and fall). Most ponds inhabited by this species are "sinkhole ponds," formed by dissolution of underlying limestone and subsequent collapse of overlying sediments. These waterbodies typically have no inlets nor outlets. Their basins vary from shallow to deep and bowl-shaped (20 m deep in some cases). *Rhynchospora pleiantha* occupies the mid-shore zone, above where the substrate is peaty or muddy and below where the substrate is very sandy and droughty. It occurs in the company of other sedges, grasses and herbs, most of which are pondshore specialists. Flowers June-August. (McMillan 2007)

Conservation Status

Global Status: G2G3 - Imperiled
Global Status Last Reviewed: 10 Mar 2009
Global Status Last Changed: 10 Mar 2009
Reasons: *Rhynchospora pleiantha* is known from 35 current and 20 (probably 20-30) historical occurrences. More than half of occurrences believed extant are in Florida, where they tend to be found on the East Gulf Coastal Plain. Also occurs in southeastern North Carolina, eastern South Carolina (1 occurrence), southern Alabama, and western Cuba; considered historical in Georgia. Major threats are development of pond margins for housing, raking or removal of pondshore vegetation for aesthetic purposes, ORV/ATV traffic, lowered water table from industrial or domestic withdrawal, and grazing by cattle.

State Status, North Carolina: S2—Imperiled
State Status, South Carolina: S1—Critically Imperiled

Degree of Threat: Substantial, imminent threat
Threat Scope: High
Threat Severity: High
Threat Immediacy: Moderate
Threats: Highly threatened by land-use conversion, habitat fragmentation, forest management practices, and succession (Southern Appalachian Species Viability Project 2002). Major threats are development of pond margins for housing, raking or removal of pondshore vegetation for aesthetic purposes, ORV/ATV traffic, lowered water table from industrial or domestic withdrawal, and grazing by cattle.

Fragility: *Rhynchospora pleiantha* occupies a narrow environmental niche within a confined home range, making this species especially vulnerable to degradation of its suitable habitat.

Trend: Global Long Term Trend: Substantial decline (decline of 50-75%).

Natural Resource Management Guidelines

Monitoring and census-taking of existing populations will prove very valuable in conservation measures for *Rhynchospora pleiantha*. Once the location and size of these extant populations is understood, specific conservation measures should include:

- Avoiding development near ponds supporting *Rhynchospora pleiantha* populations.
- Preventing drainage of these ponds.
- Limiting industrial or domestic water withdrawal from the water table near these ponds.
- Preventing pondshore vegetation removal for aesthetic purposes.
- Restricting ORV/ATV access in areas with suitable ponds.
- Limiting cattle grazing near suitable ponds.

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Additional information can be found at www.natureserve.org/explorer

LeBlond's Goldenrod

(*Solidago villosicarpa*)

Species Information

Asteraceae; non- to short-rhizomatous, perennial herb. The plants reach 1.5 meters high and stems are 1-1.5 cm thick. The species is rarely rhizomatous. The best populations occur in Coastal Fringe Evergreen forest with live oak, sand laurel oak, and loblolly pine. Other collections are within a Live Oak Thicket/ Maritime Forest and a Mesic Hardwood Forest (LeBlond 2004). Endemic to the outer Coastal Plain and always associated with a maritime influence (including freshwater tidal habitats). Extant populations occur on mainland areas either along the coast or adjacent to inland tidal systems on upland terraces that gradually to abruptly slope to adjacent tidelands (swamps, marshes, or creeks). The communities are characterized by moderately dense to dense canopies of oak, hickory, and pine and often have open understories. One site may have been a longleaf pine community before it was logged, although there is no evidence to suggest that this species is adapted to fire-dependent longleaf pine communities. This species is generally associated with natural and human-caused disturbances. However, it is apparently not fire-adapted, but it may be fire-tolerant. Two sites were impacted by hurricanes in 1996 and 1998, and plants there showed a "vigorous response" to tree blow-downs. Plants also appear to respond positively to canopy openings from logging and have been found in roadbeds. Sunlight is beneficial to the species and increases branching in inflorescence, consequently increasing flower and seed production. Populations have been observed flowering in more shaded conditions, but with fewer and less robust individuals. It is probable that prolonged full shading is detrimental to populations.

Conservation Status

Global Status: G1 – Critically Imperiled
Global Status Last Reviewed: 7 Sep 2005
Global Status Last Changed: 19 Jul 1993
Reasons: A recently described species of goldenrod (LeBlond, 2000) known only from a few sites on the outer Coastal Plain in North Carolina.

State Status, North Carolina: S1—Critically Imperiled
State Status, South Carolina: N/A

Threats: Invasive species present a low threat, particularly mimosa (*Albizia julibrissin*).

Fragility: Vulnerable to decline with canopy closure, but responds favorably to disturbance, including hurricanes (cf. LeBlond 2000). This species exists in as few as four known populations, all within North Carolina's Coastal Plain, making it exceedingly vulnerable to stochastic events.

Trend: Global Short Term Trend: Declining (decline of 10-30%).

Natural Resource Management Guidelines

Solidago villosicarpa is a recently described species with a very limited home range. At this point, effective conservation of this species relies on:

- Protection of existing populations. These extant populations should receive proactive management to ensure maintenance of a favorable disturbance regime.
- Additional research on habitat requirements, especially regarding the preferred degree and frequency of disturbance.
- Inventory to indentify additional populations, based on known habitat preferences, and protection of those populations if and when found.

References

LeBlond, R.J. 2000. Solidago villosicarpa (Asteraceae: Astereae), a rare new Southeastern Coastal Plain endemic. Sida 19(2): 291-300.

NatureServe. 2010. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: September, 2010).

Additional information can be found at www.natureserve.org/explorer

Many-flowered Grass-pink

(*Calopogon multiflorus*)

Species Information

Spring-flowering orchid with most to all flowers on a stalk opening at once. Plant is scapose, erect, rigid, glabrous, 15-45cm tall. Stem green below and dark purple above. Occasionally two stems are produced from the same corm. Leaves (when present) one or two, basal, narrowly linear, long-acuminate, firm and rigid, 4-19 cm long, mostly less than 5mm wide. Flowers are vividly deep magenta to crimson with slender pedicellate ovaries 6-10mm (Correll 1950). The flowers are infrequently pale pink (Luer 1972). It flowers from early March (rarely in February) to July (Correll 1950, Luer 1972), but primarily in April (Luer 1972). *Calopogon multiflorus* has a preference for well-drained soils of open, damp to somewhat drier pine savannas-flatwoods and meadows. *Calopogon multiflorus* is often found flowering in palmetto fields or pinelands that have been burned the preceding winter; in burned flat pinelands, this orchid is able to return with vigor (Luer 1972). It is also sometimes found in pine barrens among saw palmetto, on the edge of hammocks, or in pitcher plant bogs.

Conservation Status

Global Status: G2G3 - Imperiled
Global Status Last Reviewed: 9 Mar 2009
Global Status Last Changed: 18 Jun 2000
Reasons: A Southeastern Coastal Plain endemic, predominantly found in Florida (where scattered over much of the state), with a few outlying occurrences in Alabama, Mississippi, Louisiana, South Carolina, North Carolina, and, historically, Georgia. This species requires fire to open up habitat and stimulate flowering. Approximately 34 occurrences are believed extant range-wide. Historically described as common in central Florida, but only about 6,000 plants are estimated to remain in that state. Much of this species' habitat has been destroyed by land-use conversion (to pine plantations, for example), habitat fragmentation, and fire suppression. To some degree, these threats continue to impact the species currently; however, many remaining occurrences are located on state or federal lands. Nevertheless, the fire requirements of this species may not be able to be met on all of these otherwise protected sites.

State Status, North Carolina: S1—Critically Imperiled
State Status, South Carolina: S1—Critically Imperiled

Degree of Threat: Moderate and imminent threat
Threat Scope: Moderate
Threat Severity: High
Threat Immediacy: High
Threats: Highly threatened by land-use conversion and habitat fragmentation (resulting from, e.g., conversion to pine plantations) as well as incompatible forest management practices such as fire suppression (Chafin 2000, Southern Appalachian Species Viability Project 2002).

Fragility: Requires fire to open up habitat and stimulate flowering. Unknown how long it can remain dormant through adverse conditions. Is also endemic to the Southeast, where it has a very restricted range.

Trend: Global Short Term Trend: Declining (decline of 10-30%).

Natural Resource Management Guidelines

This orchid needs prescribed fire in order for it to persist at sites (Schotz 2004). Conservation of shrinking pine-barren habitats alone will not protect this species' habitat—it requires a carefully controlled fire regimen without which it cannot flower and reproduce. Calopogon multiflorus exhibits a pronounced fire-stimulated flowering response to dormant season fire (January to early March), whereas it rarely flowers in years without fire or following lightning season (mid-March to mid-June) burns in peninsular Florida (Goldman & Orzell 2000). More information is needed on the exact characteristics of a fire regimen that will most benefit *Calopogon multiflorus*.

References

Chafin, L. G. 2000. Field guide to the rare plants of Florida. Florida Natural Areas Inventory, Tallahassee. [http://www.fnai.org/FieldGuide/]

Corell, D.S. 1950. Native orchids of North America, north of Mexico. Waltham, MA: Chronica Botanica.

Goldman, Douglas H. and Steve L. Orzell. 2000. Morphological, geographical, and ecological re-evaluation of Calopogon multiflorus (Orchidaceae). Lindleyana 15(4): 237-251. 2000.

Luer, C. A. 1972. The native orchids of Florida. New York Botanical Garden, New York. 293 pp.

NatureServe. 2010. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer. (Accessed: September, 2010).

Schotz, A. 2004. Rangewide status survey on *Calopogon multiflorus*, many-flowered grass-pink. Alabama Natural Heritage Program, Montgomery, AL. Unpublished report for the United States Fish and Wildlife Service. 17 pp. + 3 appendices.

Southern Appalachian Species Viability Project. 2002. A partnership between the U.S. Forest Service-Region 8, Natural Heritage Programs in the Southeast, NatureServe, and independent scientists to develop and review data on 1300+ regionally and locally rare species in the Southern Appalachian and Alabama region. Database (Access 97) provided to the U.S. Forest Service by NatureServe, Durham, North Carolina.

Additional information can be found at www.natureserve.org/explorer

Fitzgerald's Sphagnum

(*Sphagnum fitzgeraldii*)

Species Information

Submerged moss (but becoming seasonally stranded), small, lax, pale-green (whitish when dry), sprawling in thin mats. Terminal bud rather large; stem leaves relatively large, much like branch leaves and sometimes larger, concave(Crum and Anderson 1981). Monoicous. Spores 38-48 µm; *Sphagnum fitzgeraldii* is barely submerged in winter and spring, completely dry in summer, growing on sand in open, weakly minerotrophic habitats in wet, burned-over pinelands, low savannas, and pocosin margins (Crum and Anderson 1981). Commonly in prostrate mats on damp sand, often in recently burned or cleared areas, also occasionally floating in ditches; low elevations (McQueen and Andrus 2007). Inhabits pond edges, wet depressions in pine forests, shrub bogs (Reese 1984).

Conservation Status

Global Status: G3 - Vulnerable
Global Status Last Reviewed: 11 Mar 2009
Global Status Last Changed: 11 Mar 2009
Reasons: *Sphagnum fitzgeraldii* is not a common moss (Reese 1984). It occurs near the coast and grows on sand in wet pinelands, low savannas, and pocosin margins from Virginia south to Florida and Alabama, Mississippi, and Louisiana. The draining and filling of coastal plain wetlands is a serious threat to this species; even on conservation lands, isolated wetlands remain threatened by off-road vehicle use.

State Status, North Carolina: S2S3 – Imperiled
State Status, South Carolina: SNR – Unranked

Degree of Threat: Localized substantial threat
Threat Scope: Low
Threat Severity: Moderate
Threats: The draining and filling of coastal plain wetlands is a serious threat to this peat moss. Isolated ponds are an important habitat for it. On conservation lands, isolated wetlands remain threatened by off-road vehicle use.

Trend: Global Short Term Trend: Rapidly declining (decline of 30-50%).

Natural Resource Management Guidelines

Sphagnum fitzgeraldii relies on quality Coastal Plain wetland habitat for survival, and this habitat is shrinking rapidly. Effective conservation for this species will rely on:

- Protecting suitable wetlands from development, dredging/draining, and filling.
- Restricting access and prohibiting off road vehicle/all-terrain vehicle use near wetland areas known to have *Sphagnum fitzgeraldii*.
- Determining other possible causes for this species' trend of rapid decline (aside from wetland degradation).

References

Crum, H.A., and L.E. Anderson. 1981. Mosses of eastern North America. 2 Volumes. Columbia Univ. Press, New York. 1328 pp.

McQueen, C.B., and R.E. Andrus. 2007. Sphagnaceae Dumortier. In: Flora of North America Editorial Committee. 2007. Flora of North America, Vol. 27. Bryophyta, Part 1. Oxford University Press.

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Reese, W.D. 1984. Mosses of the Gulf South: From the Rio Grande to the Apalachicola. Louisiana State University Press, Baton Rouge. 252 pp.

Additional information can be found at www.natureserve.org/explore

Appendix B
Analysis of Urbanization Response of Sandhills Reptiles

Report on Urban Thresholds to Use for Rare Snake and Lizard Modeling

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Goal of Project:

The goal of this project was to generate fairly accurate quantitative thresholds of urbanization intensity for two species of rare snakes (southern hognose and northern pine snake) and one species of rare lizard (mimic glass lizard). The thresholds, which should roughly indicate upper tolerance limits for the animals, can then be used to adjust vegetation-based maps of appropriate habitat, in order to identify high priority sites for future conservation of these three species.

Results:

Both the snake and lizard locations and the set of available background conditions in the broader study area were characterized by rather low degrees of average urbanization. The lack of contrast between animal points and the broader landscape (see the histograms in Figure 1) made determining urban thresholds more difficult. However, useful statistical thresholds were derived for two out of the three reptile species and 3 out of 4 of the urbanization metrics employed. Both the southern hognose and the northern pine snake appeared to be restricted in their known, recent (post 1990) locations to sites with low levels of road density (1 km radius) and impervious surface (1 km and 5 km radii). Classification and Regression Tree (CART) models indicated that for southern hognose and northern pine snakes, key upper limit thresholds occurred at road densities of 5.15 and 6.015 km roads/km^2 (at a 1 km radius), respectively. The southern hognose threshold for impervious surface (1 km) was much lower than that recorded for the pine snake (0.73 vs. 8.72 % impervious, respectively). However, the lower threshold for the hognose snakes resulted in 92 out of 471 snakes of that species falling above the threshold, whereas no snakes of either species were found at 1 km road densities exceeding the thresholds listed above. None of the pine snake locations exceeded the 8.72 % impervious surface threshold at the 1 km radius. The 5 km impervious surface threshold for southern hognose snakes (0.59%) was even lower than the 1 km, but again 106 snake locations fell in areas with greater urbanization intensity. Perhaps more informative thresholds for impervious surface for the hognose snakes could be derived from simple visual inspection of the histograms presented in Figure 1. The pine snake threshold for impervious surface at a 5 km radius was 1.44%, and only 18 snakes out of 228 were found in locations that exceeded this value.

Neither set of snake locations produced useful upper limit thresholds for road density at a 5 km radius. This may be more reflective of the limitations of the comprehensive road layer used to create the density surfaces. The US Census TIGER Roads database includes all kinds of roads, even those with very little expected impact on snake populations, such as gated gravel roads on timber plantations or wildlife management areas. At the larger radius, there are few areas in the state that are more than 5 km away from some road or another. Traffic density (like road density but with DOT traffic data incorporated in) would be more useful in this respect, but no traffic data was available for South Carolina. Even if traffic thresholds were derived from the NC snake locations, they could not be projected onto the South Carolina landscapes of interest.

Only four recent locality points for the mimic glass lizard were available, so any statistical approach to quantifying the sensitivity of this species would be questionable. However, the four mimic glass lizard locations were all from low road density and low impervious surface areas, suggesting that this species may indeed be quite sensitive to urban development (Table 1). I suggest using the maximum values recorded for the urbanization variables at the four mimic glass lizard locations as working thresholds, until more data on the distribution of these secretive lizards is available.

Table 1. Summary Statistics

		Urbanization Variables			
Species		**rdden1km**	**rdden5km**	**impsf1km**	**impsf5km**
Ophisaurus mimicus	mean	0.748	0.837	0.209	0.370
(Mimic Glass Lizard)	min	0.435	0.462	0.066	0.089
n=4	max	1.034	1.057	0.451	0.884
Pituophis melanoleucus	mean	2.942	2.576	1.008	0.884
(Pine Snake)	min	0.078	0.891	0.000	0.047
n=228	max	5.877	4.449	8.388	4.712
Heterodon simus	mean	3.031	2.483	0.847	0.724
(Southern Hognose)	min	0.243	0.608	0.000	0.047
n=471	max	5.421	3.440	20.546	9.061
random points	mean	1.814	1.793	1.367	1.344
n=5000	min	0.000	0.000	0.000	0.000
	max	11.978	9.849	45.243	32.247

Summary statistics for the two rare snake species also indicated that the snakes were sensitive to urbanization, at least as measured with the impervious surface variables (Table 1). However, mean road density values for the snakes were higher than the mean values recorded for the random background points representing the available landscape conditions in North and South Carolina. Fortunately from a conservation perspective, the mean background road densities and impervious surface values were all rather low, indicating that the bulk of the coastal plain areas of both states remain in rural condition. Even with the low background urbanization levels, the snakes and glass lizard were still found on average in sites with less human impacts. The lack of a consistent and corresponding road density effect is most likely due to the fact that the great majority of the snake locations came from specimens that were found alive or dead on roads.

The upper limit urbanization thresholds identified above for the two rare snakes should be useful for conservation planning purposes around military bases in the coastal plain and Sandhills regions of the Carolinas. I would be happy to assist with any further snake or lizard distributional modeling exercises that are needed to identify the off- and on-base sites with the greatest potential for harboring these reptiles.

Methods:

Snake and lizard location data:

For each of the three species I compiled all of the locality points that were easily accessible in digital formats. The data came from a combination of my own set of rare snake location data that I had previously put together (from the NC Museum of Natural Sciences database and the field notes of Jeff Beane and a small number of other reputable herpetologists), and from the Natural Heritage Databases for North and South Carolina. For the NHP data I used the files that Regan Lyons had been using in her previous modeling exercises with these species. The snake and lizard points were converted to UTM's, and truncated to only include those animals which were found after 1990. This cutoff seems like a reasonable way of assuring that snake location points from previous decades are not being illegitimately compared to contemporary habitat conditions. Such a mismatch would otherwise tend to underestimate the urban sensitivity levels of formerly widespread species like the southern hognose, which now may be quite restricted in range thanks to rapid habitat loss in the coastal plain region.

Urbanization Data:

I created four GIS layers representing urbanization conditions at various spatial scales of reference. Two of these focused on road density at the 1 and 5 km scales. I created the road density layers using the spatial analyst density function in ARCGIS, applied to US Census TIGER roads shapefiles from the year 2000 (downloaded from ESRI). The TIGER road data has the advantage of being available in a relatively comparable format across many if not all of the states in the US. The data is not spatially projected, so I set the projection to be WGS 1984. After calculating the road density layers (using km^2 as the units, and 1000 and 5000 meters as the search distances), the layers were converted to UTM zone 17n.

The other two layers were impervious surface at the 1 and 5 km scales, and these were derived from the USGS impervious surface data I downloaded for much of NC and SC off of the USGS seamless data server. After truncating off the "noData" values (which are otherwise > 100% impervious), I used the neighborhood statistics function in ArcGIS to calculate mean impervious surface values at 1000 and 5000 meter radii, respectively. These values were also then converted to UTM Zone 17n.

In order to save quite a bit of analysis time, the road density and urbanization variables were calculated at 100 meter resolution. This is slightly less detailed information that what could be derived from the base data (the USGS impervious data is at 30 m native resolution), but when calculating average values at a 5 km radius from every cell across much of eastern NC and SC, the 100 m final resolution sped up the calculations considerably. It should still be possible to overlay the 100 m data against 30 m vegetation maps. Very few of the snake and lizard location records were recorded using high-accuracy GPS units, and so in fact even the 100 m resolution is an overestimate of the spatial accuracy of the reptile location points on average.

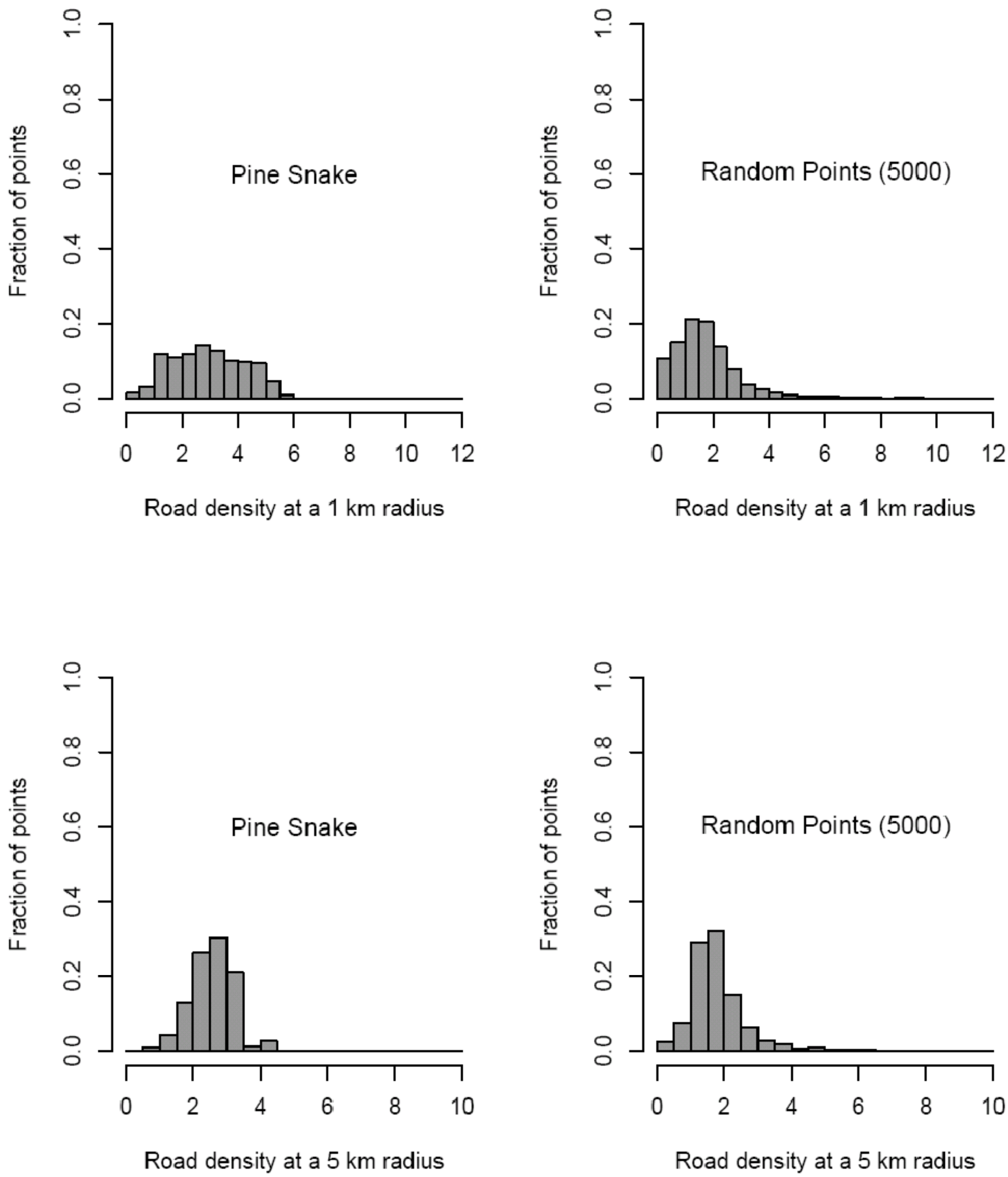
Summary Statistics:

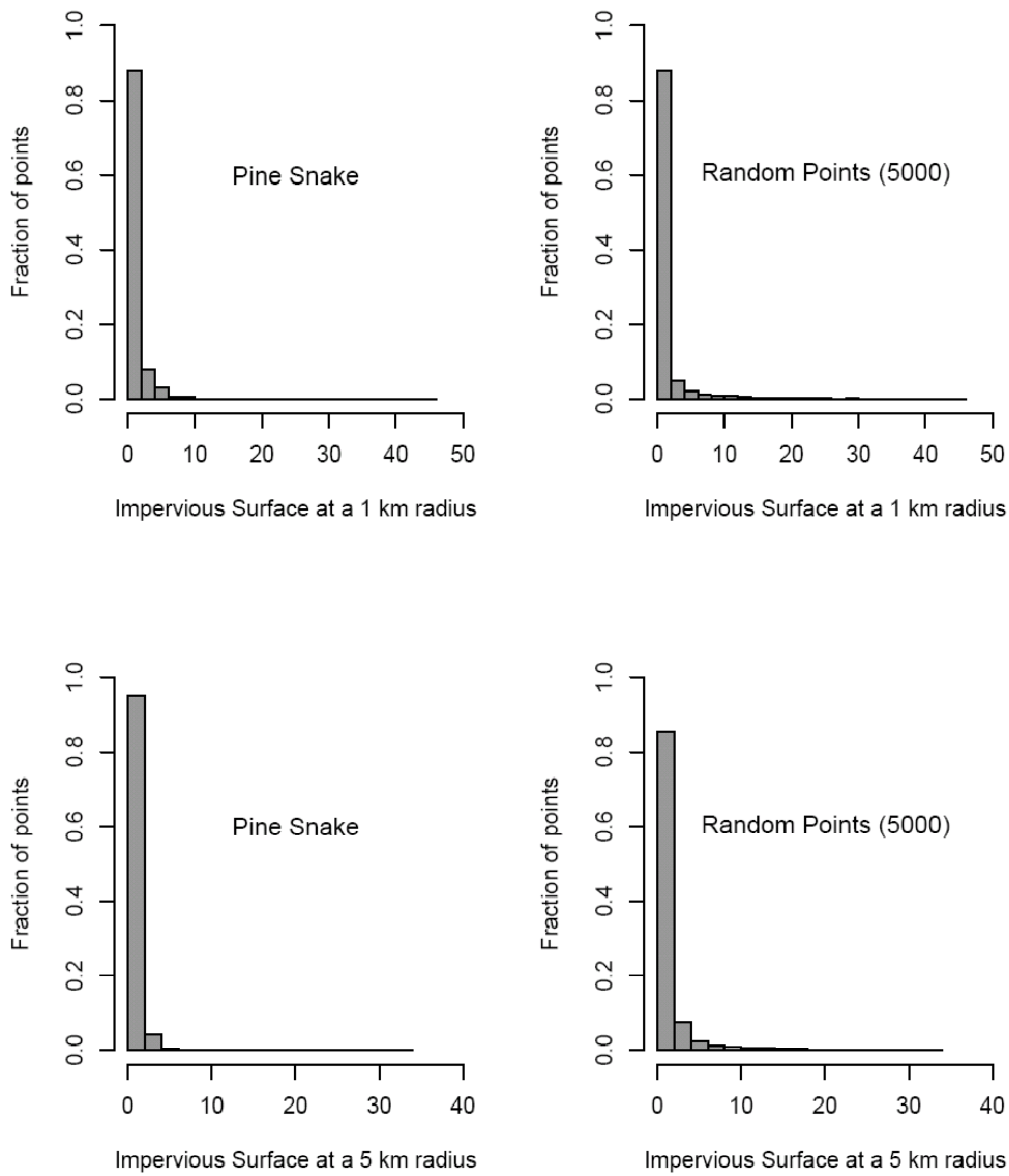
I calculated the mean, minimum, and maximum for each variable for each species. I also calculated the same parameters for a set of 5000 random points that were distributed across the larger study landscape (Figures 2 and 3) using Hawth's Tools extension for GIS. I then used R to compare the frequency distributions of the snake points and the random points for each of the four variables. Since the mimic glass lizard only had four recent records, no histograms were created.

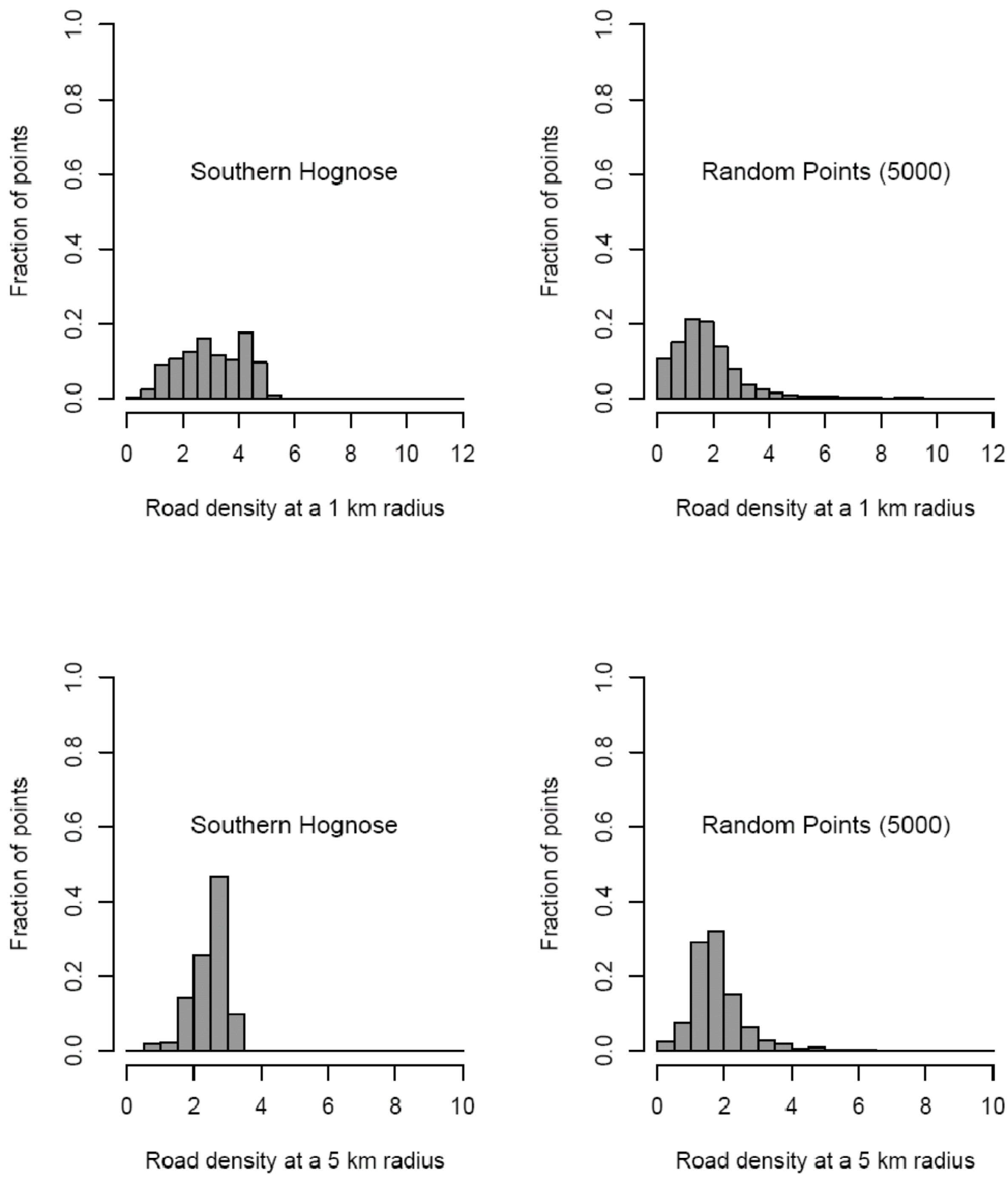
Classification and Regression Trees:

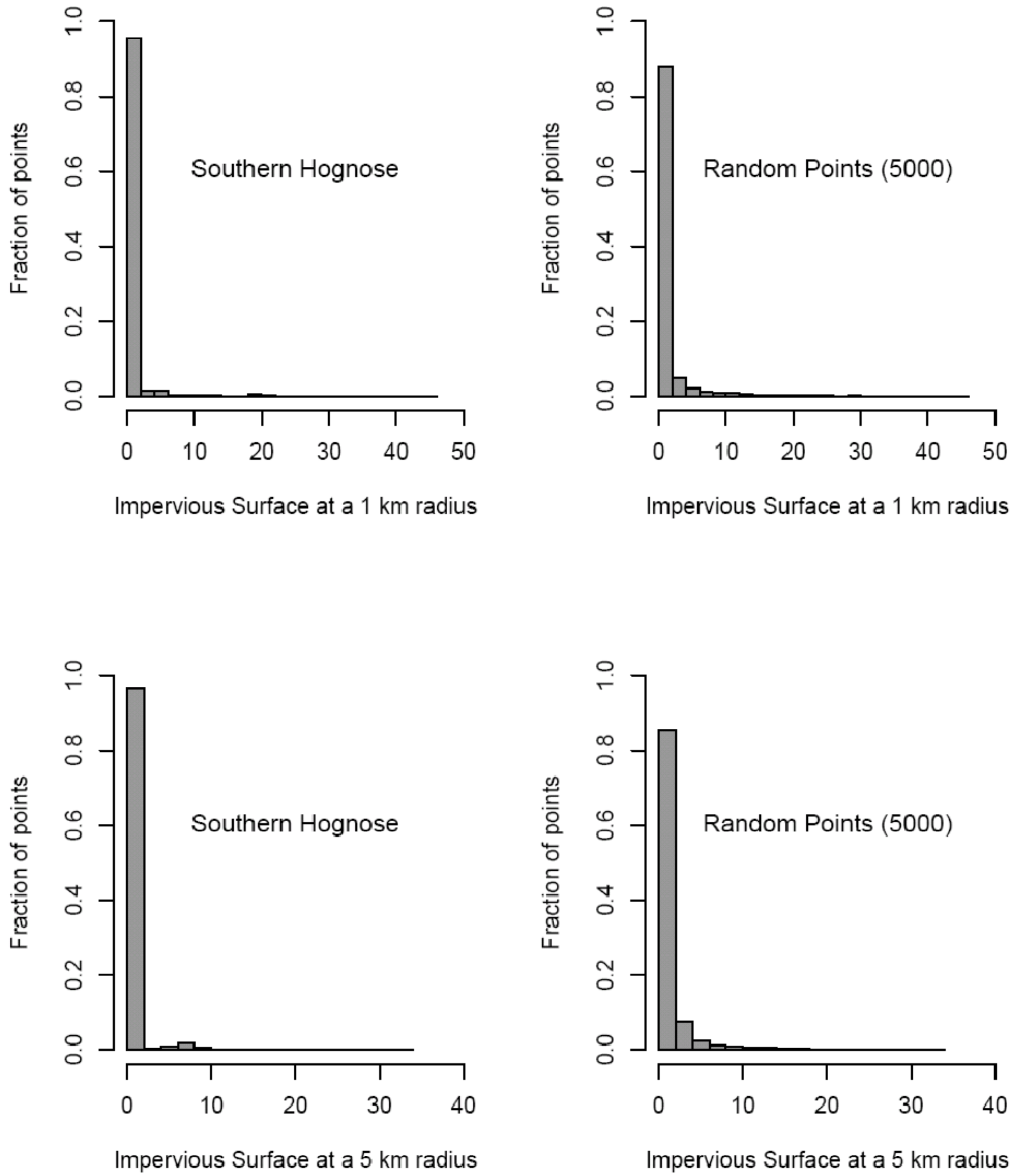
I added an equal number of random absence points to the locality data for each snake species (471 for southern hognose, and 228 for northern pine snakes). Here the random points were constrained in Hawth's Tools to fall outside of 500 m buffers created around each snake location. This prevented random points from perfectly coinciding with known snake habitat. I then used the Rpart package in R to create classification trees for each snake species as a function of each of the four urbanization variables. Since the first or second splits in CART models are generally the most informative, I limited the tree growth to only 2 splits. Interestingly, in all four cases for both species, the first split of the CART model indicated that that snakes would be found in more urbanized conditions than the random false absence points. I interpreted this pattern again as a result of the snake locations predominately falling on roads. Thus the initial threshold indicated by the CART models was basically an index of how much urbanization was associated with a typical road that these snakes were found on, not a very useful result for conservation planning purposes. The second split, however, for all but the road density 5 km tree model (which only had 1 split for both species), fell in the expected direction, indicating that the snakes would not be found when urbanization conditions exceeded some upper threshold. These are the thresholds I have reported in the results section above, and they can be used in combination with the attached GIS layers to map out favorable low-urban conditions for Pine Snakes and Southern Hognoses across North and South Carolina.

Figure 1. Histograms comparing urbanization conditions at the recent snake locations vs. the 5000 random background points:




Pine Snake
Fraction of points
0.0
0.2
0.4
0.6
0.8
1.0
0
10
20
30
40
50
Impervious Surface at a 1 km radius
Random Points (5000)
Fraction of points
Impervious Surface at a 1 km radius
Pine Snake
Fraction of points
0
10
20
30
40
Impervious Surface at a 5 km radius
Random Points (5000)
Fraction of points
Impervious Surface at a 5 km radius


Southern Hognose
Fraction of points
0.0 0.2 0.4 0.6 0.8 1.0
0 2 4 6 8 10 12
Road density at a 1 km radius
Random Points (5000)
Fraction of points
0.0 0.2 0.4 0.6 0.8 1.0
0 2 4 6 8 10 12
Road density at a 1 km radius
Southern Hognose
Fraction of points
0.0 0.2 0.4 0.6 0.8 1.0
0 2 4 6 8 10
Road density at a 5 km radius
Random Points (5000)
Fraction of points
0.0 0.2 0.4 0.6 0.8 1.0
0 2 4 6 8 10
Road density at a 5 km radius


Southern Hognose
Random Points (5000)
Fraction of points
Impervious Surface at a 1 km radius
Southern Hognose
Random Points (5000)
Fraction of points
Impervious Surface at a 5 km radius
0.0
0.2
0.4
0.6
0.8
1.0
0
10
20
30
40
50

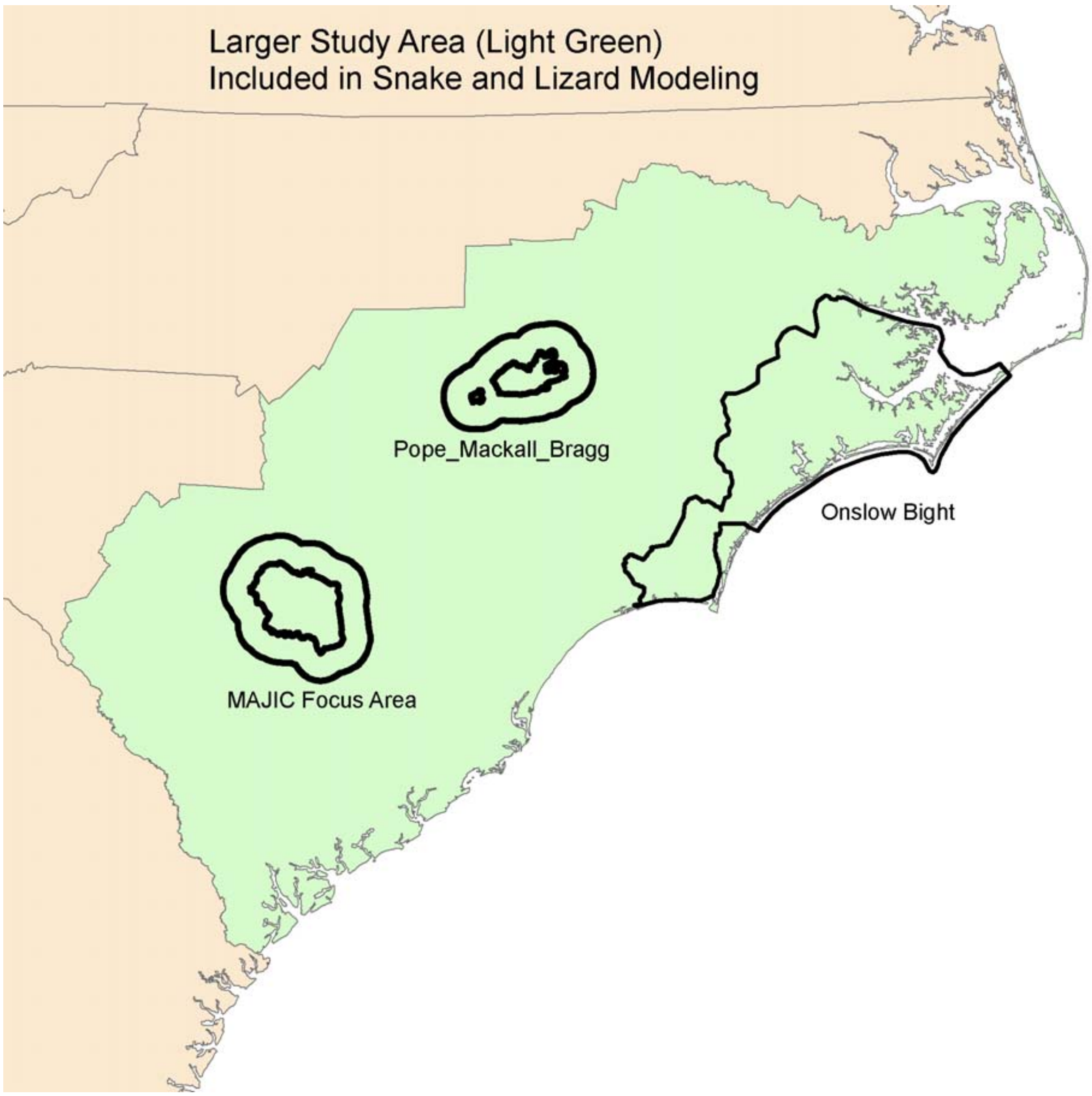


Figure 2: Larger Study Area (Light Green), with the military base and Onslow Bight project areas outlined in thick black lines (outer line = 10 mile buffer of base boundary/inner line).

5000 Random Points across Study Area

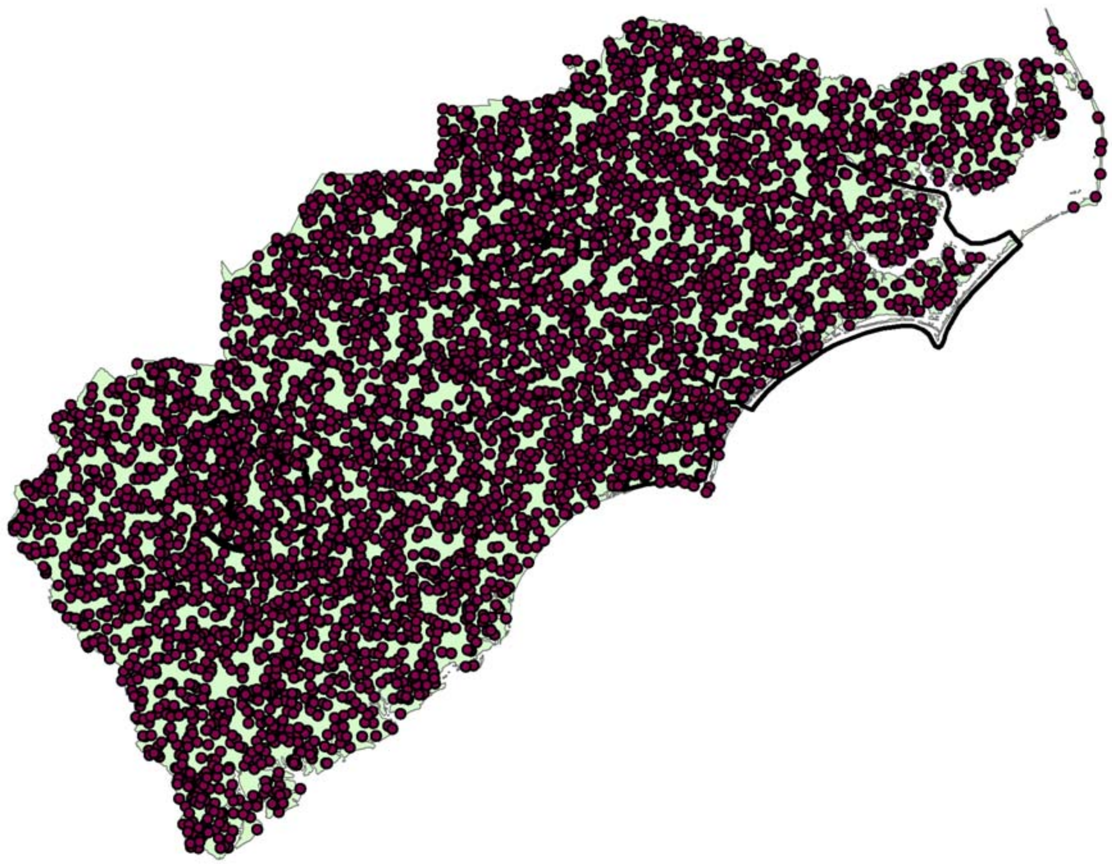


Figure 3.

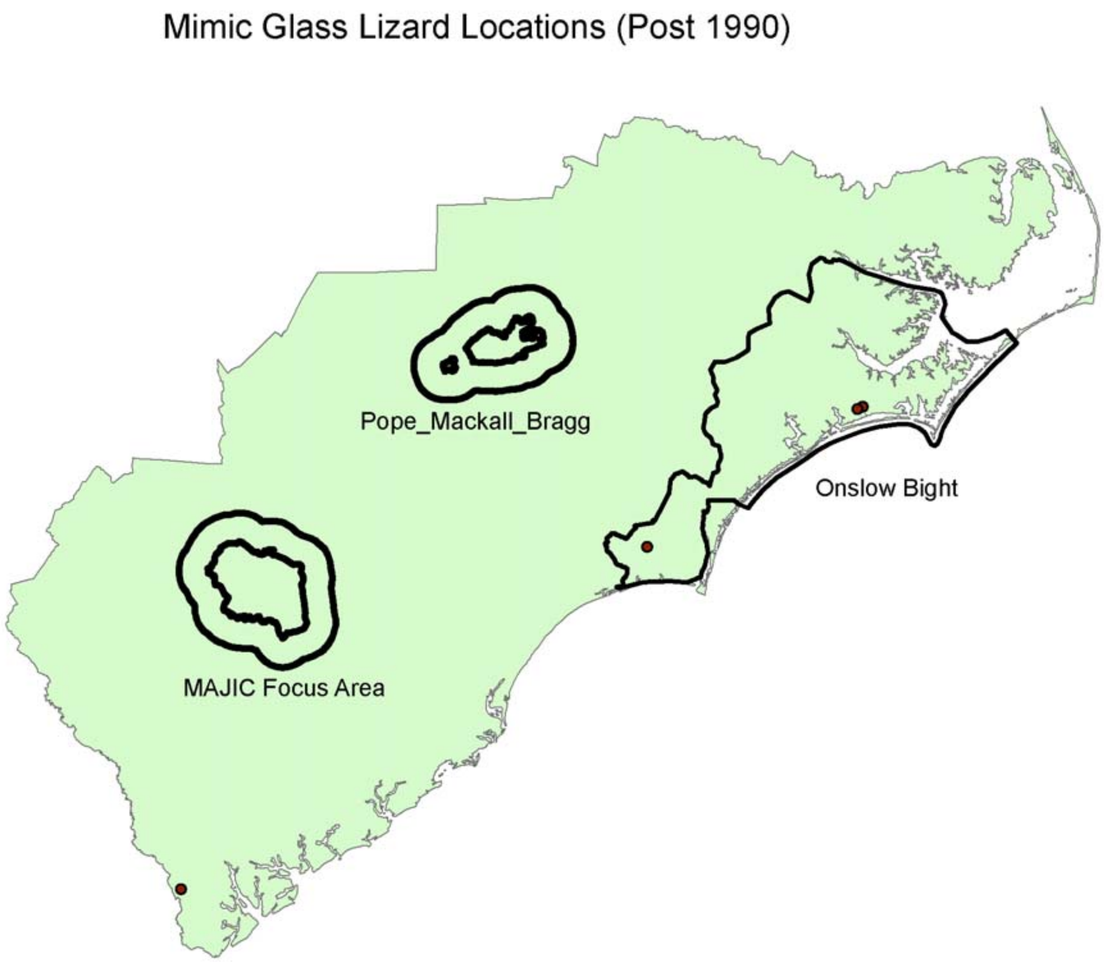


Figure 4. Mimic glass lizard locations, illustrated by red points

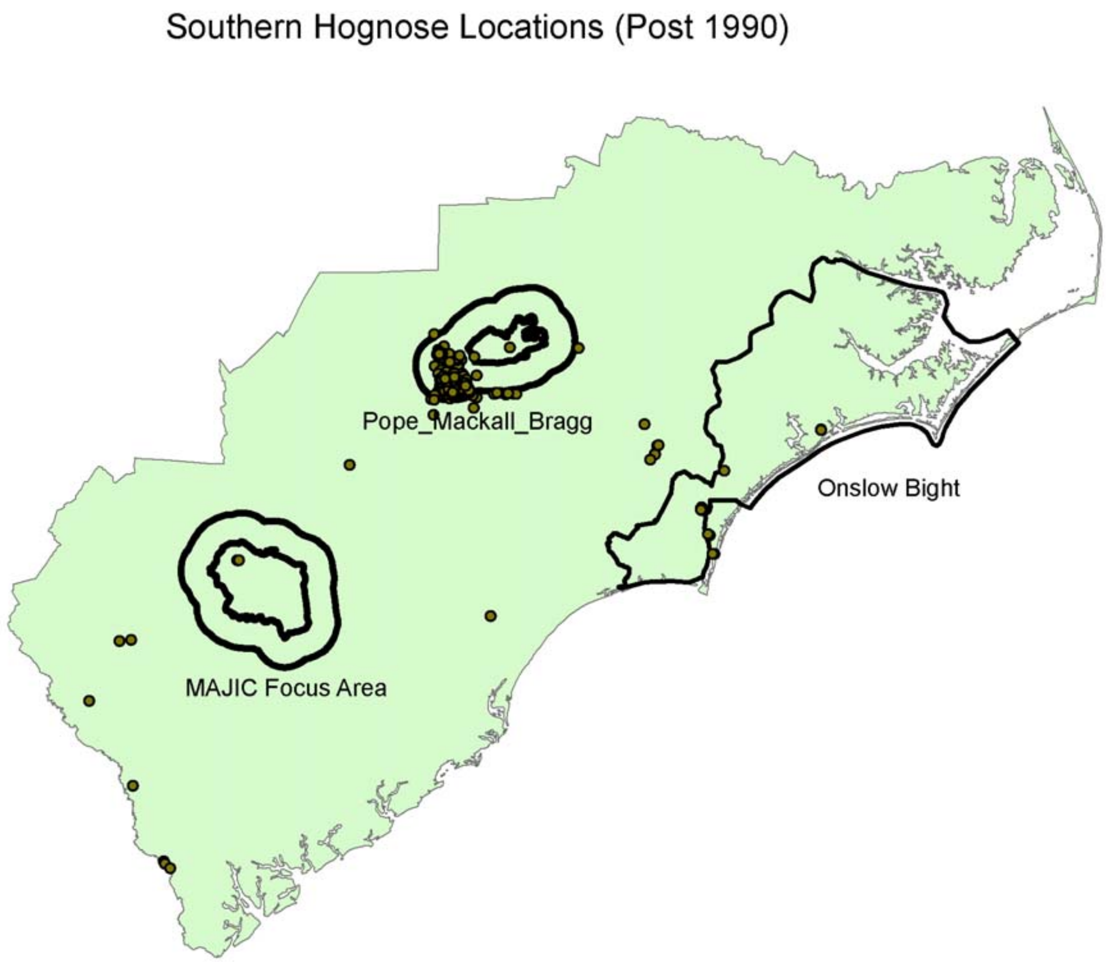


Figure 5. Southern Hognose snake locations (shown as medium green points)

Northern Pine Snake Locations (Post 1990)

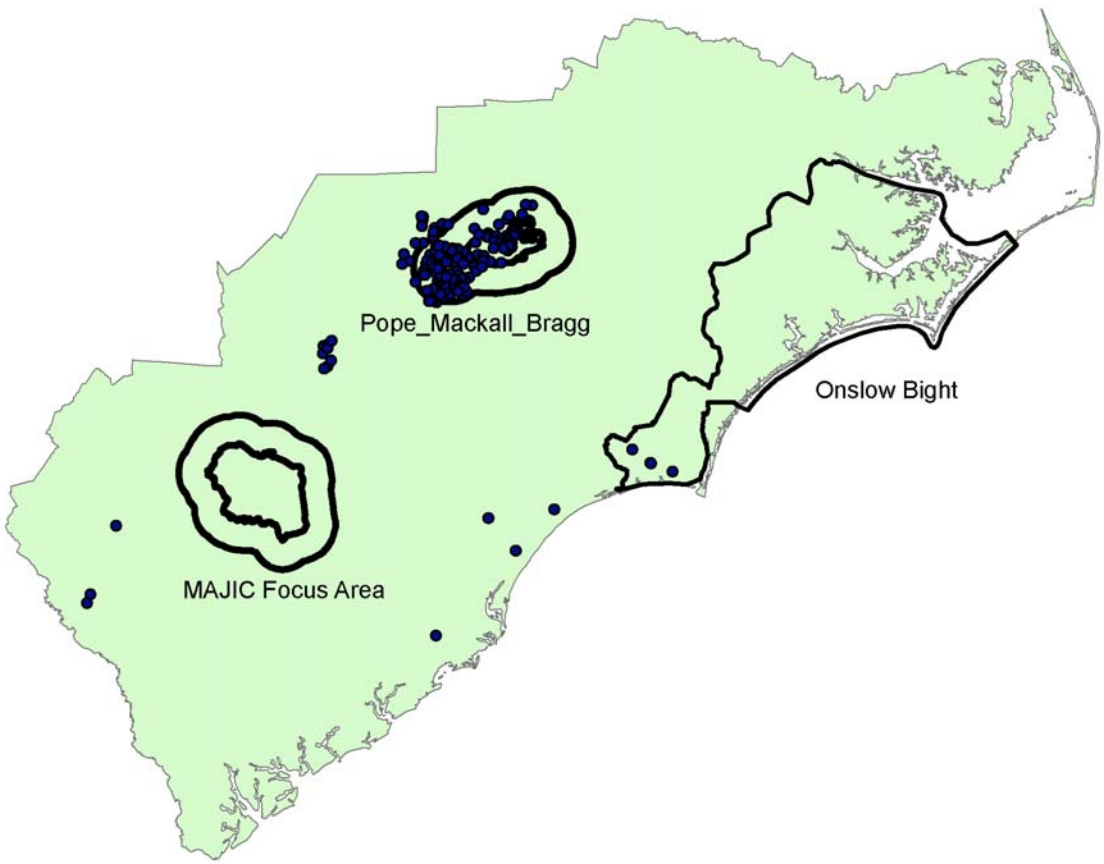


Figure 6. Northern Pine snake locations (blue points).

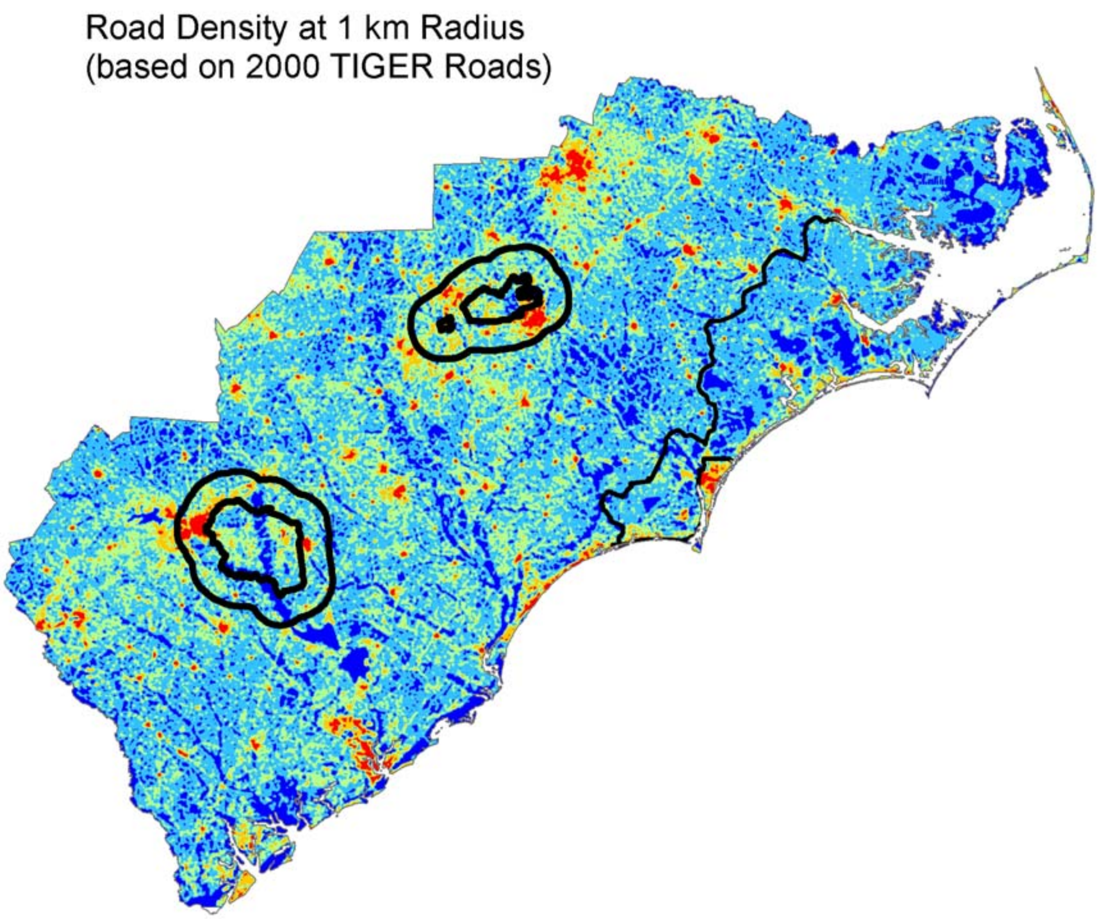


Figure 7. Road Density at a 1 km radius (5-classes via Jenks/Natural Breaks, red= highest)

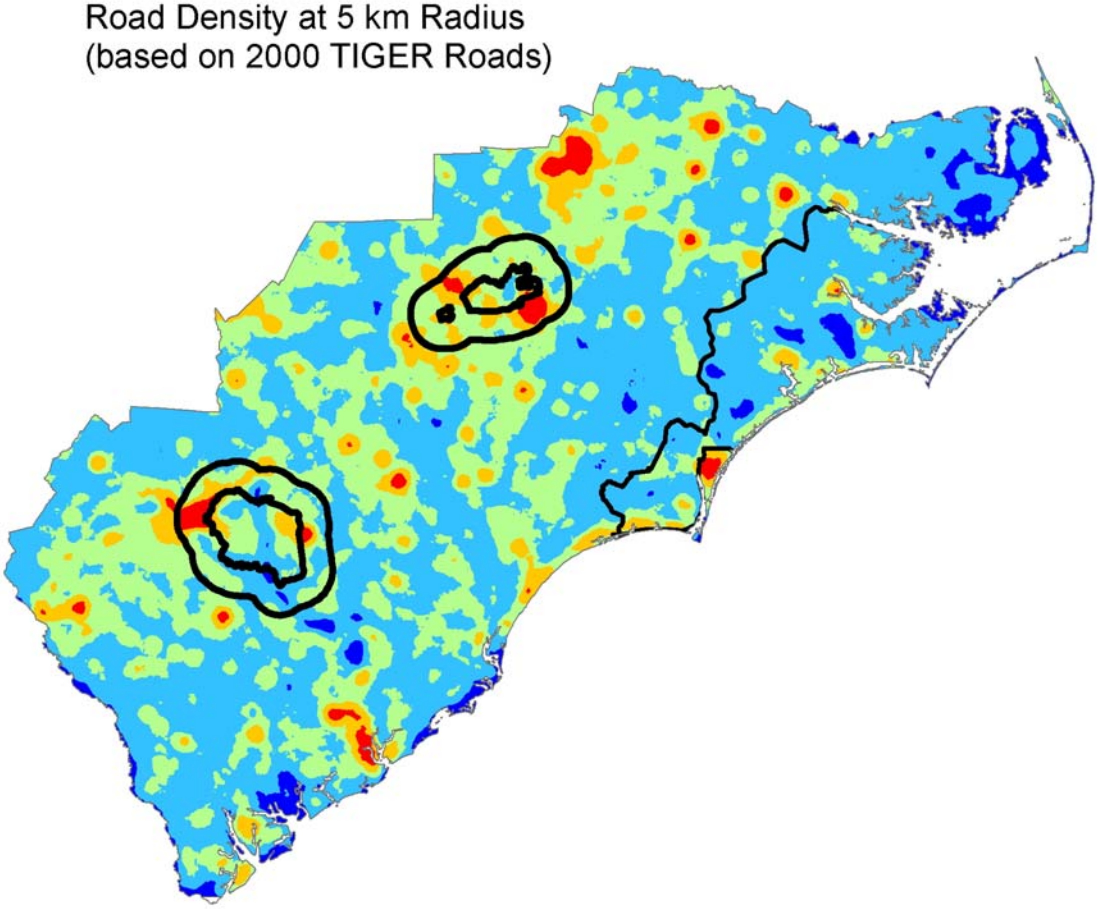


Figure 8. Road Density at a 5 km radius (5-classes via Jenks/Natural Breaks, red= highest)

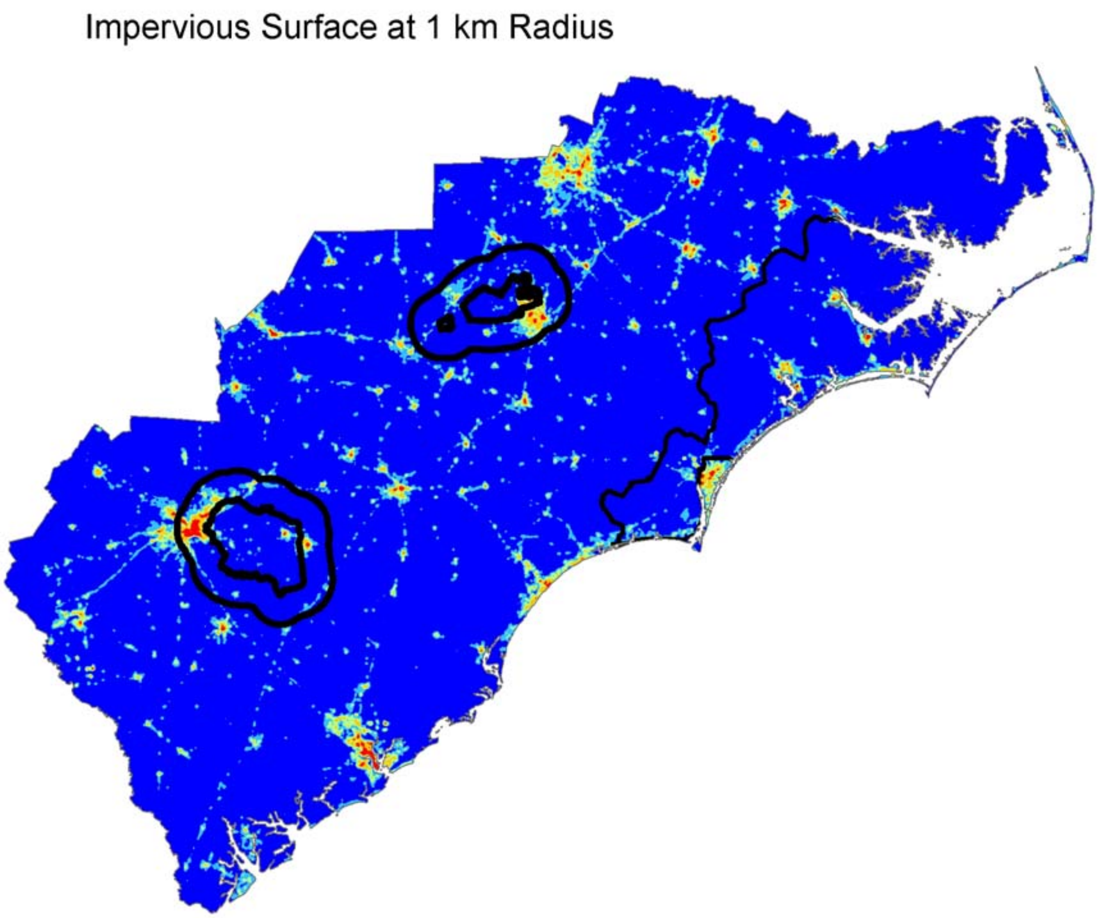


Figure 9. Impervious Surface at a 1 km radius

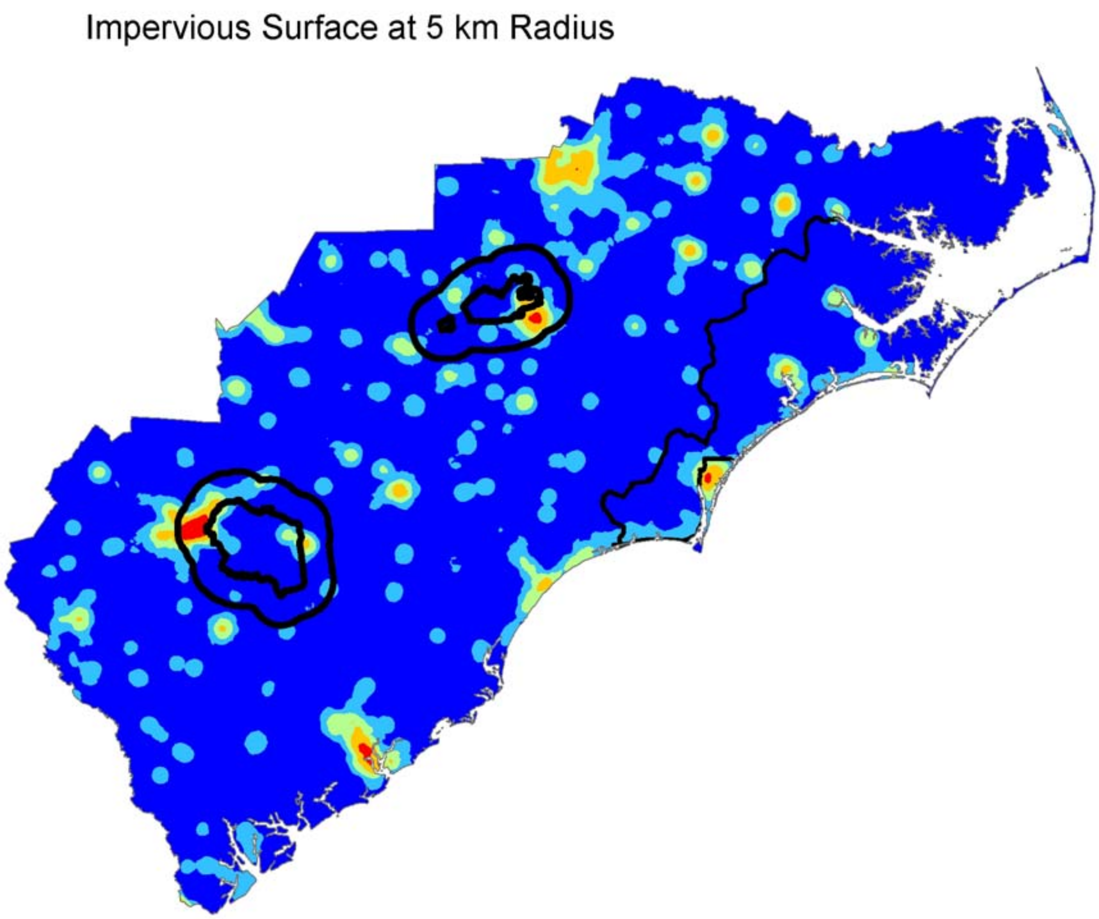


Figure 10. Impervious Surface at a 5 km radius

Appendix C
Patch Data – Metrics and Rankings

Table C-1
Patch Ranking for the Mimic Glass Lizard, Onslow Bight, NC

Patch ID	Overall Rank	Area (ha)	Area Rank	Patch Extent (m)[1]	Patch Extent Rank	Contig. Area (ha)	Contig. Area Rank	Average Road Density[2]	Road Density Rank
17388	**1**	119	**18**	1161	**1**	558	**4**	1.02	**15**
31100	**2**	132	**14**	780	**6**	560	**2**	1.06	**16**
16414	**3**	141	**9**	718	**11**	406	**15**	0.30	**4**
20404	**4**	165	**7**	742	**10**	497	**5**	1.34	**22**
29049	**5**	137	**12**	777	**7**	466	**6**	1.50	**25**
18937	**6**	131	**15**	712	**12**	623	**1**	1.52	**27**
20738	**7**	112	**21**	543	**24**	441	**8**	0.80	**10**
14852	**8**	337	**1**	1053	**2**	305	**27**	1.52	**26**
19964	**9**	141	**10**	652	**16**	559	**3**	1.73	**33**
19749	**10**	116	**20**	517	**30**	432	**9**	1.00	**14**
18360	**11**	90	**28**	639	**19**	357	**20**	0.85	**11**
21700	**12**	259	**4**	892	**5**	430	**11**	2.48	**45**
28993	**13**	139	**11**	656	**15**	341	**21**	1.42	**24**
18869	**14**	95	**25**	602	**20**	419	**13**	1.28	**20**
34329	**15**	330	**2**	1016	**4**	427	**12**	2.69	**48**
22057	**16**	92	**26**	562	**22**	431	**10**	1.33	**21**
29962	**17**	213	**5**	765	**8**	157	**47**	0.98	**13**
19271	**18**	131	**16**	651	**17**	310	**26**	1.23	**18**
28961	**19**	153	**8**	761	**9**	191	**41**	1.26	**19**
31053	**20**	178	**6**	680	**14**	339	**22**	2.02	**38**
34050	**21**	84	**32**	434	**42**	393	**16**	0.47	**5**
31551	**22**	83	**35**	533	**26**	296	**29**	0.51	**7**
16444	**23**	86	**30**	464	**39**	334	**23**	0.78	**9**
18507	**24**	290	**3**	1027	**3**	289	**31**	3.01	**50**
29375	**25**	65	**50**	562	**23**	358	**19**	1.34	**23**
27683	**26**	68	**47**	518	**29**	191	**40**	0.12	**3**
19236	**27**	108	**22**	521	**28**	182	**44**	1.18	**17**
25885	**28**	136	**13**	643	**18**	290	**30**	2.46	**44**
26552	**29**	69	**46**	528	**27**	188	**43**	0.65	**8**
23006	**30**	129	**17**	690	**13**	158	**46**	1.80	**36**
15851	**31**	96	**24**	511	**32**	378	**17**	2.22	**41**
34056	**32**	64	**51**	368	**52**	407	**14**	0.98	**12**
26084	**33**	98	**23**	476	**37**	327	**24**	1.77	**35**

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Table C-1, continued
Patch Ranking for the Mimic Glass Lizard, Onslow Bight, NC

Patch ID	Overall Rank	Area (ha)	Area Rank	Patch Extent (m)[1]	Patch Extent Rank	Contig. Area (ha)	Contig. Area Rank	Average Road Density[2]	Road Density Rank
2940	**34**	79	**37**	508	**35**	107	**50**	0.49	**6**
19099	**35**	119	**19**	510	**33**	268	**33**	1.74	**34**
20850	**36**	77	**39**	504	**36**	297	**28**	1.53	**28**
29818	**37**	78	**38**	584	**21**	251	**34**	1.82	**37**
19078	**38**	84	**33**	455	**40**	446	**7**	2.63	**47**
18517	**39**	86	**31**	541	**25**	360	**18**	3.71	**52**
24258	**40**	70	**44**	429	**45**	77	**52**	0.05	**1**
12188	**41**	68	**48**	400	**49**	156	**48**	0.10	**2**
31185	**42**	69	**45**	392	**51**	312	**25**	1.59	**30**
33829	**43**	75	**42**	418	**47**	251	**35**	1.70	**31**
25747	**44**	87	**29**	428	**46**	175	**45**	1.71	**32**
32688	**45**	75	**41**	431	**43**	238	**36**	2.21	**40**
26173	**46**	74	**43**	434	**41**	218	**38**	2.17	**39**
33010	**47**	91	**27**	398	**50**	224	**37**	2.26	**42**
34260	**48**	84	**34**	464	**38**	203	**39**	2.85	**49**
20027	**49**	83	**36**	430	**44**	288	**32**	3.09	**51**
31876	**50**	62	**52**	515	**31**	190	**42**	2.56	**46**
24906	**51**	77	**40**	508	**34**	100	**51**	2.40	**43**
20702	**52**	67	**49**	411	**48**	143	**49**	1.56	**29**

[1] Patch extent is referred to as "radius of gyration" in Fragstats.
[2] Units for road density are kilometers of roads per square kilometer, at 1 km radius.

Table C-2

Patch Ranking for the Mimic Glass Lizard, MAJIC Area, SC

Patch ID	Overall Rank	Area (ha)	Area Rank	Patch Extent (m)[1]	Patch Extent Rank	Contig. Area (ha)	Contig. Area Rank	Average Road Density[2]	Road Density Rank
3173	**1**	143	**2**	797	**1**	428	**1**	0.45	**1**
1341	**2**	95	**4**	647	**4**	406	**2**	0.51	**2**
1696	**3**	236	**1**	795	**2**	311	**4**	1.45	**6**
5014	**4**	63	**8**	581	**5**	293	**5**	0.97	**5**
2877	**5**	62	**9**	391	**9**	324	**3**	0.55	**3**
3	**6**	123	**3**	668	**3**	107	**9**	1.73	**7**
231	**7**	84	**6**	532	**7**	125	**8**	0.65	**4**
8860	**8**	87	**5**	563	**6**	175	**7**	2.30	**8**
4719	**9**	74	**7**	440	**8**	251	**6**	2.43	**9**

[1] Patch extent is referred to as "radius of gyration" in Fragstats.
[2] Units for road density are kilometers of roads per square kilometer, at 1 km radius.

Table C-3

Patch Ranking for the Northern Pine Snake, Onslow Bight, NC

Patch ID	Overall Rank	Area (ha)	Area Rank	Patch Extent (m)[1]	Patch Extent Rank	Contig. Area (ha)	Contig. Area Rank	Average Road Density[2]	Road Density Rank
7728	**1**	330	**1**	1016	**1**	427	**1**	2.69	**4**
3344	**2**	213	**2**	765	**2**	157	**4**	0.98	**1**
2343	**3**	153	**4**	761	**3**	191	**3**	1.26	**2**
4435	**4**	178	**3**	680	**4**	339	**2**	2.02	**3**

[1] Patch extent is referred to as "radius of gyration" in Fragstats.

[2] Units for road density are kilometers of roads per square kilometer, at 1 km radius.

Table C-4
Patch Ranking for the Northern Pine Snake, MAJIC Area, SC

Patch ID	Overall Rank	Area (ha)	Area Rank	Patch Extent (m)[1]	Patch Extent Rank	Contig. Area (ha)	Contig. Area Rank	Average Road Density[2]	Road Density Rank
15824	**1**	1633	**1**	2463	**1**	1359	**1**	1.22	**2**
41288	**2**	492	**6**	1346	**4**	807	**8**	1.45	**5**
35818	**3**	591	**5**	1095	**12**	600	**15**	1.29	**3**
41301	**4**	931	**2**	1918	**2**	969	**3**	2.04	**20**
19771	**5**	475	**7**	1274	**5**	864	**5**	1.92	**17**
15748	**6**	216	**14**	1118	**10**	746	**9**	1.62	**6**
36977	**7**	320	**9**	1257	**7**	898	**4**	1.91	**16**
4499	**8**	858	**3**	1602	**3**	1163	**2**	2.96	**28**
33930	**9**	596	**4**	1233	**8**	302	**28**	1.68	**10**
37264	**10**	351	**8**	1156	**9**	827	**6**	2.01	**19**
18610	**11**	209	**16**	1260	**6**	573	**17**	1.70	**11**
43545	**12**	225	**12**	956	**15**	818	**7**	2.09	**21**
21044	**13**	225	**11**	1082	**13**	699	**12**	2.16	**22**
45836	**14**	176	**23**	930	**18**	719	**11**	1.74	**13**
17596	**15**	167	**24**	860	**21**	501	**21**	1.00	**1**
41066	**16**	202	**19**	921	**20**	601	**14**	1.75	**14**
46353	**17**	230	**10**	789	**27**	291	**29**	1.38	**4**
19455	**18**	212	**15**	979	**14**	467	**23**	1.99	**18**
40408	**19**	197	**20**	784	**28**	584	**16**	1.74	**12**
6349	**20**	155	**29**	811	**23**	528	**20**	1.64	**7**
11752	**21**	157	**28**	743	**30**	666	**13**	1.64	**8**
22311	**22**	208	**17**	1101	**11**	555	**19**	3.14	**29**
35960	**23**	162	**25**	796	**25**	567	**18**	1.79	**15**
2643	**24**	194	**21**	955	**16**	496	**22**	2.45	**23**
2153	**25**	218	**13**	943	**17**	411	**24**	2.47	**24**
10876	**26**	160	**26**	782	**29**	233	**30**	1.64	**9**
40175	**27**	153	**30**	835	**22**	726	**10**	3.52	**30**
22524	**28**	205	**18**	807	**24**	409	**25**	2.72	**26**
7	**29**	160	**27**	927	**19**	345	**26**	2.61	**25**
33919	**30**	176	**22**	795	**26**	321	**27**	2.92	**27**

[1] Patch extent is referred to as "radius of gyration" in Fragstats.
[2] Units for road density are kilometers of roads per square kilometer, at 1 km radius.

Table C-5

Patch Ranking for the Southern Hognose Snake, Onslow Bight, NC

Patch ID	Overall Rank	Area (ha)	Area Rank	Patch Extent (m)[1]	Patch Extent Rank	Contig. Area (ha)	Contig. Area Rank	Average Road Density[2]	Road Density Rank
39146	**1**	185	**13**	761	**19**	516	**13**	0.377927	**6**
25668	**2**	125	**32**	1161	**2**	609	**5**	1.03972	**18**
38977	**3**	139	**25**	775	**15**	624	**4**	1.09051	**19**
24473	**4**	163	**16**	772	**16**	458	**23**	0.443428	**8**
28915	**5**	202	**10**	805	**11**	592	**6**	1.35568	**32**
41741	**6**	144	**20**	665	**32**	551	**10**	1.1159	**22**
27489	**7**	141	**21**	711	**23**	651	**2**	1.53686	**40**
37345	**8**	136	**27**	897	**8**	551	**11**	1.56242	**42**
42207	**9**	450	**2**	1132	**3**	675	**1**	2.70757	**70**
37088	**10**	239	**6**	778	**13**	471	**21**	1.57114	**43**
34393	**11**	526	**1**	1595	**1**	486	**18**	2.2224	**61**
29195	**12**	140	**22**	631	**38**	466	**22**	0.830209	**13**
34960	**13**	196	**12**	775	**14**	424	**27**	1.49692	**38**
26856	**14**	322	**4**	1074	**4**	575	**8**	3.00323	**71**
28793	**15**	134	**28**	800	**12**	346	**46**	1.01314	**17**
28547	**16**	156	**18**	672	**30**	638	**3**	1.7051	**45**
22460	**17**	344	**3**	1057	**5**	346	**45**	1.52178	**39**
30097	**18**	261	**5**	893	**9**	495	**15**	2.48097	**66**
34478	**19**	202	**11**	691	**25**	536	**12**	1.92323	**53**
37066	**20**	140	**23**	690	**26**	438	**25**	1.4272	**35**
37914	**21**	220	**7**	770	**17**	235	**68**	0.973769	**15**
28306	**22**	140	**24**	574	**48**	487	**17**	1.20074	**24**
26799	**23**	98	**46**	663	**33**	395	**33**	0.860817	**14**
37034	**24**	171	**14**	761	**18**	256	**63**	1.27846	**28**
29282	**25**	126	**31**	743	**20**	348	**43**	1.47748	**37**
38935	**26**	208	**9**	730	**22**	386	**36**	2.01956	**55**
27842	**27**	110	**40**	1028	**6**	398	**31**	2.17114	**58**
35321	**28**	115	**36**	672	**31**	488	**16**	1.97078	**54**
27901	**29**	132	**29**	653	**35**	339	**49**	1.23972	**25**
27391	**30**	96	**49**	603	**41**	436	**26**	1.27963	**29**
41923	**31**	90	**51**	436	**71**	473	**20**	0.491013	**11**
32648	**32**	114	**37**	681	**29**	149	**78**	0.239976	**5**
27657	**33**	162	**17**	584	**44**	422	**28**	1.72045	**48**

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Table C-5, continued

Patch Ranking for the Southern Hognose Snake, Onslow Bight, NC

Patch ID	Overall Rank	Area (ha)	Area Rank	Patch Extent (m)[1]	Patch Extent Rank	Contig. Area (ha)	Contig. Area Rank	Average Road Density[2]	Road Density Rank
35910	**34**	88	**52**	595	**42**	265	**62**	0.166631	**4**
28583	**35**	84	**58**	545	**50**	368	**39**	1.10846	**20**
24496	**36**	85	**57**	461	**67**	397	**32**	0.778384	**12**
42699	**37**	147	**19**	685	**28**	402	**30**	3.01606	**74**
36199	**38**	76	**66**	543	**51**	324	**51**	0.486236	**9**
42651	**39**	123	**33**	654	**34**	592	**7**	4.14678	**82**
37482	**40**	108	**42**	475	**65**	242	**65**	0	**1**
28579	**41**	64	**81**	577	**47**	455	**24**	1.38289	**33**
31123	**42**	214	**8**	989	**7**	238	**67**	3.0122	**72**
32357	**43**	96	**47**	880	**10**	88	**81**	1.4503	**36**
23290	**44**	118	**34**	581	**45**	413	**29**	2.18251	**59**
42125	**45**	170	**15**	704	**24**	342	**48**	3.01554	**73**
30435	**46**	74	**70**	457	**69**	479	**19**	1.30093	**31**
26810	**47**	116	**35**	578	**46**	558	**9**	3.66894	**80**
37316	**48**	61	**82**	584	**43**	356	**41**	1.2993	**30**
9041	**49**	78	**64**	541	**52**	229	**70**	0.43176	**7**
27806	**50**	113	**38**	534	**55**	240	**66**	1.18861	**23**
31444	**51**	136	**26**	689	**27**	209	**72**	1.81865	**51**
24782	**52**	64	**78**	507	**61**	388	**35**	1.25449	**27**
28377	**53**	76	**67**	488	**64**	289	**56**	0.984523	**16**
39069	**54**	112	**39**	512	**58**	394	**34**	2.15213	**57**
18684	**55**	108	**41**	571	**49**	132	**80**	1.24846	**26**
6856	**56**	83	**59**	508	**59**	142	**79**	0.488266	**10**
40557	**57**	96	**50**	526	**57**	377	**38**	2.08136	**56**
37772	**58**	76	**65**	615	**40**	302	**54**	1.81363	**50**
43510	**59**	128	**30**	742	**21**	233	**69**	3.02968	**75**
27054	**60**	81	**61**	469	**66**	352	**42**	1.64322	**44**
27628	**61**	87	**56**	455	**70**	496	**14**	2.67385	**69**
29679	**62**	101	**45**	620	**39**	347	**44**	3.63461	**79**
35185	**63**	103	**43**	640	**37**	244	**64**	2.42195	**65**
19177	**64**	68	**73**	400	**81**	156	**76**	0.100518	**2**
29146	**65**	79	**63**	640	**36**	218	**71**	1.86078	**52**

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Table C-5, continued

Patch Ranking for the Southern Hognose Snake, Onslow Bight, NC

Patch ID	Overall Rank	Area (ha)	Area Rank	Patch Extent (m)[1]	Patch Extent Rank	Contig. Area (ha)	Contig. Area Rank	Average Road Density[2]	Road Density Rank
40461	**66**	72	**71**	457	**68**	356	**40**	1.71911	**47**
33560	**67**	64	**80**	432	**72**	40	**82**	0.162598	**3**
37344	**68**	81	**60**	429	**74**	280	**59**	1.40409	**34**
28146	**69**	64	**77**	400	**82**	285	**57**	1.11385	**21**
41693	**70**	80	**62**	432	**73**	313	**53**	1.72122	**49**
40617	**71**	87	**53**	501	**62**	275	**60**	2.18642	**60**
28609	**72**	87	**54**	429	**76**	380	**37**	3.07464	**76**
39745	**73**	68	**74**	538	**53**	282	**58**	2.55114	**67**
34188	**74**	87	**55**	429	**75**	208	**73**	1.70849	**46**
29785	**75**	71	**72**	528	**56**	342	**47**	3.16565	**78**
33337	**76**	102	**44**	508	**60**	150	**77**	2.37684	**64**
40871	**77**	96	**48**	412	**77**	267	**61**	2.26303	**63**
20557	**78**	75	**69**	500	**63**	317	**52**	3.1612	**77**
29169	**79**	66	**75**	410	**79**	180	**74**	1.54888	**41**
29333	**80**	64	**79**	535	**54**	293	**55**	3.9801	**81**
27941	**81**	65	**76**	411	**78**	334	**50**	2.58067	**68**
38389	**82**	75	**68**	402	**80**	159	**75**	2.2598	**62**

[1] Patch extent is referred to as "radius of gyration" in Fragstats.
[2] Units for road density are kilometers of roads per square kilometer, at 1 km radius.

Table C-6

Patch Ranking for the Southern Hognose Snake, MAJIC Area, SC

Patch ID	Overall Rank	Area (ha)	Area Rank	Patch Extent (m)[1]	Patch Extent Rank	Contig. Area (ha)	Contig. Area Rank	Average Road Density[2]	Road Density Rank
13309	**1**	2561	**1**	3038	**1**	1603	**1**	1.19	**1**
35476	**2**	1003	**4**	1986	**3**	1328	**3**	1.22	**2**
35170	**3**	932	**6**	1904	**5**	1367	**2**	1.55	**7**
12166	**4**	475	**12**	1553	**7**	1034	**9**	1.40	**5**
34994	**5**	1139	**2**	1907	**4**	1138	**6**	2.13	**17**
16506	**6**	613	**9**	1338	**11**	1097	**7**	1.85	**13**
23242	**7**	1001	**5**	2341	**2**	961	**12**	2.62	**25**
3418	**8**	1047	**3**	1757	**6**	1241	**4**	3.07	**30**
22739	**9**	414	**20**	1335	**12**	888	**14**	1.79	**11**
29007	**10**	827	**7**	1404	**10**	303	**30**	1.64	**8**
44065	**11**	397	**22**	1193	**19**	804	**18**	1.38	**4**
31573	**12**	448	**14**	1189	**20**	974	**11**	1.94	**15**
31327	**13**	387	**23**	1270	**17**	1012	**10**	1.90	**14**
36723	**14**	437	**16**	1126	**25**	1220	**5**	2.19	**18**
30283	**15**	624	**8**	1098	**27**	637	**25**	1.32	**3**
9396	**16**	374	**25**	1256	**18**	849	**17**	1.75	**10**
40024	**17**	422	**18**	1294	**14**	889	**13**	2.48	**22**
23522	**18**	457	**13**	1453	**9**	865	**15**	3.00	**29**
39181	**19**	331	**29**	970	**29**	1068	**8**	1.70	**9**
3421	**20**	363	**26**	1476	**8**	861	**16**	2.56	**23**
43667	**21**	443	**15**	1102	**26**	694	**23**	1.80	**12**
4898	**22**	401	**21**	1290	**15**	689	**24**	2.26	**19**
25027	**23**	437	**17**	1279	**16**	538	**27**	2.29	**20**
22437	**24**	480	**11**	1175	**21**	725	**21**	2.93	**28**
1206	**25**	483	**10**	1166	**22**	614	**26**	2.60	**24**
8532	**26**	311	**30**	1160	**23**	705	**22**	2.07	**16**
9	**27**	419	**19**	1303	**13**	537	**28**	2.90	**27**
39576	**28**	332	**28**	929	**30**	519	**29**	1.46	**6**
2041	**29**	346	**27**	1131	**24**	753	**20**	2.37	**21**
21409	**30**	377	**24**	1019	**28**	779	**19**	2.66	**26**

[1] Patch extent is referred to as "radius of gyration" in Fragstats.
[2] Units for road density are kilometers of roads per square kilometer, at 1 km radius.