Identifying Focal Wildlife Conservation Areas on Private Lands in North Carolina

by

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Abstract

There are over 1,200 threatened or endangered animal species in the U.S, of which 36 are located in North Carolina. To address this problem of species imperilment, all 50 states developed State Wildlife Action Plans (SWAP). As requested by Congress, each SWAP is to identify priority conservation areas in which limited resources can be directed towards. The North Carolina WAP lacks priority conservation areas. This paper identifies focal wildlife conservation areas on private lands in Moore, Hoke, Richmond, and Scotland counties for the purpose of maintaining and protecting biodiversity and assisting the NC Wildlife Resources Commission in WAP implementation. A geographic information system (GIS) was used to conduct the analysis. Three principal datasets were used in identifying focal areas: 1) North Carolina Gap Analysis Project (NCGAP) wildlife distribution models, 2) North Carolina land cover from 2001, and 3) NCGAP protected land boundaries. The focal areas were ranked individually based on three metrics: betweenness, area, and distance to protected land. Betweenness is based on the Euclidean distance between pairs of patches. A habitat patch with high betweenness is significant ecologically, because it indicates how important a particular patch is in maintaining linkages among other patches. The area of a patch is important in assessing whether a species would be able to survive a large-scale natural disturbance. Also, larger patches generally support a greater number of species or individuals. Finally, conserving patches of land that are close to protected lands increases the likelihood that species associated with the patches will continue to persist (i.e., species are more able to disperse throughout the landscape). Thirty-three potential wildlife conservation sites were identified. This information can assist conservation planners when dealing with limited funding and personnel. The approach of my analysis can be applied more broadly in order to establish habitat conservation or connectivity at a regional scale.

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Introduction

There is a great need to focus attention on protecting wildlife species in the United States. Although conservation programs have been developed with the goal of maintaining or restoring depleted animal populations, the number of species at risk continues to grow. Currently, there are 1,237 animal species in the U.S. listed as threatened or endangered under the Endangered Species Act, of which 36 are located in North Carolina (USFWS, 2008). Habitat loss/degradation is the leading cause of species imperilment in the U.S. (Wilcove et al., 1998). One of the major factors causing habitat loss is urban and commercial development (Wilcove et al., 1998). To address this problem of species imperilment, Congress, in 2001, developed new conservation funding legislation, the Wildlife Conservation and Restoration Program and the State Wildlife Grants Program.

In order to receive federal funding through the State Wildlife Grants Program, each state and U.S. territory was required to create a Comprehensive Wildlife Conservation Plan, also known as a State Wildlife Action Plan (SWAP), by October 2005. The funding is meant to complement fish and wildlife programs and to target species in greatest need of conservation, species that indicate the health of the environment, and species with low and declining populations (NCWRC, 2005). The wildlife action plans present a unique opportunity to protect and conserve species before they become threatened or endangered.

Since habitat loss/degradation is one of the main threats to species endangerment, it makes most sense to target conservation actions to areas that are best suited for protection. These areas include those that, if conserved, best ensure the persistence of animal species in that area. Focal areas are clearly defined parcels of land that symbolize ecological significance (e.g., high species richness) and opportunity for directing conservation actions (Lerner et al., 2006). Criteria to consider when selecting focal wildlife conservation areas include biodiversity, patch size, and landscape context. Biodiversity is important for many reasons, such as ecological, medical, aesthetical, and ethical. As the physical environment is constantly undergoing changes, both natural and anthropogenic, maintaining ecosystem processes depends on conserving biodiversity (Naeem et al., 1994; Loreau et al., 2001). Patch size is important in assessing whether a species would be able to survive a large-scale natural disturbance (Groves et al., 2002). Also, larger areas generally support a greater number of species or individuals (MacArthur and Wilson, 1967). Landscape context can be a measure of two factors: 1) the distance to existing protected land and 2) patch connectivity, which allows species to migrate from one patch to another to meet life's needs. Conserving patches of land that are close to protected lands increases the likelihood that species associated with the patches will continue to persist.

The North Carolina Wildlife Action Plan (NCWAP) (NCWRC, 2005) broadly identifies priority conservation areas by mapping species richness for the state's priority species that were included in the North Carolina Gap Analysis Project (NCGAP) (McKerrow et al., 2006). However, focal areas, which allow conservation organizations to spend limited resources strategically, are not identified. Without maps indicating focal areas, conservation funding can be inadvertently directed toward lower priority areas (Lerner et al., 2006). Not only are maps of focal conservation areas necessary for wildlife agencies, they are important for transportation and land use planners looking to avoid developing in ecologically sensitive areas. Thus, these maps will be vital in reducing conflicts between conservation and development (Lerner et al., 2006). Additionally, identifying focal wildlife conservation areas will help the North Carolina Wildlife Resource Commission (NCWRC), as well as other state and non-profit organizations, to effectively implement the NCWAP.

Objectives

In order for states to effectively implement their wildlife action plans, they must first identify those areas in which to focus management. In order to accomplish my goal of identifying focal wildlife conservation areas on private lands within North Carolina, I have established four objectives:

- identify the conservation targets (i.e., wildlife species) and map their richness,
- identify potential conservation sites based on ecological criteria (e.g., species richness, patch size, and land cover)
- perform a connectivity analysis on the potential sites, and
- identify sites on private land to be recommended for conservation given the above criteria.

Wildlife species included in the analysis are those identified as "species with greatest conservation need," (SGCN) which are identified and listed in the NCWAP and include the four major taxa of wildlife: birds, mammals, amphibians, and reptiles (NCWRC, 2005). The study area is a four county region in south-central North Carolina: Moore, Hoke, Richmond, and Scotland counties. This region contains high species richness of SGCN for all four taxa. Additionally, existing state managed lands are located in this area (e.g., the Sandhills Game Lands and Fort Bragg military reservation).

Parcels of private land in the study area were identified as focal wildlife conservation areas. These private land parcels are habitat patches that serve as connections to existing protected patches (i.e., patches on protected lands) due to their close proximity to each other. Creating a network of connected patches can increase the likelihood that species will persist in a given area, which is important for maintaining local biodiversity. Additionally, identifying focal areas allows wildlife conservation organizations to invest their resources wisely, and may also aid local planners during development or revision of local land use plans.

Methods

Approach

Geographic information systems (GIS) are a useful tool for displaying geographic areas of interest and working with environmental data layers. A GIS was used to complete my objectives and attain the goal of identifying focal wildlife conservation areas. All GIS work was conducted in raster format in ArcGIS 9.2 (ESRI, Redlands, CA). The pixel size used for the analysis was 30 x 30m, and the model's extent was the political boundary of the State of North Carolina for mapping species richness and the political boundaries for Moore, Hoke, Richmond, and Scotland counties for all other analyses. Three principal datasets were used in identifying focal wildlife conservation areas: (1) North Carolina Gap Analysis Project (NCGAP) wildlife distribution models (NCSU, 2008), (2) North Carolina land cover, and (3) NCGAP protected land boundaries.

Conservation Targets

The NCWAP identifies 91 species of birds, 41 species of amphibians, 38 species of mammals, and 43 species of reptiles as being priority species for conservation in North Carolina (NCWRC, 2005). The plan also identifies species of freshwater fish, freshwater mussels, crayfish, and freshwater snails as priority conservation species; however, this analysis does not include these species in the process of identifying focal wildlife conservation areas. The NCGAP provides statewide species distribution maps for terrestrial vertebrates in North Carolina. The criteria that the NCGAP used in developing their lists of vertebrates to be modeled included those "terrestrial vertebrates that are known to breed (5 of the last 10 years) and that are regularly occurring non-accidentals in the state of North Carolina" (NCGAP, 2008). These criteria resulted in a list of 414 species (193 birds, 75 mammals, 76 amphibians, and 70 reptiles) for which distributions were modeled.

To map the species' distributions, the NCGAP started by examining known ranges for each vertebrate species. They used the Vertebrate Characterization Abstracts (VCA) as a starting point (NCGAP, 2008). The VCA is part of the Biological and Conservation Data System created by the The Nature Conservancy (TNC) and maintained by the North Carolina Natural Heritage Program and the NCWRC (NCGAP, 2008). The Abstracts contain species occurrence data by county. The data was developed from known occurrences and expert knowledge (NCGAP, 2008). Point data used to develop species range limits included 748 point localities from the NC Museum of Natural Sciences (NCMNS), 2,028 points from the NC Natural Heritage Program, and 27,210 new point localities that were mapped for NCGAP's project (McKerrow et al., 2006). The newly mapped points include 25,001 records from the NC Breeding Bird Atlas dataset along with NCMNS records for birds, mammals, amphibians, and reptiles (McKerrow et al., 2006).

After known ranges were established, the NCGAP developed species habitat relationships by using a variety of information, including TNC's Land Manager's Guide series, VCA habitat descriptions, and journal articles (NCGAP, 2008). Each species was then assigned a presence value (absent or present) for each land cover type (e.g., open space, forest, grassland, etc.). Presence values were also assigned for other data types (e.g., soil type, elevation, wetland type, etc.) used to define suitable habitat (NCGAP, 2008). Once species habitat relationships were defined, the NCGAP used a GIS to process layers of data to model species distributions. The data layers included a species known-range map, a NCGAP land cover map, a national wetlands inventory map, a digital elevation model, a river reach map, and a hydrological unit map.

The accuracy of the vertebrate species distribution models was assessed by comparison of species lists for National Seashores, National Wildlife Refuges, National Parks, and North Carolina State Parks and Preserves (McKerrow et al., 2006). The percent agreement for birds, mammals, and herps (reptiles and amphibians) averaged 78.8%, 64.4%, and 72.8%, respectively (McKerrow et al., 2006). Omission error rates were fairly low (5.6%, 3.1%, and 2.1%), but commission rates were significantly higher (15.6%, 32.4%, and 25.1%) (McKerrow et al., 2006). Omission errors occur when a pixel is not assigned a value (here, a potential "habitat"), when in fact, it should be assigned. Commission errors occur when a pixel is assigned a value other than its true value. An example of a commission error is a wildlife distribution model depicting a species occurring on a particular pixel, but that species does not actually occur on that pixel. Therefore, these commission error rates should be kept in mind when reviewing the results of the analyses: the GAP pixels are rather generous.

Distribution models for those species identified in the NCWAP were downloaded from the NCGAP's website (NCGAP, 2008). However, the NCGAP has not modeled every priority species listed in the NCWAP. Those NCWAP priority species in which NCGAP models were provided include 80 species of birds, 33 species of mammals, 38 species of reptiles, and 36 species of amphibians, for a total of 187 priority species.

Species Richness and Study Area

The NCGAP distribution models for all 187 priority species were combined in ArcGIS to map statewide species richness (Fig. 1). A pixel's value represents the number of species that are predicted to occur at that site. The pixel values ranged from 0 (representing no species) to 66 species occurring on a single pixel. The pixel values were classified into natural breaks, and the species richness map was reclassified so that only those pixels containing a value ≥ 45 were displayed (Fig. 2). The remaining high species richness pixels were concentrated in Moore, Hoke, Richmond, and Scotland counties. These four counties represent the study area and became the model's extent. The NCWAP priority species located in the study area are displayed in Appendix A.1 – A.4. The study area contains 40 bird species, 12 mammal species, 29 reptile species, and 21 amphibian species, for a total of 102 species.

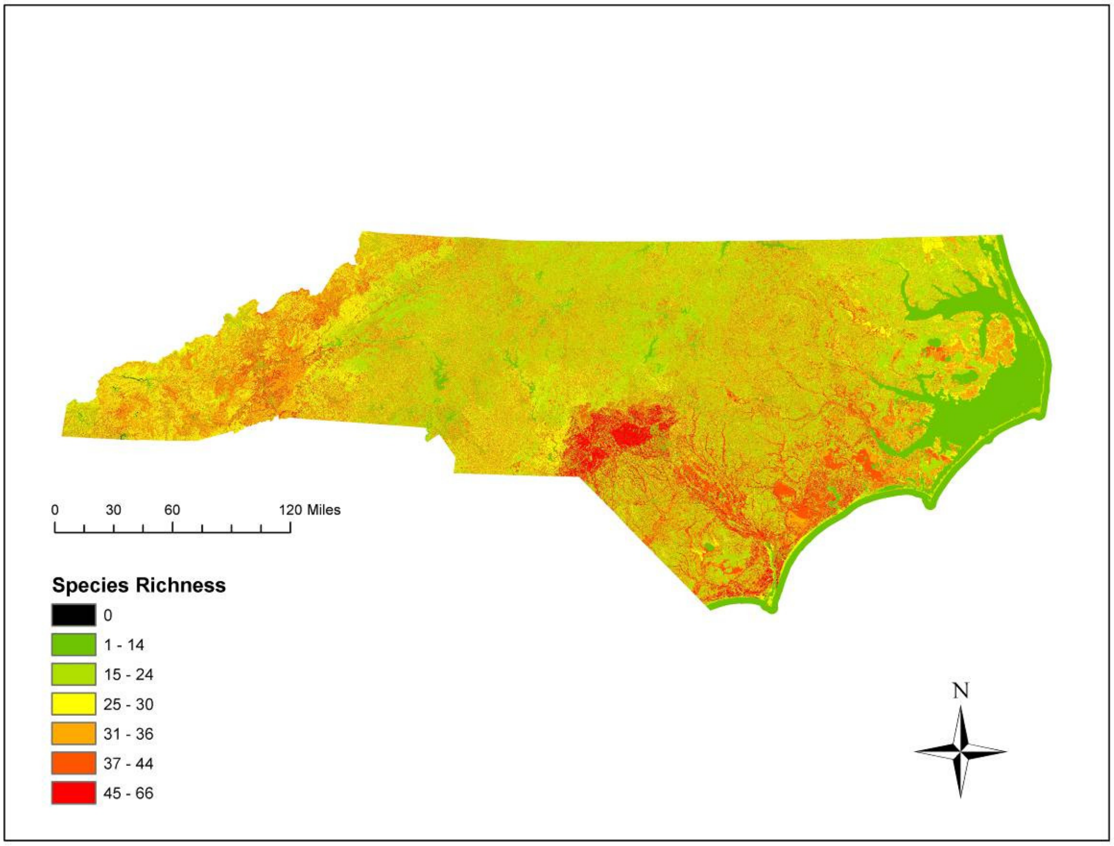

Figure 1. Species richness for 187 priority vertebrate species in North Carolina. Map includes 80 birds, 36 amphibians, 33 mammals, and 38 reptiles. Species obtained from the North Carolina Wildlife Action Plan. Light green represent pixels with low species richness. Red pixels represent high species richness.

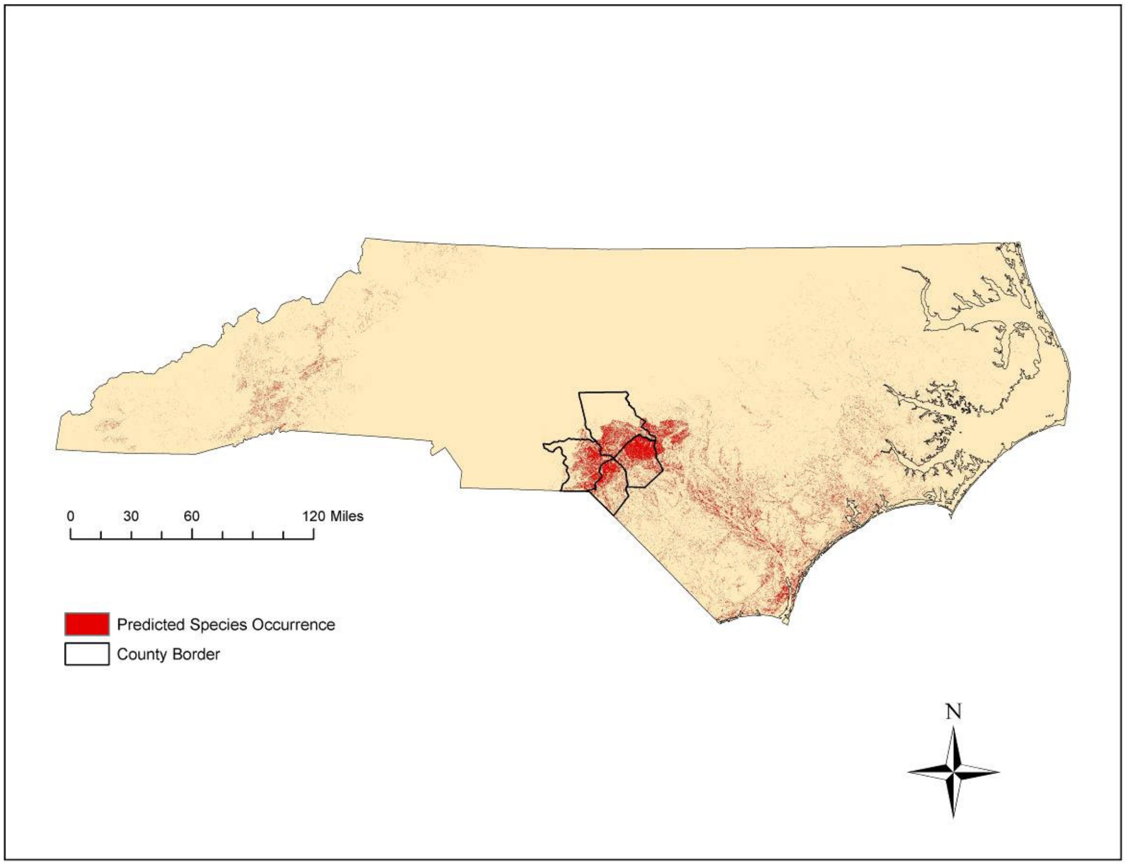

Figure 2. Reclassified terrestrial vertebrate species richness in North Carolina. Only pixels containing values ranging from 45 to 66 species are displayed. High species richness pixels are concentrated in Moore, Hoke, Richmond, and Scotland counties.

Potential Conservation Sites

A data layer depicting North Carolina land cover associated with the reclassified species richness pixels was created. This layer was then reclassified so that low-, medium-, and high-intensity development pixels were omitted, as these areas are not suitable for most wildlife or ecological restoration. The reclassified land cover raster layer was converted to a polygon layer, resulting in 324,672 contiguous polygons. The area for each of these polygons was calculated.

In order to determine the minimum polygon size needed (i.e., the minimum habitat patch size required for the priority species), the average home-range size of the

Red-cockaded Woodpecker (RCW) was obtained from scientific studies. The RCW was chosen based upon an endangered species list (state or federally listed) for the study area (based upon the NCGAP distribution maps) (Table 5). Of the three species in Table 5, the RCW has the largest home-range size; therefore, the RCW's home-range size was chosen to be the minimum patch size requirement. Doster and James (1998) documented 15 studies which estimated the home-range size of the RCW. The average home-range size from theses studies was 76.1 ha. The 324,672 polygons were reduced to 116 polygons by selecting for those polygons that were ≥ 76 hectares. This new data layer represented potential wildlife conservation sites (Fig. 3). As Fig. 3 depicts, most of the potential conservation sites are already protected, i.e., they lie within protected land.

Table 5. Endangered Priority Species Located in Study Area.

Common Name	Scientific Name	NC Status (Federal Status)
Red-cockaded Woodpecker	*Picoides borealis*	E (E)
Eastern Diamond-backed Rattlesnake	*Crotalus adamanteus*	E
Eastern Coral Snake	*Micrurus fulvius*	E

E = Endangered

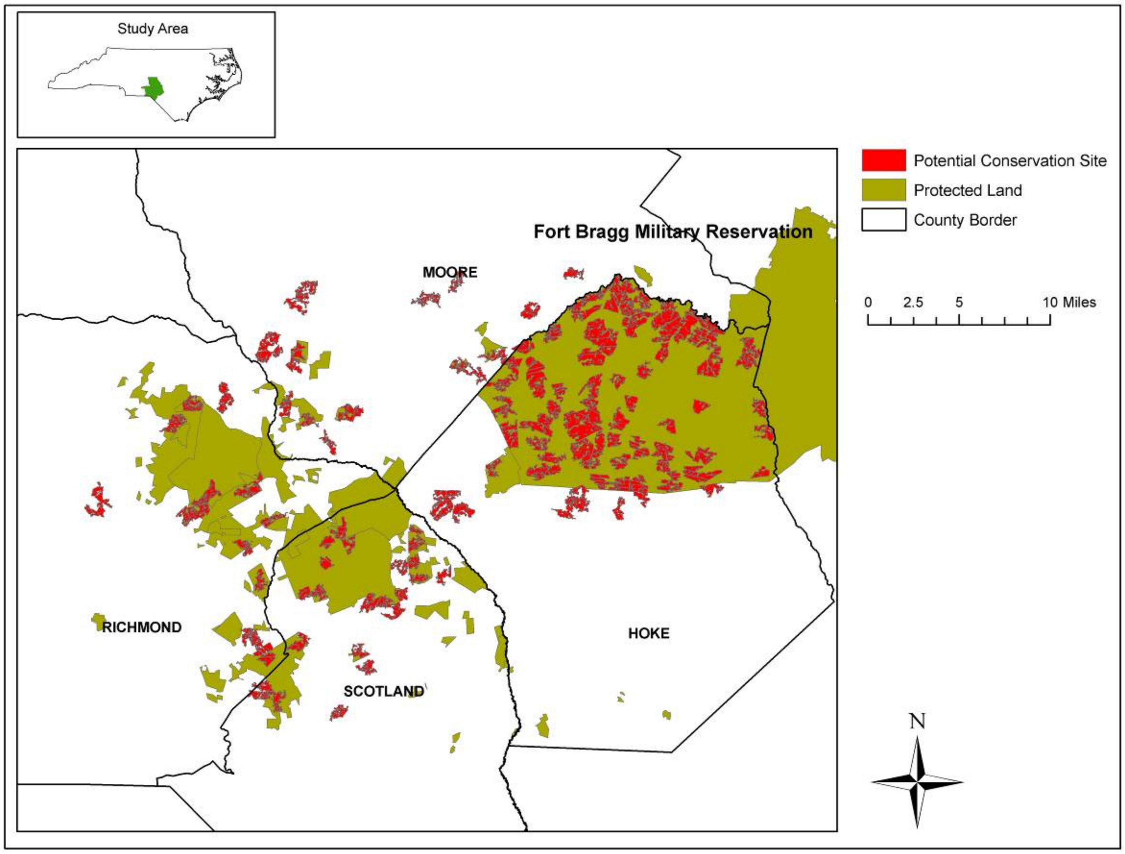

Figure 3. Potential wildlife conservation sites in Richmond, Moore, Hoke, and Scotland counties, North Carolina. The map depicts 116 potential conservation sites. Each site is at least 76 ha in size.

Distance to Protected Land

Protecting areas surrounding existing protected lands may prevent development from encroaching upon protected lands. Additionally, conserving patches of land that are close to protected lands increases the likelihood that species associated with the patches will continue to persist. Using stewardship data provided by the NCGAP, protected land that intersected the study area was selected, and a new stewardship data layer was created. Using this new layer, Status 4 (not protected/private) lands were removed. With private lands removed, the Euclidean distance from protected lands was calculated.

Network Analysis

The potential conservation sites displayed in Fig. 3 represent a network of habitat patches. Patches can be defined as areas with internally homogenous habitat surrounded by a landscape of unsuitable habitat (Urban and Keitt, 2001). The degree to which the spatial pattern of the habitat patches assists or hinders the dispersal of wildlife, i.e., the connectivity of the landscape, is of particular interest in landscape ecology (Bodin and Norberg, 2007). The persistence of wildlife populations within a given regional landscape is strongly related to the connectivity of the landscape (Bodin and Norberg, 2007).

A graph is a representation of habitat patches in a landscape, where the patches are displayed as nodes (points) connected by edges (Urban and Keitt, 2001). Edges represent the distance between nodes and imply potential organism dispersal between the nodes (Urban and Keitt, 2001). The distance reflects the ability of organisms to migrate from one patch to another (Bodin and Norberg, 2007). If a path (series of edges) exists between all pairs of nodes, the graph is considered *connected* (Urban and Keitt, 2001).

One focus of connectivity analysis is an organism's dispersal capacity (Urban and Keitt, 2001). This is often modeled in terms of a threshold distance, in which the threshold represents a selected species' maximum distance to move in the landscape matrix (Bodin and Norberg, 2007). This maximum distance is important when determining the connectivity of habitat patches. For example, using a maximum dispersal threshold, a connected graph can be disconnected by removing a key node or edge that results in more than one component (connected subgraph) (Urban and Keitt, 2001). By removing the key node/edge, the path connecting all nodes is broken, and there exists a space where the selected species cannot migrate from one patch to another.

Since this analysis incorporates 102 wildlife species, a maximum dispersal threshold was not used in quantifying individual habitat patches' contributions to the overall landscape connectivity. Rather, a measurement of *betweenness* was obtained for each node in the patch network. Betweenness is based on the Euclidean distance between pairs of nodes. The betweenness of a node is a measure of the number of shortest paths that run through that node (Bodin and Norberg, 2007). A node with high betweenness is significant ecologically, because it indicates how important a particular patch is in maintaining linkages among other patches. It is expected that patches with a high betweenness value should (1) reduce the overall distance between pairs of patches, (2) connect otherwise largely separated patches or groups of patches, and (3) to be traveled through often by wildlife migrating throughout the landscape, providing landscape traversability for those species (Bodin and Norberg, 2007).

Using the potential conservation sites in Fig. 3, a triangulated irregular network (TIN) was created. A TIN is a digital data structure used in a GIS to represent a surface. The TIN represents a graph as described above. Betweenness values were then obtained for each patch/node and classified into natural breaks.

Sites on Private Land

As noted earlier, most of the potential conservation sites lie within protected lands. Therefore, in order to identify sites on private land, those potential conservation sites that have their centroid located on private land were identified (Fig. 4). The centroid was used because some patches contain area on private and protected land. The number of potential conservation sites having their centroid on private land was 33.

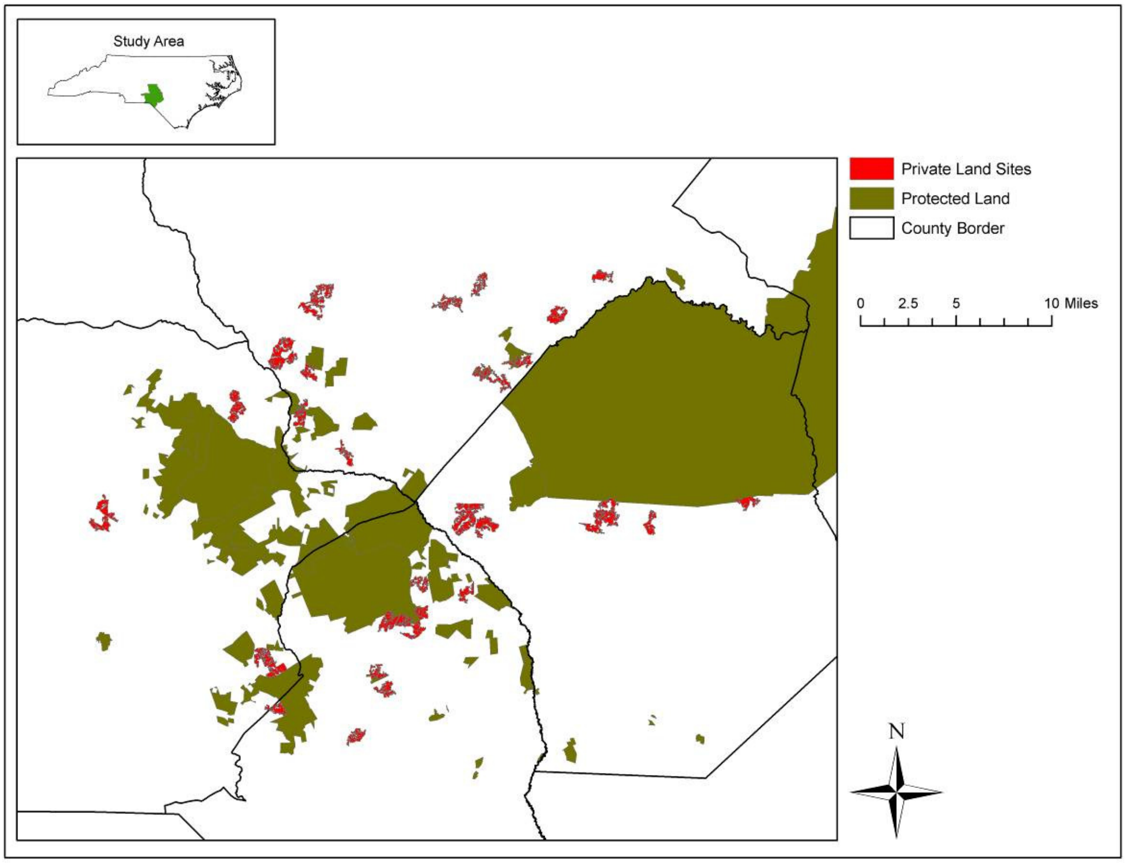

Figure 4. Potential conservation sites located on private land. Sites may contain area on protected land; however, their centroid is located on private land. The map depicts 33 potential conservation sites.

Results

The betweenness for the 33 potential conservation sites is displayed in Fig. 5. Each site is represented as a node. Large nodes represent conservation sites with high betweenness. These sites were ranked separately for three metrics: betweenness, area, and distance to protected land (Appendix B.1 – B.3). The top five sites for each ranking are displayed in Figs. 6 – 8. Two sites ranked high in both betweenness (sites 1 & 4 in

Fig. 6) and area (sites 1 & 2 in Fig. 7). The land cover for all but two of the 33 potential sites is evergreen forest. Of the two sites without evergreen forest, one site is composed entirely of open space, which could potentially be private lawns, and the other site is composed entirely of grassland/herbaceous vegetation. However, all of the sites ranking high for each metric are composed of evergreen forest.

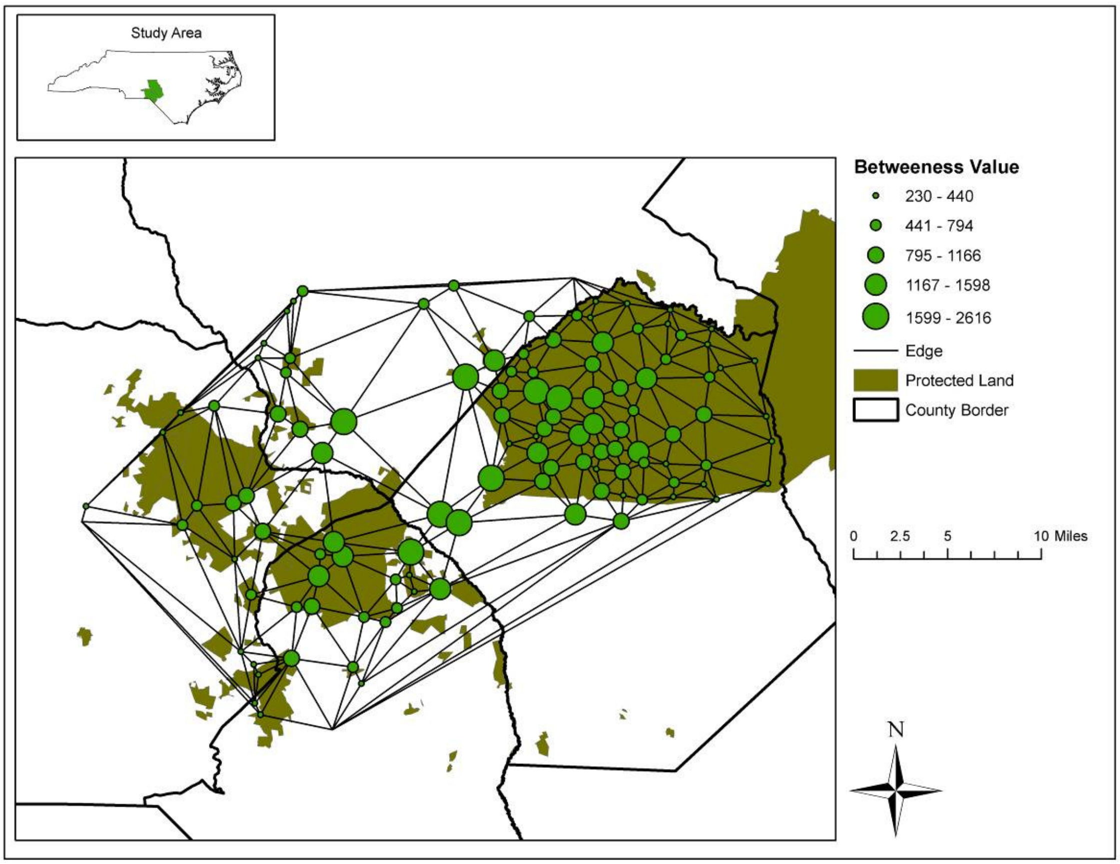

Figure 5. Graph of potential conservation sites. Betweenness values are represented as different sized nodes. Large nodes represent conservation sites with high betweenness. The betweenness of a node is based on the Euclidean distance between pairs of nodes. It is a measure of the number of shortest paths that run through a particular node. A node with high betweenness is significant ecologically, because it indicates how important a particular patch is in maintaining linkages among other patches.

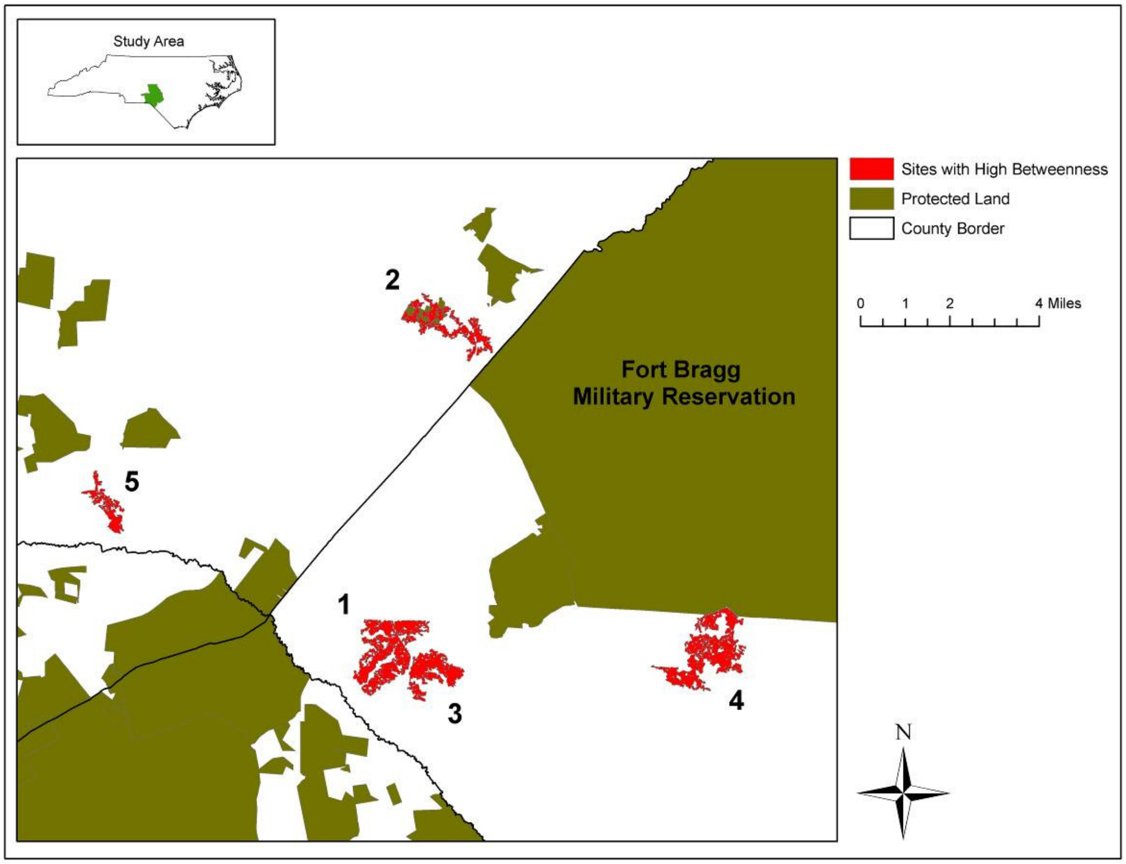

Figure 6. Top five sites having high betweenness. Sites are labeled 1 – 5 representing their rank.

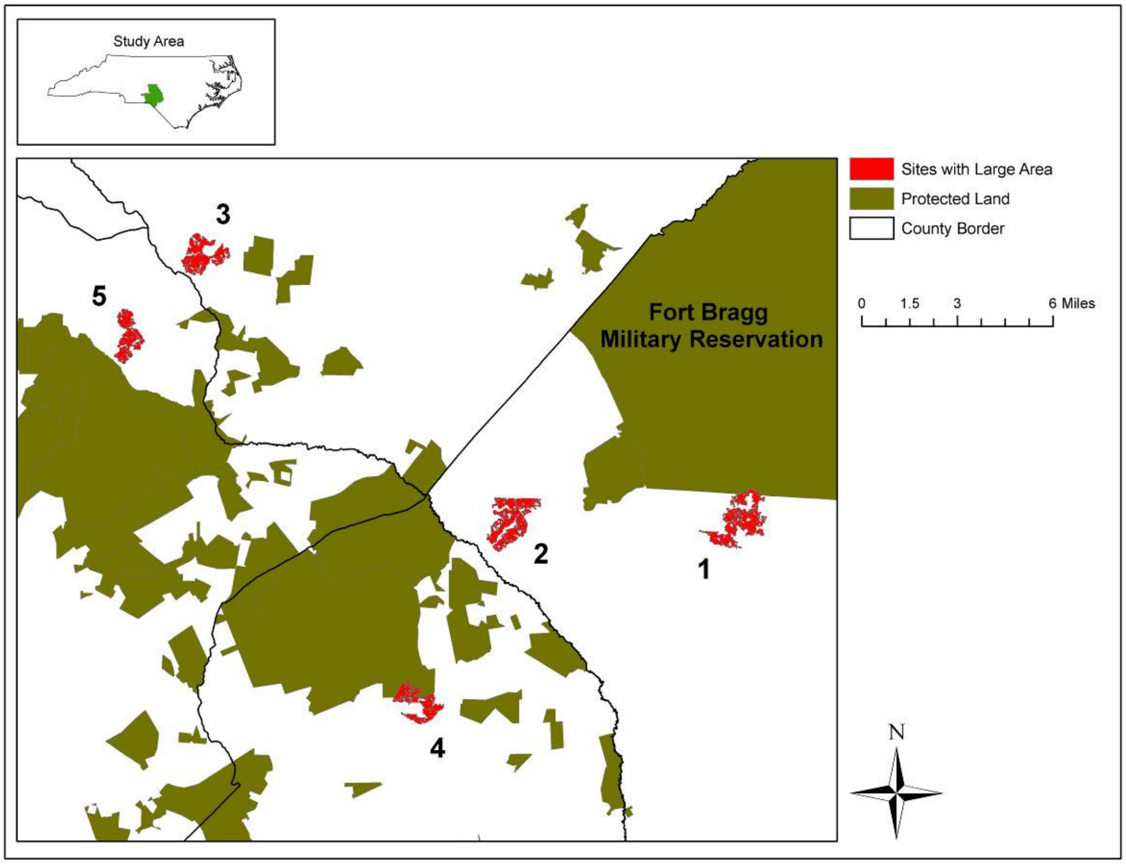

Figure 7. Top five sites having large area. Sites are labeled 1 – 5 representing their rank.

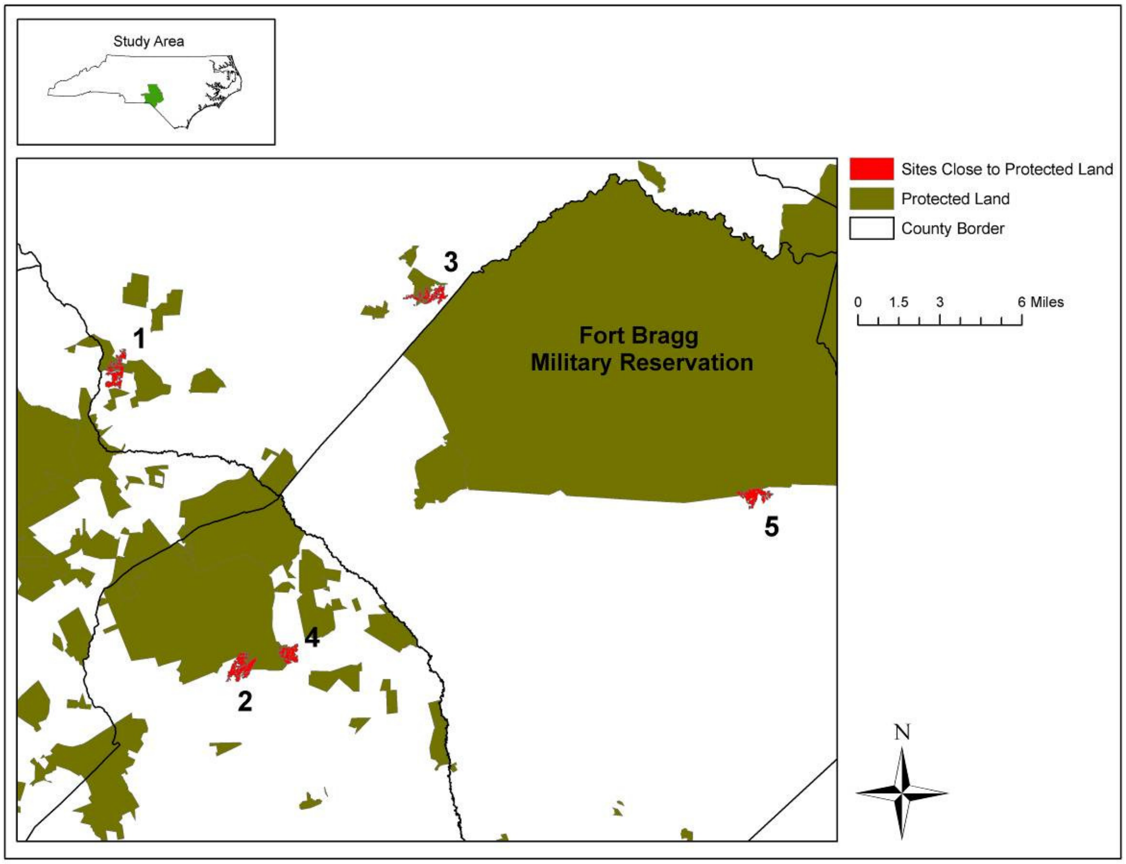

Figure 8. Top five sites located near protected land. Sites are labeled 1 – 5 representing their rank.

Discussion

The top five potential conservation sites for each metric represent focal wildlife conservation sites in which conservation planners, such as the NCWRC or land trusts, should focus attention. Acquiring these lands directly or communicating with landowners about land stewardship that benefits wildlife are two ways in which the NCWRC or other conservation organizations could implement the NCWAP. Focusing on these sites is an efficient method of spending limited conservation dollars, since these sites not only potentially have high species richness, but are ecologically important. The two sites mentioned above that have both high betweenness and large area could serve as starting points for land acquisition or stewardship.

Depending on the metric(s) chosen by conservation planners, different sites will emerge as potential "best sites" to protect. The area and distance to protected land metrics are straightforward assessments of an individual site's significance as an isolated entity. However, the betweenness metric measures the role of each site in the context of the surrounding landscape. It is up to the conservation planner to decide which metric is more important in determining those sites to focus initial conservation efforts.

It is also important to note that the identification of the potential conservation sites is based on NCGAP distribution models that contain fairly high commission errors and land cover data from 2001. If more accurate distribution models are produced, the species richness of specific areas (or pixels) could change, thus perhaps altering the results of my analysis. Furthermore, the results of my analysis represent a snapshot of the study area. The land cover of the potential sites may have changed since 2001. For example, all or part of some sites may now be considered low, medium, or high density development. In this case, these areas would not be included in the analysis.

Additional limitations include not knowing the species richness of the entire site or pixels. The richness of individual pixels is known to range between 45 and 66 species. However, those species associated with each pixel is not easily obtained from this analysis, since 187 species were included. Therefore, calculating the richness of entire sites would be very time consuming, as you would have to list all the species potentially occurring on every pixel, and then eliminate any duplicates when determining the richness for the whole site.

Another limitation involves site betweenness. Since 187 species were included in the analysis, a dispersal threshold was not used in determining the contribution of each site in maintaining landscape connectivity. If conservation planners are interested in a particular species, this analysis could be manipulated to identify those sites important to the dispersal of the particular species. Additionally, the cost associated for species to migrate from one patch to another was not calculated. Only the Euclidean distance from one site to another was evaluated. Again, this is because of the amount of species included in the analysis. Each species has its own cost of travelling from one habitat patch to another while passing through a matrix of developed land. If conservation planners are interested in one species, a cost path analysis may be more appropriate in determining important conservation sites.

Finally, the approach of my analysis can be applied more broadly. Conservation sites could be identified in all counties of North Carolina using the same methods. If neighboring states adopted a similar process of identifying focal wildlife conservation sites, habitat conservation or connectivity at a regional scale could potentially be established. This is one way of not only efficiently conserving wildlife, but protecting and maintaining overall biodiversity.

Conclusion

In order for the NCWRC to continue to receive necessary federal funding through the State Wildlife Grants Program, it is essential that they identify areas in which to focus management. This analysis is one attempt at identifying ecologically important wildlife areas that are currently not protected. By identifying sites with appropriate vegetative cover and high species richness that have high betweenness, large area, or a short distance to protected land, conservation planners are presented with a suite of potential sites for wildlife conservation. As new data becomes available and wildlife distribution models are improved, this analysis can be revised to reflect those changes.

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Appendix A.1. Bird Species Prioritized for Conservation in North Carolina.

Common Name	Scientific Name
Cooper's Hawk	*Accipiter cooperii*
Sharp-shinned Hawk	*Accipiter striatus*
Bachman's Sparrow	*Aimophila aestivalis*
Grasshopper Sparrow	*Ammodramus savannarum*
Chuck-will's-widow	*Caprimulgus carolinensis*
Whip-poor-will	*Caprimulgus vociferus*
Chimney Swift	*Chaetura pelagica*
Lark Sparrow	*Chondestes grammacus*
Common Nighthawk	*Chordeiles minor*
Yellow-billed Cuckoo	*Coccyzus americanus*
Northern Flicker	*Colaptes auratus*
Northern Bobwhite	*Colinus virginianus*
Eastern Wood-pewee	*Contopus virens*
Prairie Warbler	*Dendroica discolor*
Black-throated Green Warbler	*Dendroica virens*
Little Blue Heron	*Egretta caerulea*
Snowy Egret	*Egretta thula*
Horned Lark	*Eremophila alpestris*
American Kestrel	*Falco sparverius*
Bald Eagle	*Haliaeetus leucocephalus*
Worm-eating Warbler	*Helmitheros vermivorus*
Wood Thrush	*Hylocichla mustelina*
Orchard Oriole	*Icterus spurius*
Mississippi Kite	*Ictinia mississippiensis*
Least Bittern	*Ixobrychus exilis*
Loggerhead Shrike	*Lanius ludovicianus*
Swainson's Warbler	*Limnothlypis swainsonii*
Red-headed Woodpecker	*Melanerpes erythrocephalus*
Yellow-crowned Night-heron	*Nyctanassa violacea*
Kentucky Warbler	*Oporornis formosus*
Red-cockaded Woodpecker	*Picoides borealis*
Hairy Woodpecker	*Picoides villosus*
King Rail	*Rallus elegans*
American Woodcock	*Scolopax minor*
Dickcissel	*Spiza americana*
Field Sparrow	*Spizella pusilla*
Eastern Meadowlark	*Sturnella magna*
Eastern Kingbird	*Tyrannus tyrannus*
Barn Owl	*Tyto alba*
Hooded Warbler	*Wilsonia citrina*

Appendix A.2. Mammal Species Prioritized for Conservation in North Carolina.

Common Name	Scientific Name
Star-nosed Mole	*Condylura cristata*
Rafinesque's Big-eared Bat	*Corynorhinus rafinesquii*
Least Shrew	*Cryptotis parva*
Seminole Bat	*Lasiurus seminolus*
Meadow Vole	*Microtus pennsylvanicus*
Long-tailed Weasel	*Mustela frenata*
Cotton Mouse	*Peromyscus gossypinus*
White-footed Mouse	*Peromyscus leucopus easti*
Eastern Mole	*Scalopus aquaticus*
Eastern Fox Squirrel	*Sciurus niger*
Marsh Rabbit	*Sylvilagus palustris*
Meadow Jumping Mouse	*Zapus hudsonius*

Appendix A.3. Reptile Species Prioritized for Conservation in North Carolina.

Common Name	Scientific Name
American Alligator	Alligator mississippiensis
Spiny Softshell	Apalone spinifera
Scarlet Snake	Cemophora coccinea
Spotted Turtle	Clemmys guttata
Eastern Diamond-backed Rattlesnake	Crotalus adamanteus
Timber Rattlesnake	Crotalus horridus
Chicken Turtle	Deirochelys reticularia
Corn Snake	Elaphe guttata guttata
Broad-headed Skink	Eumeces laticeps
Mud Snake	Farancia abacura
Rainbow Snake	Farancia erytrogramma
Eastern Hog-nosed Snake	Heterodon platirhinos
Southern Hog-nosed Snake	Heterodon simus
Striped Mud Turtle	Kinosternon baurii
Mole Kingsnake	Lampropeltis calligaster
Common Kingsnake	Lampropeltis getula
Eastern Coachwhip	Masticophis flagellum
Eastern Coral Snake	Micrurus fulvius
Northern Water Snake	Nerodia sipedon
Slender Glass Lizard	Ophisaurus attenuatus
Pine Snake	Pituophis melanoleucus
Glossy Crayfish Snake	Regina rigida
Pine Woods Littersnake	Rhadinaea flavilata
Black Swamp Snake	Seminatrix pygaea
Pigmy Rattlesnake	Sistrurus miliarius
Southeastern Crowned Snake	Tantilla coronata
Eastern Box Turtle	Terrapene carolina
Eastern Ribbon Snake	Thamnophis sauritus
Smooth Earth Snake	Virginia valeriae

Appendix A.4. Amphibian Species Prioritized for Conservation in North Carolina.

Common Name	Scientific Name
Mabee's Salamander	*Ambystoma mabeei*
Spotted Salamander	*Ambystoma maculatum*
Marbled Salamander	*Ambystoma opacum*
Mole Salamander	*Ambystoma talpoideum*
Tiger Salamander	*Ambystoma tigrinum*
Oak Toad	*Bufo quercicus*
Southern Dusky Salamander	*Desmognathus auriculatus*
Three-lined Salamander	*Eurycea guttolineata*
Dwarf Salamander	*Eurycea quadridigitata*
Four-toed Salamander	*Hemidactylium scutatum*
Pine Barrens Treefrog	*Hyla andersonii*
Barking Treefrog	*Hyla gratiosa*
Slimy Salamander	*Plethodon glutinosus*
Brimley's Chorus Frog	*Pseudacris brimleyi*
Southern Chorus Frog	*Pseudacris nigrita*
Ornate Chorus Frog	*Pseudacris ornata*
Gopher Frog	*Rana capito*
Eastern Spadefoot	*Scaphiopus holbrookii*
Lesser Siren	*Siren intermedia*
Greater Siren	*Siren lacertina*
Many-lined Salamander	*Stereochilus marginatus*

Appendix B.1 Potential Conservation Sites Ranked by Betweenness.

Patch ID	Betweenness Value	Area (ha)	Distance to Protected Land (m)
167256	**2616**	**316.46**	**2905**
86172	**1914**	**172.14**	**323**
166104	**1796**	**156.92**	**2475**
150834	**1468**	**324.97**	**1350**
138055	**1432**	**82.60**	**2145**
203382	1298	85.39	759
75538	1288	95.93	108
146033	910	91.99	1660
122034	872	118.03	42
60300	716	123.56	5000
202184	690	93.68	713
225998	672	136.95	60
250574	592	83.01	210
125752	574	176.80	1415
226849	570	186.38	240
96899	570	85.68	430
58180	546	134.18	1994
54181	516	97.23	4352
62793	496	82.55	4895
215906	486	80.19	150
254606	440	139.21	644
67993	372	95.00	3994
94784	364	216.51	2130
257916	348	99.33	939
124598	320	101.90	192
257890	282	110.95	510
272176	276	82.35	457
194368	258	113.21	3224
84016	254	76.50	1989
71009	250	82.04	3065
200283	0	98.76	3713
278736	0	92.96	3566
39904	0	89.91	2156

Appendix B.2. Potential Conservation Sites Ranked by Area.

Patch ID	Area (ha)	Betweenness Value	Distance to Protected Land (m)
150834	**324.97**	**1468**	**1350**
167256	**316.46**	**2616**	**2905**
94784	**216.51**	**364**	**2130**
226849	**186.38**	**570**	**240**
125752	**176.80**	**574**	**1415**
86172	172.14	1914	323
166104	156.92	1796	2475
254606	139.21	440	644
225998	136.95	672	60
58180	134.18	546	1994
60300	123.56	716	5000
122034	118.03	872	42
194368	113.21	258	3224
257890	110.95	282	510
124598	101.90	320	192
257916	99.33	348	939
200283	98.76	0	3713
54181	97.23	516	4352
75538	95.93	1288	108
67993	95.00	372	3994
202184	93.68	690	713
278736	92.96	0	3566
146033	91.99	910	1660
39904	89.91	0	2156
96899	85.68	570	430
203382	85.39	1298	759
250574	83.01	592	210
138055	82.60	1432	2145
62793	82.55	496	4895
272176	82.35	276	457
71009	82.04	250	3065
215906	80.19	486	150
84016	76.50	254	1989

Appendix B.3. Potential Conservation Sites Ranked by Distance to Protected Land.

Patch ID	Distance to Protected Land (m)	Betweenness Value	Area (ha)
122034	**42**	**872**	**118.03**
225998	**60**	**672**	**136.95**
75538	**108**	**1288**	**95.93**
215906	**150**	**486**	**80.19**
124598	**192**	**320**	**101.90**
250574	210	592	83.01
226849	240	570	186.38
86172	323	1914	172.14
96899	430	570	85.68
272176	457	276	82.35
257890	510	282	110.95
254606	644	440	139.21
202184	713	690	93.68
203382	759	1298	85.39
257916	939	348	99.33
150834	1350	1468	324.97
125752	1415	574	176.80
146033	1660	910	91.99
84016	1989	254	76.50
58180	1994	546	134.18
94784	2130	364	216.51
138055	2145	1432	82.60
39904	2156	0	89.91
166104	2475	1796	156.92
167256	2905	2616	316.46
71009	3065	250	82.04
194368	3224	258	113.21
278736	3566	0	92.96
200283	3713	0	98.76
67993	3994	372	95.00
54181	4352	516	97.23
62793	4895	496	82.55
60300	5000	716	123.56