Habitat suitability analysis for mountain lions (*Puma concolor*) on the Southern Cumberland Plateau

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Ecology and Biodiversity

by

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on

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Certified by: ______________________________ Thesis Advisor

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ABSTRACT

Since the 1940's mountain lions (*Puma concolor*) have been extirpated from the eastern United States due to exhaustive hunting, habitat loss, and declining prey populations. Recently, however, evidence suggests that existing mountain lion populations are expanding and recolonizing sites where they have been absent for nearly a century. The southern Cumberland Plateau ecoregion of Tennessee and Alabama, part of the historic home ranges for the extirpated Florida panther (*Puma concolor coryi*) and Eastern Cougar (*Puma concolor cougar*), contains some of the largest remaining tracts of contiguous native forests in the southeast. We built this habitat suitability model because the southern Cumberland Plateau represents unique potential mountain lion habitat in the southeastern US and because there is a need for landscape level habitat analyses in the eastern US for this species. Using a geographic information system (GIS) we examined landscape and habitat characteristics including road density, land cover type, patch density, and contagion in seven counties in Tennessee and three counties in Alabama to determine the quality and extent of potential mountain lion habitat in the Southern Cumberland Plateau Ecoregion. Based on habitat characteristics for mountain lions in other areas, we identified between 940 km^2 and 2,240 km^2 of likely suitable habitat, which could theoretically support a population of 27 to 65 individuals. High suitability habitat predicted by the model also correlates with the locations of unconfirmed mountain lion sightings in the study area.

INTRODUCTION

The current and future status of mountain lions (*Puma concolor*) in Eastern North America has been widely debated and discussed as the number of reported sightings has increased in recent decades. These highly adaptable carnivores have the broadest geographic distribution of any terrestrial mammal in North America and can inhabit nearly every vegetation type ranging from coniferous and deciduous forests to swamps to desert canyons and mountains (Cougar Management Guidelines 2005). However, in the 1940's mountain lions were extirpated from the eastern United States after more than a century of exhaustive hunting, habitat loss, and declining prey populations. The eastern cougar (*Puma concolor cougar*) is deemed extinct in the wild and the Florida panther (*Puma concolor coryi*) has been reduced to a population of less than 100 individuals in south Florida (Maehr et al. 2003, Taverna et al. 1999, U.S. Fish and Wildlife Service 1982). Mountain lion sightings throughout the East have increased markedly and have sparked the attention of the media and the public at large (Harden 2002, Simmons 2002, Walker 2003). Although many wildlife managers contend that these reported mountain lions are escaped captives or released pets, the origin of these individuals has yet to be confirmed (Bolgiano et al. 2000).

Recent evidence is accumulating which suggests that mountain lions are beginning to recolonize sites where they have been absent for nearly a century. Scat, photographs, or mountain lion carcasses have been recovered in Arkansas, Louisiana, Missouri, and other Midwestern states (Leberg et al. 2004, Clark et al. 2002, Genoways et al.1996, Bolgiano et al. 2000). Mountain lions' natural propensity to roam vast distances to establish new territories coupled with the increase in white-tailed deer (*Odocoileus virginiana*) populations is a possible explanation for the eastward migration of western mountain lions into the prairie and Midwest (Kemper 2006, Bolgiano et al. 2000). Evidence of individual mountain lions in our southern Cumberland Plateau study area include a mountain lion shot by a hunter in 1971 in Bledsoe County, Tennessee and mountain lion tracks confirmed by Tennessee Wildlife Resources Agency Wildlife Officer in 1997 in Marion County, Tennessee (Simms 1997).

In light of this evidence, wildlife managers must devise new research plans and rethink previous management strategies in order to accommodate the possible return of these apex predators to eastern ecosystems. In 2007 The US Fish and Wildlife Service initiated the first review of the status of the eastern cougar (*Puma concolor couguar*) since 1982, acknowledging the growing number of confirmed and unconfirmed mountain lion sightings within the species' historic range (Barklay *personal communication*). The Fish and Wildlife Service (Barclay *personal communication*) and Cougar Management Guidelines (2005) state that landscape level analyses that document available habitat are useful in defining existing or potential mountain lion populations.

A common tool used in this capacity is a habitat suitability analysis. These analyses use geographic information systems (GIS) to analyze multiple landscape characteristics to determine the quality of habitat for a focal species (Guisan and Zimmermann 2000; Morrison et al. 1997). Habitat suitability models can be empirical, i.e., based on field observations of species distribution in a particular area, or conceptual, i.e., based on plausible causal relationships between a species and its distribution on the landscape (Dettki et al. 2003). Several habitat suitability analyses have been produced in areas for which the large mammal focal species is currently extirpated (Schadt et al. 2002; Mladenoff et al. 1995; Merrill et al. 1998). In these cases there is often a lack of historical or contemporary information on the biology of resident individuals. Therefore habitat suitability analyses dealing with extirpated species must rely on qualitative conceptual information found in the literature or given by experts, empirical presence/absence data for the species in different locations, or a mixture of both (Merrill et al. 1999).

In this paper, we present a local-scale GIS habitat suitability model for the Cumberland Plateau ecoregion in southern Tennessee and northern Alabama. We built this habitat suitability model because the southern Cumberland Plateau represents unique potential mountain lion habitat in the southeastern US and because there is a need for landscape level habitat analyses for this. The southern Cumberland Plateau's high density of white-tailed deer, rugged sandstone bluffs, and large tracts of native hardwood forests fulfill the two essential requirements for mountain lion habitat: adequate prey and cover (Cougar Management Guidelines 2005, Evans et al. 2002, Ben Layton, personal communication, 2007). In a preliminary coarse-scale habitat analysis of the southeastern US, Thatcher et al. (2003) identified the southern Cumberland Plateau as having 1,000 km^2 of potential mountain lion habitat. With territorial home ranges varying from 25 to over 400 km^2, mountain lions require large patches of contiguous forest or native habitat to maintain viable populations (Maehr and Cox 1995, Kobalenko 1997). Mountain lions establish home ranges in areas with minimal human influence on the landscape such as paved roads and human-modified vegetation types (Dickson et al. 2005, Belden and Hagedorn 1993, Dickson and Beire 2002, Van Dyke et al. 1986, Maehr and Cox 1995). In order to capture habitat characteristics important to mountain lion use at a local scale, we selected the following parameters for our GIS habitat suitability model: land cover type, road density, contagion (a measure of spatial aggregation of land-cover patches), and patch density (a measure of habitat fragmentation) (Table 1).

The purpose of our investigation was:

- To quantify the extent of suitable habitat in this region;
- To compare the relative habitat levels between this finer scale model and the coarser scale model developed by Thatcher et al. (2003); and
- To identify areas of potentially suitable habitat for field investigation.

STUDY AREA

The southern Cumberland Plateau lies at the southwestern edge of the Appalachian mountain range and crosses the Tennessee/Alabama border. Though most of the land on the Plateau is privately owned, it contains some of the largest remaining tracts of privately owned native forests in the southeast and some of the highest woody plant, herpetofaunal, and aquatic biodiversity in the southeastern region (Evans *et al.* 2002). The Cumberland Plateau lies inside the region where the original ranges of the Eastern cougar and the Florida panther historically overlapped (Mirarchi 2004, USFWS 1982).

We used the southern portion of EPA Level IV ecoregions 68a (Cumberland Plateau) and 68c (Plateau Escarpment) as the basis for our study area (Griffith et al. 1997) (Figure 1). Our study area included the portion of the southern Cumberland Plateau that lies within seven counties in Tennessee (Franklin, Marion, Sequatchie, Grundy, Bledsoe, Van Buren, and Warren) and three counties in Alabama (Jackson, Madison, and Marshall). The total area for the study was 6,912 km^2.

METHODS

Model Parameters

Our habitat suitability analysis for the plateau study area is based on a GIS database that included spatial data on vegetative landcover, road density, and habitat patch characteristics. The four landscape metrics for our GIS habitat suitability model included land cover, road density, forest patch density, and contagion.

These parameters were selected based on empirical and qualitative data from mountain lion habitat studies in different habitats and the availability of resolved spatial data for our study area (Table 1). We chose landcover as a parameter based on several studies which indicate that mountain lions prefer habitats with ample vegetative cover and minimal human disturbance (Logan and Irwin 1985, Van Dyke et al. 1986, Dickson and Jenness 2005). We chose road density based upon a suite of studies indicating that mountain lions actively seek out home ranges that have lower road densities than surrounding areas (Belden and Hagedorn 1993, Dickson and Beire 2002, Van Dyke et al. 1986, Maehr and Cox 1995). Forest patch density and contagion are landscape metrics that we chose based on an empirical study of Florida panther home ranges that indicated that these metrics have high biological significance for mountain lions yet have low inter-correlation (Thatcher et al. 2003). The patch density landscape metric quantifies the patches of a given land cover class (in this case native forest) within a given area. Higher patch density indicates higher forest fragmentation and as a result less suitable mountain lion habitat (Thatcher et al. 2003). Contagion is a landscape metric that quantifies spatial aggregation of patches of all land cover types, or the frequency with which different land cover types appear side-by-side. Higher values for contagion indicate greater landscape homogeneity, or less landscape fragmentation, and therefore also more suitable mountain lion habitat.

Model Structure

Our spatial information was collected in database developed using ArcGIS software (ESRI, Redlands, California). Each model parameter was represented by a raster layer that was resampled at a resolution of 90 meters. Analyses for each parameter were conducted using a moving window analysis that incorporated the area within a 3,000 meter radius of each raster cell. Therefore each cell in the final parameter rasters represents the average of the habitat parameter over an area that corresponds to average daily movement patterns of male and female Florida panthers (Thatcher et al. 2003).

Land cover information was derived from 2001 Landsat Thematic Mapper imagery with a resolution of 30 meters (NASA Landsat Program 2001). We resample the imagery to a resolution of 90 meters and performed a supervised maximum likelihood classification in ERDAS IMAGINE 8.7 (Leica Geosystems 2004). This classification method creates statistical parameters based on the spectral signature of user-defined land cover classes to "train" a classifier. Six land cover classes were chosen and ranked *a priori* on a scale of 0 to 10 based on known mountain lion habitat preferences (Table 2) (Logan and Irwin 1985, Van Dyke et al. 1986, Dickson and Jenness 2005).

We created a ranked land cover raster in which the percentage of each land cover class within a 3000 meter radius of each cell was multiplied by its assigned habitat ranking according to the following equation:

$$\text{Ranked Land Cover} = (0 * \%\ \text{water}) + (2 * \%\ \text{urban}) + (4 * \%\ \text{dirt}) + (6 * \%\ \text{grass}) + (8 * \%\ \text{pine}) + (10 * \%\ \text{forest})$$

In the resulting layer, higher cell values indicate areas surrounded by a greater percentage of highly ranked land cover types according to mountain lion habitat preferences.

We obtained a road dataset containing all highways, paved roads, and improved unpaved roads from the US Census Bureau's 2000 TIGER/Line files (U.S. Census Bureau 2001). We calculated road density within a 3000 meter radius of each cell as total road length divided by area within the radius.

We used our land cover classification to analyze land cover patch characteristics using FRAGSTATS 3.3 (McGarigal et al. 2002). We calculated patch density for native hardwood forest within a 3,000 meter radius around each cell. We also calculated contagion for all six land cover classes within a 3,000 meter radius around each cell. Lower values for patch density and higher values for contagion correspond with lower mountain lion habitat fragmentation.

The values for each model parameter were reclassified into the same relative scale of habitat suitability from 1 to 10 with 1 indicating poor habitat suitability and 10 indicating high habitat suitability. The four parameters were summed to yield a composite map of habitat suitability (Figure 2). This map was reclassified again on a scale of 1 to 10 so that the final map displayed 10 relative levels of habitat suitability.

RESULTS

We divided the ten relative habitat suitability rankings into three groups: classes 8, 9, and 10 represent *likely habit*, classes 6 and 7 represent *less likely habitat*, and classes 1, 2, 3, 4, and 5 represent *unlikely habitat*. Likely habitat represents areas with low road density, high proportion of forest cover, low forest patch density, and high contagion. The total area of likely habitat (class 8, 9, and 10) area is approximately 3400 km^2 or 50% of the study area (Table 3). Patches of the highest suitability habitat (class 10) are generally surrounded by concentric rings of decreasing habitat suitability (class 9, followed by class 8, and the pattern continues). We found one large habitat patch in the center of the study area and several smaller habitat patches extending northward along the western edge of the plateau (Figure 2).

We are most interested in contiguous patches of habitat as mountain lions will most likely avoid crossing lower suitability areas characterized by more human development and less forest cover (Van Dyke et al. 1986, Maehr and Cox 1995, Dickson and Jenness 2005). The largest patch of contiguous likely habitat occurs in Franklin and Marion Counties in TN and Jackson County in Alabama. At its center is a patch of the highest ranked suitability habitat, class 10, measuring 940 km^2. Surrounding this class 10 patch is a ring of class 9 habitat with several smaller class 10 patches interspersed. The area of class 9 and 10 is 1,500 km^2. Surround this, is a ring of class 8 habitat. The total area of this patch of class 8, 9, and 10, which we have called likely mountain lion habitat, is 2,240 km^2.

Other portions of the study area along the western edge of the plateau contain patches of likely habitat. However, these patches are smaller and isolated. One of these small patches exists around Savage Gulf State Park in Grundy County, TN to the north of the 2,240 km^2 patch of habitat. However this smaller patch, measuring 550 km^2 is surrounded by less likely and unlikely habitat in classes ranging from 4-7 (Figure 2).

A map of unconfirmed mountain lion sightings (Moye and Keen unpublished data) was overlayed on the habitat suitability map (Figure 4). Twenty-three of the 24 sightings fell within the boundaries of likely mountain lion habitat.

DISCUSSION

There is a tremendous amount of interest among private citizens and wildlife agencies in monitoring the status of mountain lions in the East. The US Fish and Wildlife Service is beginning an extensive study of confirmed and unconfirmed sightings, records of captive mountain lions, prey populations, and landscape analyses throughout the Eastern US in order to update our understanding of the status of Eastern cougar (*Puma concolor couguar*). Our habitat suitability analysis of the southern Cumberland Plateau suggests that this region, with its large patches of contiguous forest and elevated deer densities, should be a focal point of such scientific inquiries.

The feasibility of the Southern Cumberland Plateau supporting a small population of mountain lions depends largely on whether the region meets minimum amount of habitat required to maintain a breeding population. We estimated that the amount of suitable habitat in one contiguous patch is between 940 km^2 and 2,240 km^2. Beier (1993) found that a minimum reserve size of 1,000 – 2,200 km^2 is needed to sustain a mountain lion population for 100 years without immigration. Our model shows that the potential mountain lion habitat on the southern Cumberland Plateau is in the range of minimum habitat requirements. However, Beier's (1993) minimum habitat model was validated on a small population of mountain lions in the desert chaparral environment of southern California. It remains uncertain how this minimum habitat requirement translates to the upland mixed mesophytic environment of the Cumberland Plateau.

The number of individual mountain lions that could potentially be supported in the southern Cumberland Plateau region depends not only on the amount of habitat available but also on the density of mountain lions within that habitat. Belden and Hagedorn (1993) reported that average mountain lion density for the western US is 2.9 individuals / 100 km^2. Based on our habitat estimates of 940^2 – 2,240 km^2 and a mountain lion density of 2.9 individuals / 100 km^2, we calculated that the southern Cumberland Plateau could support 27 to 65 individuals. Based on lower mountain lion densities of 0.91 individuals / 100 km^2 found in the Florida Everglades, Thatcher et al. (2003) estimated that the southern Cumberland Plateau could sustain 24 individuals. It is imperative to note, however, that mountain lion densities and range sizes fluctuate dramatically between different habitats and between different seasons (Dickson and Beier 2002, Grigione et al. 2002, Riley and Malecki 2001). The territory size that a mountain lion would require in the mid-Atlantic region remains unknown (Linzey 2005). Extrapolating mountain lion population estimates in areas with different topography, vegetation, land use, and management history can be unreliable (Cougar Management Guidelines 2005).

Thatcher et al. (2003) evaluated the southern Cumberland Plateau in the context of a reintroduction feasibility study for Florida panthers and identified 1,004 km^2 of potential habitat. Their habitat estimate lies close to our conservative habitat estimate, however it does not show local scale variation within the landscape. They ultimately dismissed the southern Cumberland Plateau as a reintroduction site because it contained relatively high road density, lacked public land, and was smaller than other potential reintroduction sites in the southeast (Thatcher et al. 2003). Our study, however, was completed in the context of identifying suitable habitat for a potentially pre-existing population of mountain lions in the south Cumberland Plateau region.

The completeness of our habitat suitability model was limited by the availability of spatially resolved data for our study area. Although ungulate prey density has been shown to correlate with mountain lion habitat suitability (Jordan 1994, Riley and Malecki 2001, Cougar Management Guidelines 2005), we did not include this parameter in our model because of the lack of white tail deer (*Odocoileus virginianus*) population density data at a resolved scale. A big game biologist with the Tennessee Wildlife Resources Association was able to give deer density estimates at a county-wide scale, but indicated that deer densities differed significantly between the Cumberland Plateau than on the surrounding Highland Rim (Ben Layton *personal communication*). Similarly we were unable to use the human population density as a parameter because the most resolved data available is on the scale of the US Census Bureau block group.

Another challenge of creating a habitat suitability model for a species that is locally extinct is the lack of empirical data or historical information on habitat use in this region. For this reason, drawing the line between what is "suitable" and what is "unsuitable" habitat in habitat suitability models such as ours can be difficult. Our study is simply intended to rank areas within the South Cumberland as better or worse. Our classification as habitat class 8, 9, and 10 as "likely habitat" is a best estimate given our current state of knowledge.

While our study indicates that there currently may be enough suitable habitat to support a small population of mountain lions on the southern Cumberland Plateau, the region is experiencing substantial land use changes. Between 1981 and 2000 the Tennessee portion of our plateau study area lost 14 % (65,660 acres) of native forest cover (Evans et al. 2002). About three quarters of this forest was converted to pine plantations and the other quarter of this forest was converted to residential land use. However, more recently the trend has been shifting away from pine conversion towards more residential development (Gottfried 2007). We identified 38 new or proposed residential developments within likely mountain lion habitat in Franklin, Marion, and Grundy Counties in Tennessee (McGrath et al. unpublished data) (Figure 5). Within the primary contiguous habitat that we identified, these residential developments cover an area of approximately 1 km^2 and represent a 4% decrease in likely mountain lion habitat.

Mountain lions' extensive home ranges create low density populations that are vulnerable to habitat fragmentation in isolated habitats where movement between patches is obstructed (Cougar Management Guidelines 2005). There is little chance of mountain lions immigrating to the southern Cumberland Plateau from the east, south, or west as the plateau is surrounded by predominantly agricultural land uses with little forest cover. Immigration from the northern parts of the Cumberland Plateau is a more likely scenario, although our habitat analysis shows that areas to the north are less suitable due to higher road density and greater forest fragmentation. The Interstate 24 corridor also creates a possible impasse to immigration from the north. In light of the improbability of immigration to the South Cumberland, maintenance of native hardwood forest in high suitability mountain lion habitat should be a primary land management goal.

Even though the southern Cumberland Plateau is dominated by private land ownership and hosts a multitude of land uses, it still may be a suitable site for a small population of mountain lions. Experimental reintroductions in north Florida have demonstrated that mountain lions can persist in forested landscapes that simultaneously sustain a number of human activities; these animals are not strictly "wilderness obligates"

(Maehr et al. 2003). In this habitat suitability study, we identified a large patch of potential suitable habitat, but land use trends in the study area indicate that the quality and extent of this habitat may decline in the future. Without proactive land management strategies the size and contiguity of native hardwood patches may dip below minimum requirements to sustain a population of wide-ranging predators.

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Tables

Table 1: Description of Model Parameters

Model Parameter (Raster data layer)	Source	Software	Description	Literature cited in parameter selection
Ranked land cover	Landsat TM leafoff imagery; 2001	ERDAS Imagine 8.7 ArcGIS 9.1	Six land cover classes classified using maximum likelihood supervised classification. Percent of land cover type within 3000 meter radius multiplied by relative habitat quality rankings chosen a priori.	(Logan and Irwin 1985, Van Dyke et al. 1986, Dickson and Jenness 2005, Taverna et al. 1999)
Road Density	US Census Bureau TIGER/Line files; 2000	ArcGIS 9.1	Road density calculated as total road length within 3000 meter radius divided by area within radius	Belden and Hagedorn 1993, Dickson and Beire 2002, Van Dyke et al. 1986, Maehr and Cox 1995, Thatcher et al. 2003, Taverna et al. 1999.
Patch density	Supervised land cover classification created from Landsat TM imagery, 2001	FRAG-STATS 3.3	Forest patch density calculated within a 3,000 meter radius around each cell. Lower values for patch density indicate a lower amount of forest fragmentation	Thatcher et al. 2003
Contagion	Supervised land cover classification created from Landsat TM imagery, 2001	FRAG-STATS 3.3	Quantify degree of spatial aggregation of patches of all land cover types within 3,000 meter radius around each cell. Higher values for contagion indicate lower amount of habitat fragmentation (i.e. a more homogeneous landscape)	Thatcher et al. 2003

Table 2: Six land cover classes ranked according to mountain lion habitat preference.

Rank	Land Cover Class
0	Water
2	Urban
4	Cleared/Recently logged
6	Grass
8	Pine plantation
10	Native hardwood forest

Table 3: Area and percentage of study area for each habitat suitability class for mountain lions on the Southern Cumberland Plateau.

Habitat Suitability Class	Area (km^2)	% of study area
Highest - 10	1043.82	15.10
9	1126.19	16.29
8	1260.00	18.23
7	1346.10	19.47
6	1145.74	16.58
5	741.93	10.73
4	141.20	2.04
3	59.42	0.86
2	40.15	0.58
Lowest - 1	7.50	0.11
Total:	6912.05	100.00

Figures

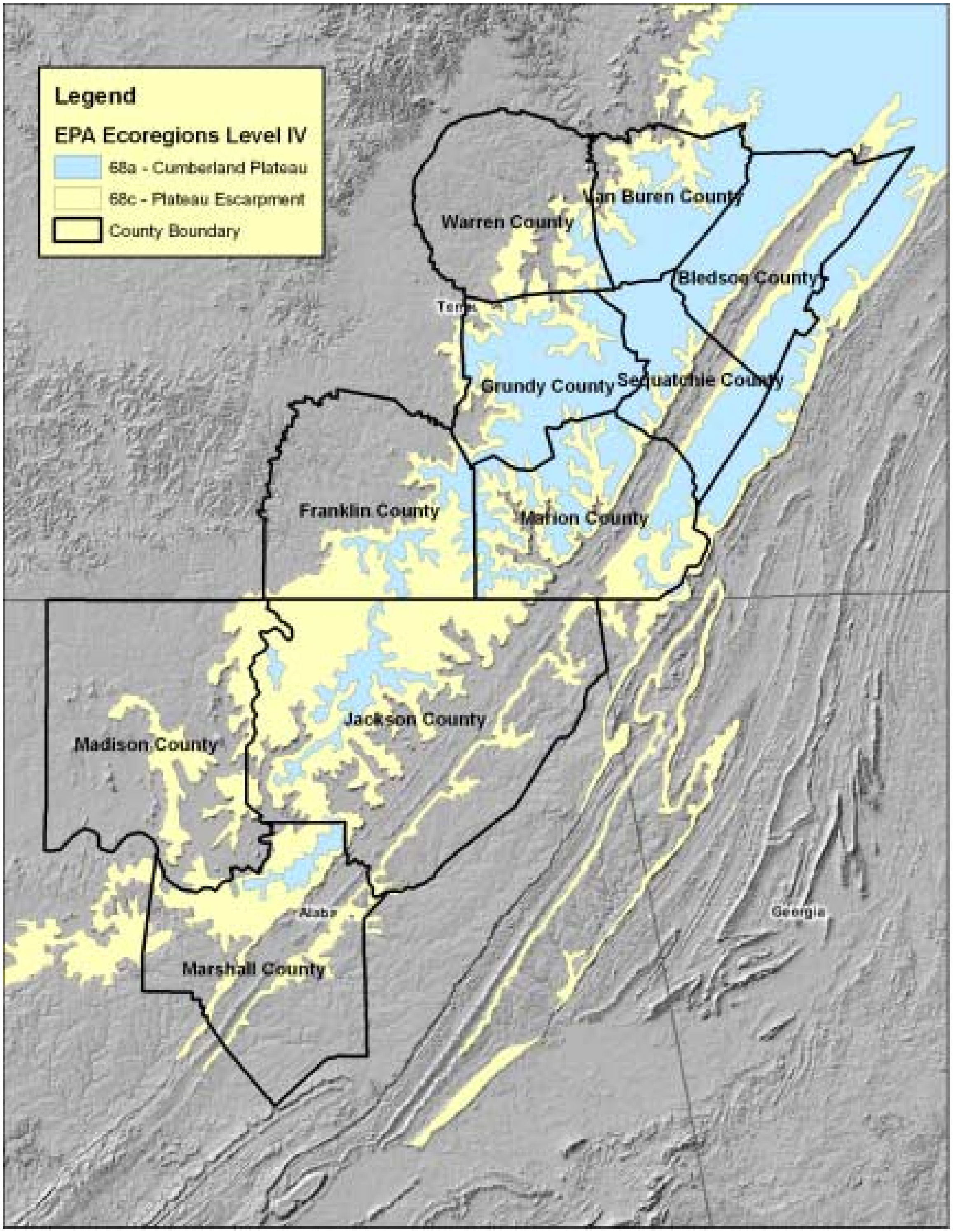

Figure 1: EPA Level IV Ecoregions 68a and 68c study area within 10 Tennessee and Alabama counties

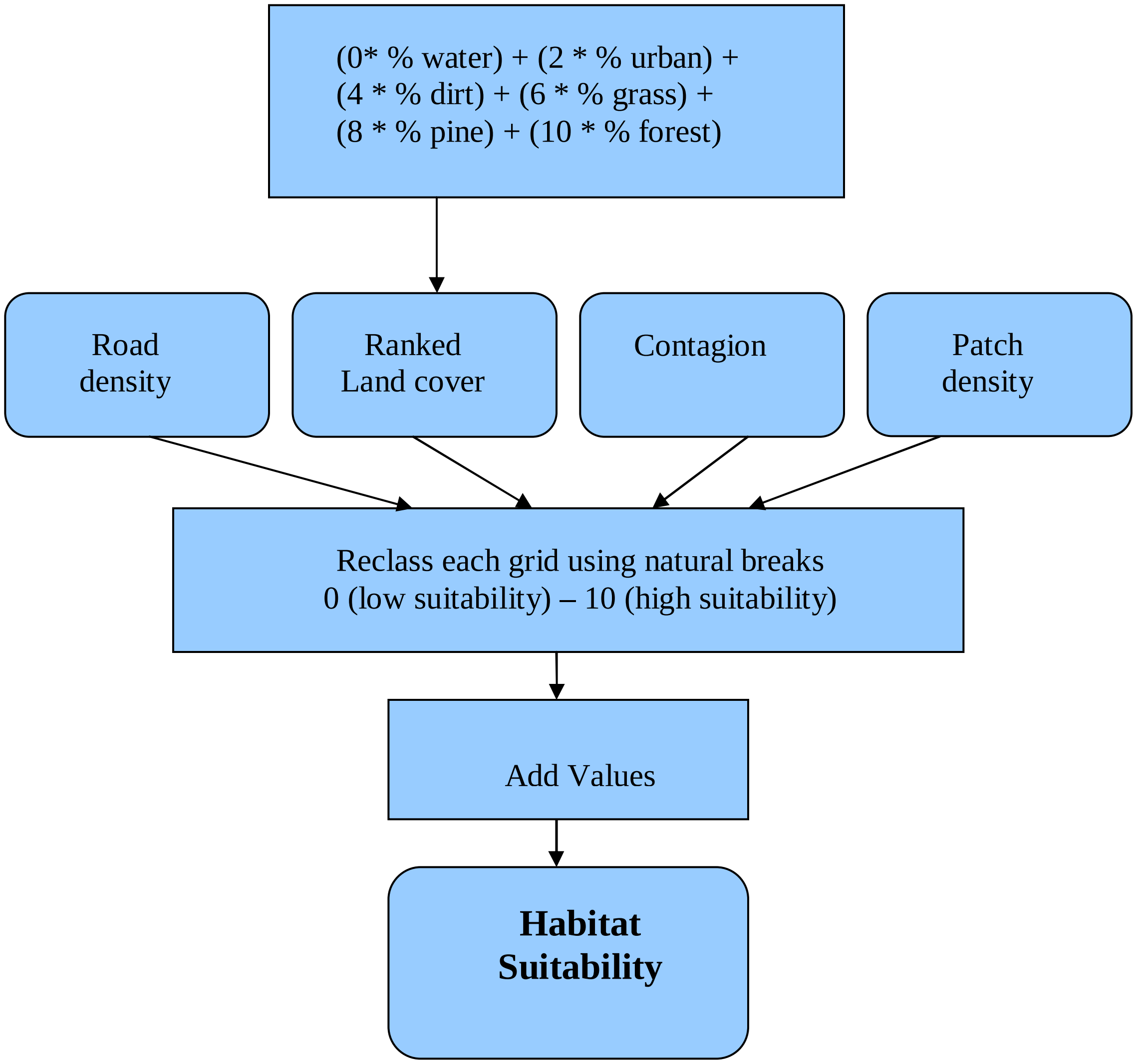

Figure 2: Flow diagram of habitat suitability model for mountain lions on the Southern Cumberland Plateau.

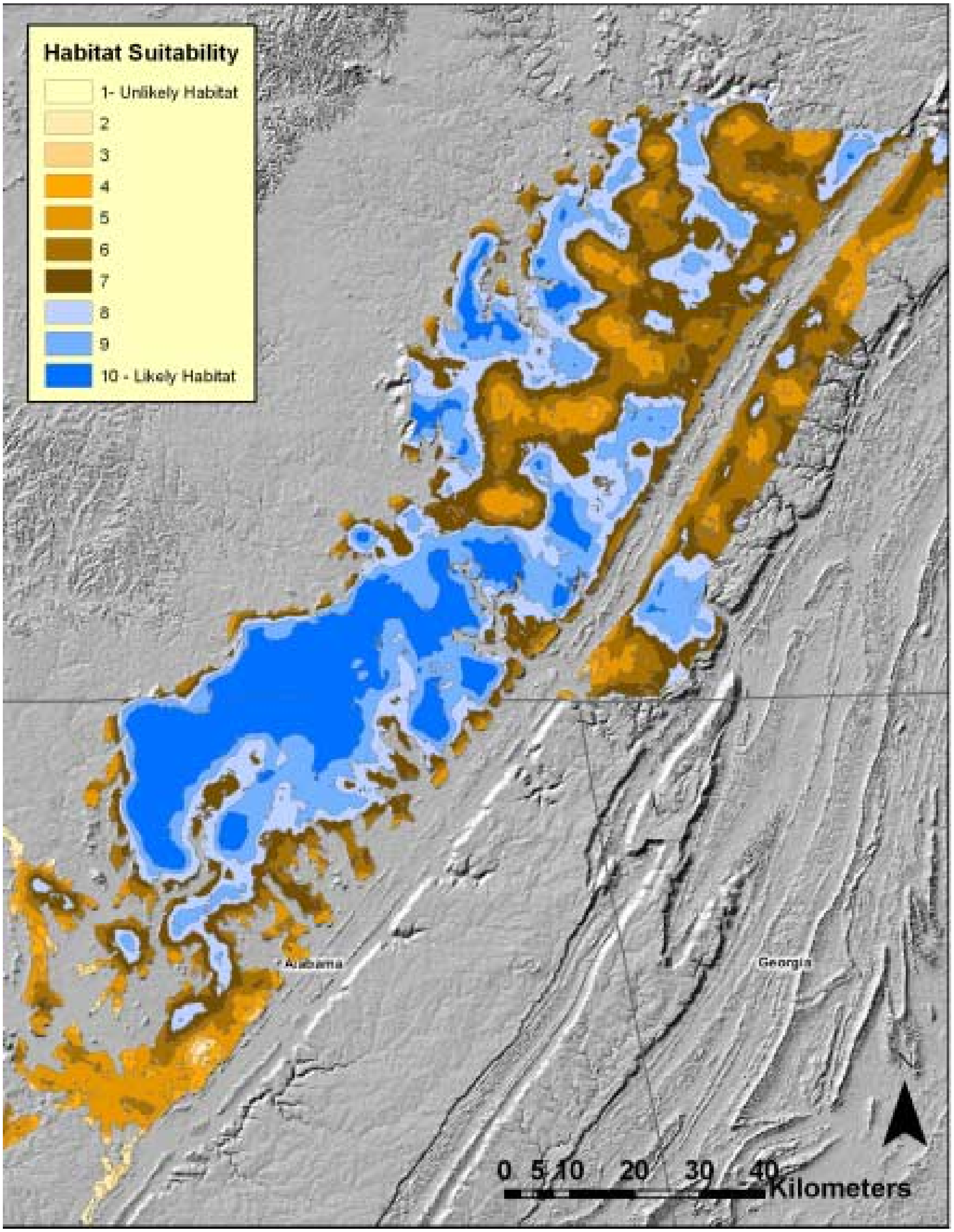

Figure 3: Habitat suitability map for mountain lions on the southern Cumberland Plateau.

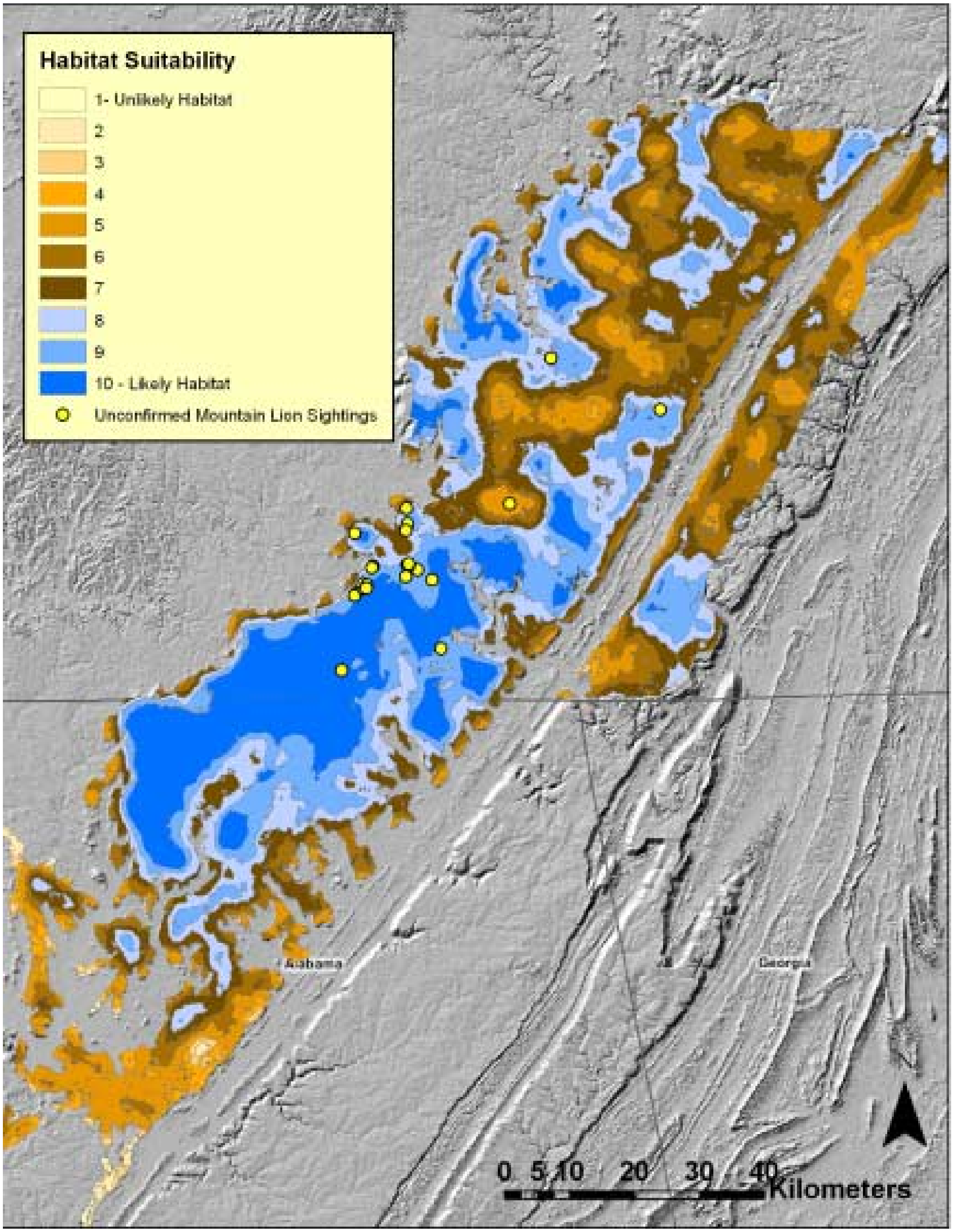

Figure 4: Map of unconfirmed mountain lion sightings superimposed on habitat suitability classes

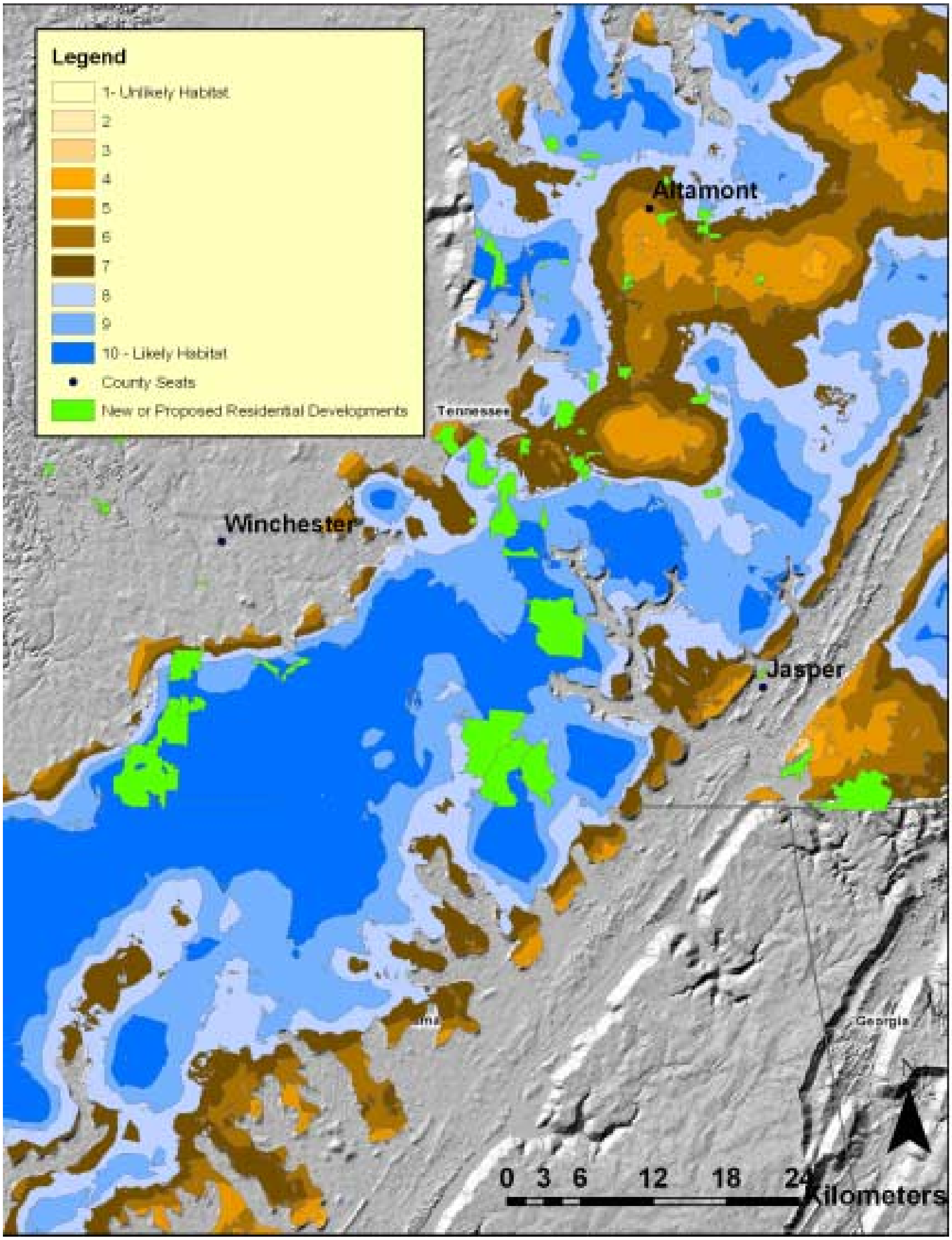

Figure 5: Map of new and proposed residential developments superimposed on habitat suitability classes