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CONSERVATION ISSUES

Extent of Alabama's Terrestrial Nature Reserve System in Representing Ecosystem Diversity: a Coarse-filter Gap Analysis

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ABSTRACT: Exponential human population growth has resulted in overexploitation of resources, the introduction of alien invasive species, habitat destruction and fragmentation, and the subsequent global endangerment and extinction of many species. Globally, governmental, and nongovernmental programs, use nature reserves (NRs) to mitigate against the decline of biological diversity by protecting habitats and their inhabitants from fragmentation and other negative anthropogenic impacts. However, numerous studies conducted at multiple spatial and temporal scales have revealed that existing NRs do not effectively represent biodiversity, or are experiencing declines in biodiversity because of anthropogenic encroachment around NRs. Our study examined the spatial distribution and characteristics of the NR system in Alabama using coarse-filter gap analysis. We compiled a dataset of private and public NRs in Alabama, and analyzed the extent and effectiveness of Alabama's NR system in representing ecosystem diversity. We found that NRs occupied approximately 840,000 ha (6.2%) of land area in Alabama. Public NRs covered 6.0% of Alabama land area, and private NRs covered 0.2% of the land area. We found a latitudinal shift in NR parcels from majority private NR parcel presence in northeast Alabama to majority public parcel ownership in southwest Alabama. The statewide mean NR parcel area was 2149.47 ha; the mean public NR area was 4789 ha; the mean private NR area was 151 ha; and the mean distance (isolation) between NRs was 4.5 km. We hypothesize the distribution of parcel property types throughout Alabama was related to socioeconomic status, race, and metropolitan areas throughout the state. Our results may be used to improve conservation planning in Alabama, and our approach used as a model to assess NR systems in other states or regions.

Index terms: Alabama, biogeography, ecoregions, gap analysis, nature reserves

INTRODUCTION

Anthropogenic degradation of the environment has resulted in the global decline of biological diversity (Polasky et al. 2000; Scott et al. 2001; MacDonald 2003; Wilson et al. 2005; Hunter and Gibbs 2007; Primack 2008; Wu et al. 2011; Piekielek and Hansen 2012). The exponential human population growth that has been occurring throughout the last two centuries has resulted in overexploitation of resources, the introduction of alien invasive species, habitat destruction and fragmentation, and the subsequent global endangerment and extinction of many species (Powell et al. 2000; Scott et al. 2001; Primack 2008; Cantu-Salazar and Gaston 2010; Piekielek and Hansen 2012).

Habitat fragmentation is hypothesized to endanger, or cause, extinction in many plant and animal species (MacDonald 2003; Hunter and Gibbs 2007; Primack 2008). Fragmented habitats are small, heterogeneous, isolated patches where several deleterious issues to populations can arise: (1) decreases in varying species' populations and resource bases; and (2) increases in species' vulnerability to genetic variation loss events, such as genetic bottlenecks, inbreeding depression, and loss of evolutionary flexibility (Nikolakaki 2003).

Globally, governmental and nongovernmental programs use nature reserves (NRs) to mitigate against the decline of biological diversity by protecting habitats and their inhabitants from fragmentation and other negative anthropogenic impacts (Polasky et al. 2000; Salomon et al. 2006; Cantu-Salazar and Gaston 2010; Piekielek and Hansen 2012). NRs are used to "ensure the persistence of biodiversity and the ecological processes that maintain it" (Salomon et al. 2006). However, numerous studies conducted at multiple spatial and temporal scales have revealed that existing NRs do not effectively represent biodiversity, or are experiencing declines in biodiversity because of anthropogenic encroachment around NRs (Jenkins and Joppa 2009; Wu et al. 2011; Piekielek and Hansen 2012).

In our study, we compiled a dataset of private and public NRs in Alabama and analyzed the extent and effectiveness of Alabama's NR system in representing biodiversity. Alabama is ranked 25th in land area in the United States, but is ranked fourth in biodiversity, after Hawaii, Florida, and California (Primack 2008; Union of Concerned Scientists 2009; Paemelaere and Balmer 2011). The biodiversity of Alabama is attributed, in part, to physiographic diversity and latitude (ADCNR, 2005). Alabama is ranked second in the country in the number of faunal species per hectare (Paemelaere and Balmer 2011). However, Alabama ranks third in the number of threatened and endangered species, behind Hawaii and California (Paemelaere and Balmer 2011). According to the U.S. Geological Survey's Protected Area's database, Alabama has four percent of its public land area permanently protected, which makes it the least publically protected state in the southeastern United States (PAD-US 2007).

Our study examined the spatial distribution and characteristics of the NR system in Alabama using coarse-filter gap analysis, a technique used to assess the ecological representation and distribution of regionally representative ecological communities (Dietz and Czech 2005; Huber et al. 2007; Hunter and Gibbs 2007; Piekielek and Hansen 2012). A gap analysis identifies ecological components that are not represented in a NR network. In Alabama, a gap analysis of this extent, which considers public (including U.S. Department of Defense lands) and private reserves, has never been conducted. A comprehensive gap analysis is used to target areas where biological elements are unprotected by the NR system and help researchers as well as private, state, and federal agencies make well-informed decisions to set, and meet, conservation goals. Our study had three primary objectives: (1) quantify spatial distribution of NRs across Alabama ecoregions; (2) document characteristics such as area, isolation, ecoregion location, property type, and owner type; and (3) identify potential factors that influence area, isolation, location, property type, and owner type. Based on our findings, we make recommendations to improve the NR system in Alabama**.**

METHODS

Study Area

Alabama is located in the southeastern United States and has a land area of 135,775 km^2 (Encyclopedia of Alabama 2011). Forest cover occupies 67% of Alabama's land area (Yarrow and Yarrow 1999). The state extends north from the State of Tennessee at 35°N, to the Gulf of Mexico in the south at ca. 30°N. The climate is classified as humid mesothermal with long, hot summers and short, mild winters (Thornthwaite 1948; ADCNR 2005). Mean annual rainfall ranges from 114 cm to 165 cm across the state (ADCNR 2005). In 2012, the population of Alabama was ca. 4.8 million (U.S. Census Bureau 2012).

In this study, we analyzed ecosystem diversity, as opposed to species richness or species diversity. Ecosystem diversity is used to describe diversity of the biophysical environment at the landscape scale. It represents the "collective response of all interacting species to different environmental conditions" (Primack 2008). Although Alabama's land area is comparatively moderate among other U.S. states, Alabama is ecologically, and physiographically, diverse. Physiographic units are broad-scale regions based on geology, soils, and topography (Fenneman 1938). A three-tiered classification system, which divides physiographic regions into divisions, provinces, and sections, is used to spatially organize physical features (Fenneman 1938). The physiographic provinces of Alabama are the Highland Rim, Cumberland Plateau, Ridge and Valley, Piedmont Upland, and East Gulf Coastal Plain (Fenneman 1938; ADCNR 2005). Edaphic and topographic features across physiographic provinces influence vegetation coverage and the distribution of other biotic organisms (ADCNR 2005). These areas of relative biotic and abiotic homogeneity are considered ecoregions. Ecoregions are interpretive subdivisions based on biotic and abiotic patterns such as "geology, topography, vegetation, climate, soils, wildlife, and hydrology" (Omernik 1987; Yarrow and Yarrow 1999; ADCNR 2005; EPA 2011). In our study, Omernik's (1987) and the EPA's (2001) Level III ecoregions served as a surrogate of habitat types across Alabama (Margules and Pressey 2000). The Level III ecoregions for Alabama correspond well to the major physiographic regions of the state. Level III ecoregions are used for coarse-scale conservation planning throughout various state organizations, including the Alabama Gap Analysis Program (ADCNR 2005). The six ecoregions in Alabama are the Interior Plateau (IP), Southwestern Appalachians (SWA), Ridge and Valley (RV), Piedmont (PD), Southeastern Plains (SEP), and Southern Coastal Plain (SCP). Biological diversity results from having six different ecoregions in one state, which provides a greater opportunity for protection by NRs (EPA 2011). These ecoregions serve as a means to compare the spatial distribution and characteristics of NRs.

Methods

We created a georeferenced database featuring all public (n = 154) and private (n = 206) NR parcels that met our criteria (outlined below; Figure 1). All public and private NR parcels and variables of interest were input into the database. We recorded five different variables for each reserve: (1) area (ha); (2) location (level III ecoregion); (3) property type (public or private); (4) owner type (local, state, federal, or land trust); and (5) distance (km, parcel isolation from nearest NR). No minimum or maximum size or isolation requirements were established. Thus, there was great variation in area and isolation of NRs. We included terrestrial NRs used only for passive recreation, which are areas that are used for activities that place minimal stress on a site (EPA, n.d.). We also chose to include Department of Defense (DoD) lands. Many NR-related studies have not included these lands, but DoD lands have been found to be ecologically important (Benton et al. 2008; Havlick 2011). The DoD has managed public lands and natural resources since 1823 and must follow policies on environmental protection and regulation, including the National Environmental Policy Act and the Endangered Species Act (Benton et al. 2008; Stein et al. 2008).

Public NR data and shapefiles were acquired from the United States Geological Survey (USGS) Protected Areas Database (PAD) (PAD-US 2007). Private NR data were collected only from land trusts that were accredited by the Accreditation Commission of the Land Trust Alliance (LTA), and those that had formally adopted the standards and practices of the LTA. We elected to restrict our analyses to such NRs

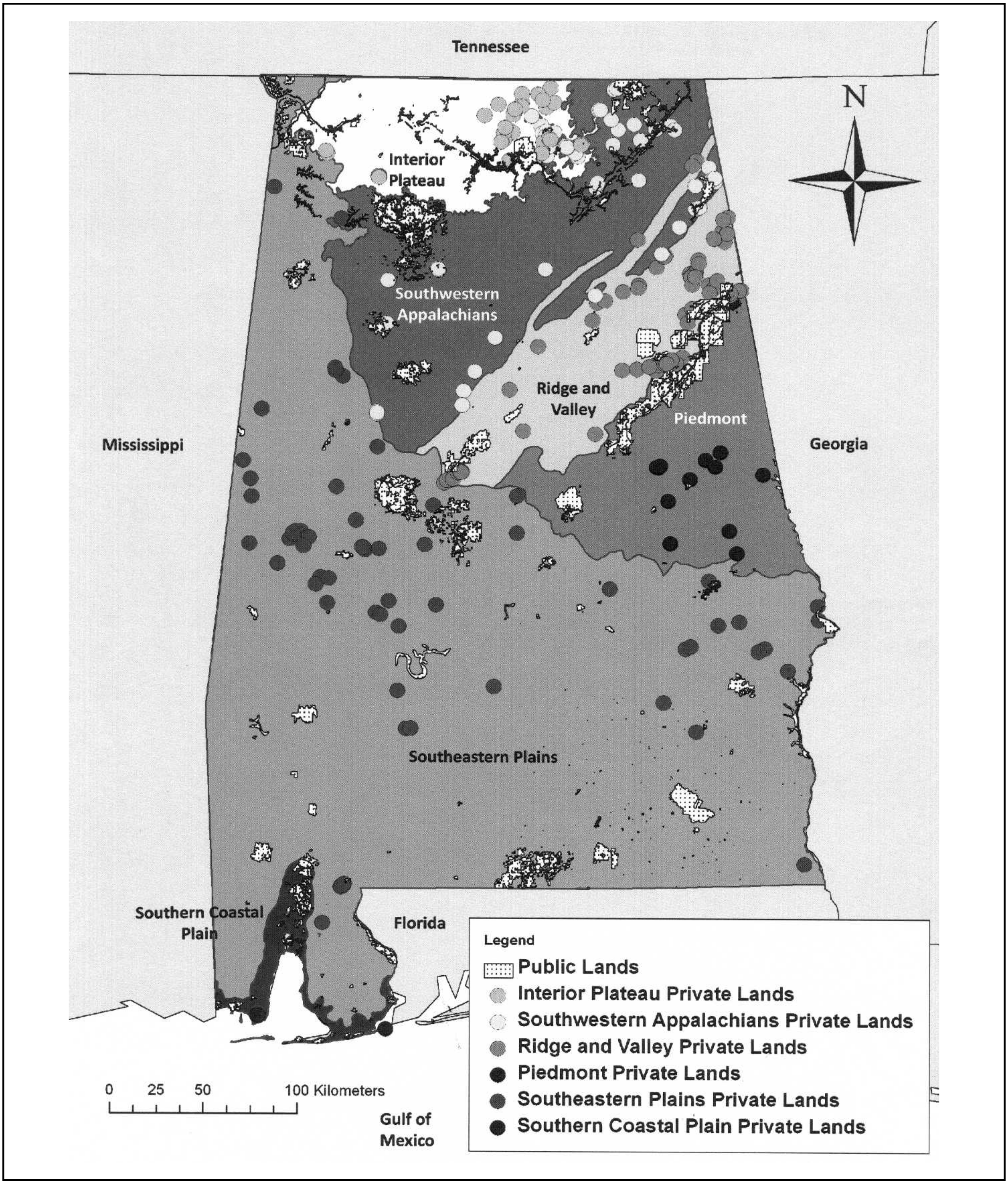

Figure 1. Map showing the State of Alabama, level III ecoregions, and terrestrial nature reserves (NR) by property type (public and private).

to ensure inclusion of reserves that met national standards (Land Trust Alliance 2007). Alabama land trust organizations listed by the LTA as accredited by the LTA, or as adoptees of the LTA's standards and practices, were contacted and all provided available data on all properties in outright ownership and conservation easements in perpetuity. The private land trusts that were included in this study provided us with parcel names, coordinates or addresses, and size.

In ArcMap v. 10, public and private NRs were overlaid on the EPA's Level III ecoregion shapefile (EPA 2011). Public NRs were displayed as polygons. Many land trusts provided NR shapefiles in polygon form, but some land trusts requested that specific boundaries, or any other identifying characteristics of easement parcels, not be displayed (Morris and Rissman 2009). The most efficient option for this research was to display private NRs as points in ArcMap. All parcel shapefiles in polygon form were converted to points. Overlap of points in ecoregions, or modifiable areal unit problems (MAUPS), were accounted for and corrected using the Intersect Tool in GIS to analyze parcel-ecoregion overlap and the measuring tool to measure proximity in cases where MAUPs might be an issue (Jenkins and Joppa 2009; ESRI 2011).

NR characteristics were evaluated using descriptive and inferential statistics in SPSS v.15. Kolmolgorov-Smirnov tests were used to test for normality. In cases where data were not normally distributed, we used nonparametric tests. We used Kruskal-Wallis one-way analysis of variance to compare mean area and distance across Alabama ecoregions. We also used Mann-Whitney U for post-hoc testing. Additionally, we calculated relative NR area of each ecoregion (percent of land area in each ecoregion occupied by NRs). In gap analyses, a predefined minimum extent of each ecological component is considered necessary to analyze ecological function and viability (Villard and Jonsson 2009; Huber et al. 2010). These conservation thresholds assure that no ecological components are excluded from gap analyses (Margules and Pressey 2000; Villard and Jonsson 2009; Huber et al. 2010). We set the threshold for our study at 10% minimum extent coverage by NRs in each ecoregion based on previous studies (Soutullo et al. 2008; Jenkins and Joppa 2009; Huber et al. 2010; Wu et al. 2011).

RESULTS

Statewide NR Characteristics

NRs occupied approximately 840,000 ha (6.2%) of land area in Alabama (Table 1). Public NRs covered 6.0% of Alabama land area, and private NRs covered 0.2% of the land area. The public reserves were comprised of local, state, and federal lands. State-owned reserves represented 58% of all publicly owned parcels. Federally owned NRs represented 39% of all public reserves, and locally owned NRs represented 3% of public NRs. Privately owned NRs were 100% owned by land trusts.

The analysis of statewide results showed that the ratio of NR land area to ecoregion land area was not balanced across the ecoregions (Figure 2). The SEP occupies 60% of Alabama land area, but SEP NRs only accounted for 40% of NR land area in Alabama. In contrast, the PD occupies 9% of Alabama's land area, but PD NRs accounted for 17% of NR land area in Alabama. The SWA, RV, PD, and SCP exceeded the ratio of NR land area to land area of Alabama occupied by each ecoregion. The ratio was most unbalanced for the IP and SEP. Both public and private NRs ranged widely in area. The mean area for public NRs was 4789 ha ± 12,742 standard deviation (SD) and 151 ha ± 267 (SD) for private NRs. The minimum NR area was 0.2 ha, and the maximum was 99,579 ha. The mean distance between public NRs and the nearest reserve was 4.8 km, and the mean distance between private reserves and the nearest NR was 4.3 km.

Area and Isolation of NRs by Ecoregions

Of the six ecoregions, four had less than 10% of their land area protected by NRs (Table 2). The SCP, with 19.3% coverage, and the PD, with 10.4% coverage, were the only ecoregions that exceeded the 10% conservation threshold. The mean area and standard deviation of NRs across ecoregions varied greatly. Mean NR area was lowest for the IP (833 ha) and largest for the PD (5225 ha; Table 2). These averages and standard deviations differ greatly because land parcels are often opportunistically purchased. Thus, there was a large range in NR sizes. The Kruskall-Wallis analysis showed a statistically significant relationship between ecoregion and area ($P < 0.001$). Mann-Whitney U tests between ecoregions revealed statistically significant relationships in area between the IP and PD, ($P = 0.002$), the IP and SEP ($P < 0.001$), the IP and SCP ($P = 0.012$), the

Table 1. Characteristics of the Alabama terrestrial nature reserve network across public (local, state, and federal lands) and private (land trust parcels) property types.

Characteristic	Public	Private
Total Area in Reserve Status (%)	6.0	0.2
Mean (ha)	4789	151
Minimum (ha)	0.4	0.2
Maximum (ha)	99,579	1863
Range (ha)	99,579	1863
Standard Deviation (ha)	12,742	267
Mean Distance between Reserves (km)	4.8	4.3
Landtrust Owned (%)	–	100
Local Owner (%)	3	–
State Owned (%)	58	–
Federal Owned (%)	39	–

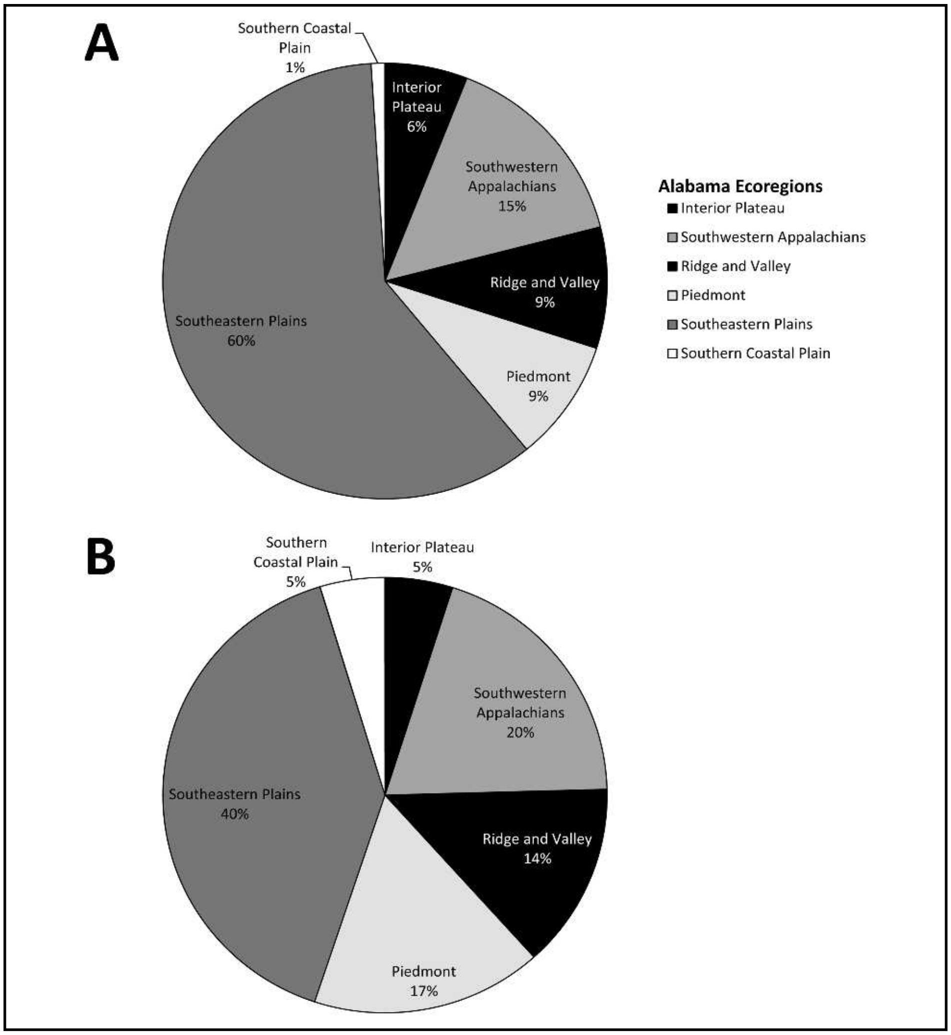

Figure 2. (A) Relative land area of Alabama represented in each level III ecoregion and (B) relative land area of the Alabama nature reserve system represented in each level III ecoregion.

SWA and RV ($P = 0.012$), the SWA and PD ($P = 0.013$), the SWA and SEP ($P < 0.001$), the SWA and SCP ($P = 0.025$), the RV and PD ($P < 0.001$), the RV and SEP ($P < 0.001$), and the RV and the SCP ($P = 0.004$).

Mean distance between NRs also varied across ecoregions. The mean distances between NRs in the IP, SWA, and RV were similar (2.6–2.7 km). Mean distances of the SCP, PD, and SEP were 4.0, 5.1, and 7.7 km, respectively. The Kruskal-Wallis analysis revealed statistically significant relationships between ecoregions and distance ($P < 0.001$). Mann-Whitney U tests between ecoregions revealed statistically significant differences in isolation of NRs between the IP and SEP ($P < 0.001$), the IP and SCP ($P = 0.012$), the SWA and RV ($P = 0.012$), the SWA and PD ($P = 0.013$), the SWA and the SEP ($P < 0.001$), the SWA and SCP ($P = 0.006$), the RV and SEP ($P < 0.001$), and the RV and SCP ($P = 0.036$).

NR Property Type by Ecoregion

Public land area accounted for the majority of NR land in all ecoregions. The SEP had the smallest amount of publicly owned NR land area (94.5%), and the largest amount of privately owned land (5.5%). Conversely, the SCP had the highest amount of publicly owned NR land (99.8%), and the smallest amount of privately owned NR land (0.2%). However, public and private NR parcels were unevenly distributed throughout ecoregions (Figure 3). Private NR parcels accounted for the majority of NR parcels in the IP (61%), SWA (65%), RV (79%), and the Piedmont (52%), by a small margin. Public NR parcels accounted for the majority of NR parcels in the SEP (58%) and SCP (72%). Kruskal-Wallis analysis showed a statistically significant difference between property type and ecoregion ($P < 0.001$). Post-hoc testing revealed significant differences in property type between the IP and RV ($P = 0.032$), the IP and SEP ($P = 0.034$), the IP and SCP ($P = 0.002$), the SWA and SEP ($P = 0.003$), the SWA and SCP ($P < 0.001$), the RV and the PD ($P = 0.003$), the RV and the SEP ($P < 0.001$), the RV and SCP ($P < 0.001$), the PD and the SCP ($P = 0.028$), and the SEP and the SCP ($P = 0.03$).

NR Owner Type by Ecoregion

NR parcels varied by owner type (local, state, federal, or land trust) (Figure 4). Land trusts owned over 60% of NR parcels in the IP (61%), SWA (65%), RV (79%), and PD (52%). In contrast, local, state, and federal entities comprised the majority of NR parcels in the SEP, and represented 58% of NR ownership. The SCP exhibited a departure in owner type compared to the other ecoregions. In the SCP, 55% of NRs were state-owned. We found statistical significance between ecoregion and owner type ($P < 0.001$). Post-hoc testing revealed significant differences in owner types between the IP and RV ($P = 0.022$), the IP and SCP ($P = 0.019$), the SWA and SEP ($P = 0.002$), the SWA and SCP ($P = 0.001$), the RV and PD ($P = 0.004$), the RV and SEP ($P < 0.001$), and the RV and SCP ($P < 0.001$).

DISCUSSION

Statewide NR Characteristics

Of all Alabama land area, 6.2% was in NR status (based on our NR criteria). This percentage was lower than the 10% policy-based conservation threshold established by the Convention on Biological Diversity (CBD) that has been used to evaluate effectiveness of NR networks in many studies (e.g., Soutullo et al. 2008; Jenkins and

Table 2. Characteristics of the Alabama terrestrial nature reserve system across level III ecoregions.

Characteristic	Interior Plateau	Southwestern Appalachians	Ridge and Valley	Piedmont	Southeastern Plains	Southern Coastal Plain
Land Area in Reserve Coverage (ha)	38302.0	152,826	107,105	130,636	312,482	36,755
Relative Ecoregion Land Area in Reserve Coverage (%)	4.4	7.8	9.2	10.4	3.9	19.3
Mean Area (ha)	833	2152	1274	5225	2604	2450
Minimum Area (ha)	1	3	0.2	16	0.4	0.4
Maximum Area (ha)	14,869	73,049	49,465	99,579	63,533	25,494
Range of Area (ha)	14,868	73,047	49,465	99,563	63,532	25,494
Standard Deviation (ha)	2,472	9059	5777	19,926	8087	6420
Mean Distance between Reserves (km)	2.7	2.6	2.6	5.1	7.7	3.9
Public Land Area (%)	96.7	96.5	95.2	97.9	94.5	99.8
Private Land Area (%)	3.3	3.5	4.8	2.1	5.5	0.2
Public Parcels (%)	39	35	21	48	58	72
Private Parcels (%)	61	65	79	52	43	28
Landtrust-Owned Parcels (%)	61	65	79	48	42	28
Locally-Owned Parcels (%)	4	1	1	–	1	–
State-Owned Parcels (%)	11	23	12	36	34	55
Federally-Owned Parcels (%)	24	11	8	16	23	17

Joppa 2009; Huber et al. 2010; Wu et al. 2011). The 10% conservation threshold is somewhat arbitrary and does not necessarily indicate that ecological diversity (i.e., the biodiversity of an ecoregion) is represented in NR systems. The criticisms are "aimed at how targets are set rather than exposing reasons for not settings targets at all" (Margules and Pressey 2000). The percentage of Alabama in NR status we documented was higher than what was reported by PAD-US (2007). However, unlike the PAD-US study, we include DoD lands and private lands held by land trusts that met national standards. Although our study was more inclusive than the PAD-US study, the conservative 10% threshold was still unmet at the state level.

Public NRs in Alabama were generally much larger than private NRs. Public NRs comprised almost all of Alabama NR land. Of the total Alabama land area, 6.0%, out of the 6.2% that was occupied by NRs, was public land. The remaining 0.2% was comprised of private lands. State-owned NRs accounted for 58% of public NRs, and 39% of NRs were owned by federal entities. The high percentage and large size of public NRs in Alabama demonstrates the importance of public NRs in conservation. Specifically, we note that DoD lands represented 11.3% of all Alabama NR land area. The DoD has managed public lands and natural resources since 1823 and must follow policies on environmental protection and regulation, including the National Environmental Policy Act and the Endangered Species Act (Benton et al. 2008; Stein et al. 2008). DoD lands have the highest percentage and densities of federally listed endangered and imperiled species per 1000 km^2, compared to lands managed by the Bureau of Land Management, Forest Service, Fish and Wildlife Service, and National Park Service (Benton et al. 2008; Stein et al. 2008). In 1994, the DoD's "Implementation of Ecosystem Management in the DoD" policy emerged (Benton et al. 2008). The goal of this policy was to maintain and improve the sustainability and native biological diversity of terrestrial, aquatic, and marine ecosystems (Benton et al. 2008). Despite DoD lands being managed for conservation and restoration of resources, many studies

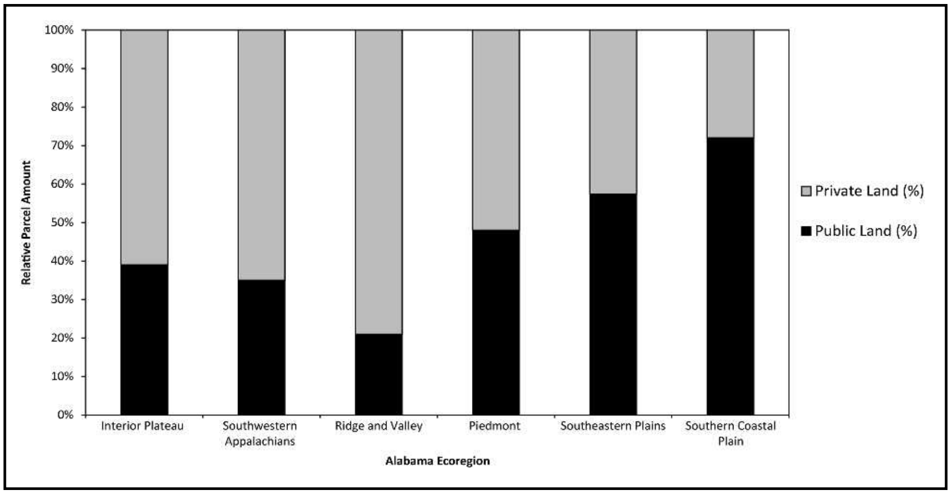

Figure 3. Relative distribution of nature reserve land parcels in Alabama by property type (public v. private) across level III ecoregions.

that have evaluated the effectiveness of NR systems have not included these lands (Ripley and Leslie 1997; Bhuta et al. 2011). We acknowledge that DoD lands may be vulnerable to shifts in changing political agendas and public expectations, as well as some unique processes such as munitions testing and associated fires (Signell and Abrams 2007; Benton et al. 2008; Havlick 2011), but we contend that DoD lands are a major contributor to public lands managed for conservation and should be included in coarse-filter gap analyses to quantify the effectiveness of NR systems.

Ideally, the ratio of NR land area to ecoregion land area would be 1:1 to ensure NR land is distributed evenly among various ecoregions (we acknowledge that some ecoregions are more complex and biodiverse than others). Our results showed that all Alabama ecoregions either exceed or fell under the ratio. The ratio of NR land area to ecoregion land area can be used to evaluate where conservation areas are most needed and, thus, best placed. The PD represented 17.0% of the Alabama's NR land area, but represents only 9.3% of statewide land. Conservation agencies should consider acquiring land in ecoregions that fall below the ratio to ensure even distribution of NRs and ecoregionally equal protection of ecological elements. NR presence in the IP and SEP should be increased to approximate the 1:1 relationship between ecoregion size and protected land area.

Area and Isolation of NRs by Ecoregion

In our study, only two of six ecoregions had 10%, or more, of land area protected by NRs (SCP and PD). The RV almost met the threshold with 9.2% of its land area in NR status. The IP, the SWA, and the SEP were well below the threshold, and we suggest that these ecoregions be prioritized for land purchases and conservation easements. NRs comprised 19% of land area in the SCP, and this ecoregion was the most protected in Alabama. The tourism industry, formed in part around the ecological diversity of the SCP, provides many jobs and produces ca. $2 billion in revenue annually (Douglass 2012). Although human presence has been productive for the economy, the SCP suffers from beach erosion attributed to human-made waterways (Douglass 2012). This combination of factors makes the SCP particularly targeted for conservation efforts. The focus and methods of land protection on the SCP should be replicated in other ecoregions.

Isolation also differed across ecoregions. Our study revealed that mean distance between NRs was greatest in the SEP at 7.74 km. For small ground-traveling animals or migratory animals, these distance barriers can be challenging and life threatening. We speculate the 7.74 km mean distance between NRs was attributed to the large size of the SEP. The mean distance is indicative of a need for greater connectivity between NRs in this ecoregion. Island biogeography theory states that the number of species an island (e.g., an NR) contains at equilibrium is a function of its area and isolation (Mac Arthur and Wilson 1967; Diamond 1975; Margules and Pressey 2000; MacDonald 2003). Connectivity between NRs is important for increased species immigration and for the resulting genetic diversity (MacArthur and Wilson 1967; MacDonald 2003). Corridors, geographic features that promote dispersal and colonization, link isolated protected areas and create a connected NR system (MacDonald 2003; Primack 2008). Ecological corridors are especially important for animals with small, sexually mature populations, and species that must migrate seasonally for food and water (Hunter and Gibbs 2007; Primack 2008). Although corridors are difficult to purchase and there is still a dearth of research in their effectiveness (Hunter and Gibbs 2007), future land purchases in Alabama, especially in the SEP, should consider connectivity and methods to reduce NR isolation.

Although the 10% coarse-filter conservation threshold is useful, many other thresholds have been recommended in the literature. Various science-based thresholds recommend 30%–50% NR coverage of ecoregions (Villard and Jonsson 2009; Huber et al. 2010). Other authors argue that no one threshold should be applied to every ecoregion because thresholds vary between land types and species (Villard and Jonsson 2009). In this study, the CBD's very conservative threshold of 10% was used. This threshold does not necessarily ensure protection of ecological diversity in ecoregions as ecoregions differ in the number of unique ecosystems they support, and some reserve lands in the same ecoregion may be very similar. Thus, some ecosystems within an ecoregion may be underrepresented. Only two of six Alabama ecoregions met the policy-based 10% threshold (PD and SCP); no ecoregion in the state met the commonly cited, science-based conservation threshold of at least 30%.

Property and Owner Type by Ecoregion

NR ownership type for parcels shifted from private NR presence in northeast Alabama to public ownership in southwest

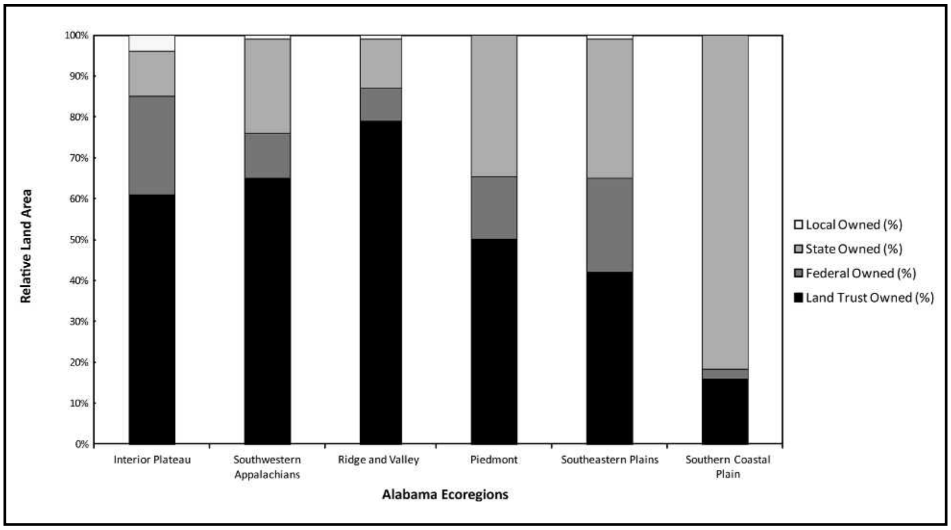

Figure 4. Relative distribution of nature reserve land parcels in Alabama by owner type (local, state, federal, or land trust) across level III ecoregions.

Alabama. The IP, SWA, RV, and PD are the northeastern-most ecoregions, and they were also comprised of the highest relative amount of private NR parcels. Over 60% of NR parcels in the IP (61%), SWA (65%), and RV (79%) were privately owned by land trusts, and half of PD NR parcels (52%) were privately owned by land trusts. NRs in the SEP (58% of NR parcels were public) and the SCP (72% of NR parcels were public) were composed mainly of public NR lands. As with high relative amount of NR coverage in the SCP, the high economic and ecological value of coastal Alabama may be a reason for increased NR coverage. However, the SEP ecoregion does not have the same economic, or perceived ecological value, as that placed on the SCP. We hypothesized the distribution of parcel property types throughout Alabama was related to the distribution of socioeconomic status, race, and metropolitan areas throughout the state. Socioeconomic status is highest in north and central Alabama (U.S. Census Bureau 2012). All regional or local land trusts in this study, except the Weeks Bay Foundation, are headquartered in north or central Alabama or Atlanta, Georgia. In the IP, SWA, and RV, the overwhelming majority of NR parcels were owned by land trusts, which need donors to help land trust continuation. Estabrooks et al. (2003) and Moore et al. (2008) found individuals with low socioeconomic status were less likely to have access to fee-for-use resources and limited accessibility to parks. Moore et al. (2008) also found that areas that were predominantly composed of African- and Hispanic-Americans had lower accessibility to parks. Dwyer (1994) and Tierney et al. (2001) found that African-Americans were significantly less likely than whites to participate in rural and wildland activities, such as hiking and tent camping in underdeveloped natural areas. In the SEP, where the majority of the poorest, predominantly African-American counties are located, NR parcels were mostly comprised of public lands (U.S. Census Bureau 2012). Land trust presence in south Alabama is minimal, while poor African-American presence is high. Similarly, Montgomery and Mobile are the only major cities in south Alabama, as the region is predominantly rural. We found that most land trusts were headquartered in metropolitan areas, and their land purchases and easements were largely concentrated around these locations (i.e., near larger cities where wealthy benefactors are more likely to live).

Our findings indicate that although public agencies are the major contributor to conservation lands throughout the state, land trust presence should be increased to bolster conservation efforts and NR land area in ecoregions that fall below the 10% NR land area threshold, such as the SEP, IP, SWA, and RV. For example, the SEP, the least protected ecoregion, is home to the two known sites inhabited by the federally threatened Red Hills salamander (*Phaeognathus hubrichti* Highton). All known Red Hills salamander habitat sites occur on private land (FWS 2010). In Alabama's conservative political climate, government land acquisition is often seen as a violation of property rights. Land acquisition for conservation by private organizations (i.e., land trusts) or conservation easements, may appear less threatening to this ideology.

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LITERATURE CITED

[ADCNR] Alabama Department of Conservation and Natural Resources. 2005. Alabama comprehensive wildlife conservation strategy. Alabama Department of Conservation and Natural Resources, Division of Wildlife and Freshwater Fisheries, Marion.

Benton, N., J.D. Ripley, and F. Powledge. 2008. Conserving Biodiversity on Military Lands: A Guide for Natural Resources Managers Arlington (VA). NatureServe, Arlington, VA.

Bhuta, A.A.R., J.L. Hart, and R.M. Schneider. 2011. Forest vegetation and development patterns in secondary stands on the Alabama Highland Rim: an examination of the largest landholding in the region. Natural Areas Journal 31:256-269.

Cantu-Salazar, L., and K.J. Gaston. 2010. Very large protected areas and their contribution to terrestrial biological conservation. BioScience 60:808-818.

Diamond, J.M. 1975. The island dilemma: lessons of modern biogeographic studies for the design of nature reserves. Biological Conservation 7:129-146.

Dietz, R.W., and B. Czech. 2005. Conservation deficits for the continental United States: an ecosystem gap analysis. Conservation Biology 19:1487.

Douglass, S. 2012. Alabama coastline. In Encyclopedia of Alabama, Auburn University, Auburn, AL. <http://www.encyclopediaofalabama.org/face/Article.jsp?id=h-2049>.

Dwyer, J.F. 1994. Customer diversity and the future demand for outdoor recreation. General Technical Report RM-22, U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Encyclopedia of Alabama. 2011. Quick facts. In Encyclopedia of Alabama, Auburn University, Auburn, AL. <http://www.encyclopediaofalabama.org/face/QuickFacts.jsp>.

[EPA] U.S. Environmental Protection Agency, Western Ecology Division. 2001. Alabama ecoregion descriptions. Corvallis, OR. <http://www.epa.gov/wed/pages/ecoregions/alga_eco.htm>.

[EPA] U.S. Environmental Protection Agency, Western Ecology Division. 2011. Models, softwares, and datasets. Corvallis, OR. <http://www.epa.gov/wed/pages/ecoregions.htm>.

[EPA] U.S. Environmental Protection Agency, Western Ecology Division. n.d. Meeting Community Needs, Protecting Human Health and the Environment: Active and Passive Recreational Opportunities at Abandoned Mine Lands. Corvallis, OR. <http://www.epa.gov/superfund/programs/recycle/pdf/rec_mining.pdf>.

[ESRI] Environmental Systems Research Institute. 2011. ArcGIS Desktop: Release 10. Environmental Systems Research Institute, Redlands, CA.

Estabrooks, P.A, R.E. Lee, and N.C. Gyurcsik. 2003. Resources for physical activity participation: does availability and accessibility differ by neighborhood socioeconomic status? The Society of Behavioral Medicine 25:100-104. <http://link.springer.com/article/10.1207/S15324796ABM2502_05?LI=true>.

Fenneman, N.M. 1938. Physiography of Eastern United States. McGraw-Hill, New York.

[FWS] U.S. Fish and Wildlife Service, Alabama Field Office. 2010. Red hills salamander. U.S. Fish and Wildlife Service, Alabama Field Office, Daphne, AL. <http://www.fws.gov/daphne/Fact_Sheets/RHS fact sheet_final.pdf>.

Havlick, D.G. 2011. Disarming nature: converting military lands to wildlife refuges. The Geographical Review 101:183-200.

Huber, P.R., S.E. Greco, and J.H. Thorne. 2010. Boundaries make a difference: the effects of spatial and temporal parameters on conservation planning. The Professional Geographer 62:409-425.

Hunter, M.L., and J.P. Gibbs. 2007. Fundamentals of Conservation Biology, 3rd ed. Wiley-Blackwell, Victoria, BC.

Jenkins, C.N., and L. Joppa. 2009. Expansion of the global terrestrial protected area system. Biological Conservation 142:2166-2174.

Land Trust Alliance. 2007. Land trust standards and practices. <http://www.landtrustalliance.org/training/sp/lt-standards-practices07.pdf>.

MacArthur, R.H., and E.O. Wilson. 1967. The Theory of Island Biogeography. Princeton University Press, Princeton, NJ.

MacDonald, G.M. 2003. Biogeography: Space, Time, and Life. J. Wiley, Los Angeles, CA.

Margules, C.R., and R.L. Pressey. 2000. Systematic conservation planning. Nature 405:243-253.

Moore, L.V., A.V. Diez Roux, K.R. Evenson, A.P. McGinn, and S.J. Brines. 2008. Availability of recreational resources in minority and low socioeconomic status areas. American Journal of Preventative Medicine 34:16-22.

Morris, A.W., and A.R. Rissman. 2009. Public access to information on private land conservation: tracking conservation easements. Wisconsin Law Review, 1237. <http://heinonline.org/HOL/Page?handle=hein.journals/wlr2009&div=42&g_sent=1&collection=journals>.

Nikolakaki, P. 2003. A GIS site-selection process for habitat creation: estimating connectivity of habitat patches. Landscape and Urban Planning 68:77-94.

Omernik, J.M. 1987. Ecoregions of the conterminous United States. Map (scale 1:7,500,000). Annals of the Association of American Geographers 77:118-125.

[PAD-US] Protected Areas Database – U.S. Geological Survey, Gap Analysis Program. 2007. Protected areas database of the United States. U.S.Geological Survey, Gap Analysis Program, Reston, VA.

Paemelaere, E., and A. Balmer. 2011. Endangered animal species of Alabama. In Encyclopedia of Alabama. Auburn University, Auburn, AL. <http://encyclopediaofalabama.org/face/Article.jsp?id=h-1656>.

Piekielek, N.B., and A.J. Hansen. 2012. Extent of fragmentation of coarse-scale habitats in and around the U.S. National Parks. Biological Conservation 155:13-22.

Polasky, S., J.D. Camm, A.R. Solow, B. Csuti, D. White., and R. Ding. 2000. Choosing reserve networks with incomplete species information. Biological Conservation 94:1-10.

Powell, G.V.N., J. Barborak, and M. Rodriguez. 2000. Assessing representativeness of protected natural areas in Costa Rica for conserving biodiversity: a preliminary gap analysis. Biological Conservation 93:35-41.

Primack, R.B. 2008. A Primer of Conservation Biology, 4th ed. Sinauer Associates, Sunderland, MA.

Ripley, J.D., and M. Leslie. 1997. Conserving biodiversity on military lands. Federal Facilities Environmental Journal 8:93-105. <http://onlinelibrary.wiley.com/doi/10.1002/ffej.3330080210/pdf>.

Salomon, A.K., J.L. Ruesink, and R.E. DeWreede. 2006. Population viability, ecological processes and biodiversity: valuing sites for reserve selection. Biological Conservation 128:79-92.

Scott, J.M., F.W. Davis, R.G. McGhie, R.G. Wright, C. Groves, and J. Estes. 2001. Nature reserves: do they capture the full range of America's biological diversity? Ecological Applications 11:999-1007.

Signell, S.A., and M.D. Abrams. 2007. Interactions between landscape features, disturbance and vegetation in frequently burned Appalachian oak forests. Pp. 147-166 *in* N.C. Verne, ed., Forest Ecology Research Horizons. Nova Science Publishers, Hauppauge, NY.

Soutullo, A., M. DeCastro, and V. Urios. 2008. Linking politically and scientifically derived targets for global biodiversity conservation: implications for the expansion of the global network of protected areas. Diversity and Distributions 14:603-613.

Stein, B.A., C. Scott, and N. Benton. 2008. Federal lands and endangered species: the role of military and other federal lands in sustaining biodiversity. BioScience 58:339-347.

Thornthwaite, C.W. 1948. An approach toward a rational classification of climate. Geographical Review 3:55-96.

Tierney, P.T., R. Dahl, and D. Chavez. 2001. Cultural diversity in use of undeveloped natural areas by Los Angeles County residents. Tourism Management 22:271-277.

U.S. Census Bureau. 2012. Alabama quickfacts from the U.S. Census Bureau. <http://quickfacts.census.gov/qfd/states/01000.html>.

Union of Concerned Scientists. 2009. Gulf Coast's Alabama biodiversity and land conservation. Union of Concerned Scientists. <http://www.ucsusa.org/gulf/gcstateala_bio.html>.

Villard, M-A., and B.G. Jonsson. 2009. Tolerance of focal species to forest management intensity as a guide in the development of conservation targets. Forest Ecology and Management 258:S142-S145.

Wilson, K.A., M.I. Westphal, H.P. Possingham, and J. Elith. 2005. Sensitivity of conservation planning to different approaches to using predicted species distribution data. Biological Conservation 122:99-112.

Wu, R., S. Zhang, D. Yu, P. Zhao, X. Li, L. Wang, Y. Qian, J. Ma, A. Chen, and Y. Long. 2011. Effectiveness of China's nature reserves in representing ecological diversity. Frontiers in Ecology and the Environment 9:383-389.

Yarrow, G., and D. Yarrow. 1999. Managing Wildlife. Sweetwater Press, Birmingham, AL.