EASTERN COUGAR
(*Puma concolor couguar*)

HABITAT SUITABILITY ANALYSIS FOR THE CENTRAL APPALACHIANS

Kristin Taverna, Jason E. Halbert, and David M. Hines
Appalachian Restoration Campaign
A Project of Heartwood

Please note that the Appalachian Restoration Campaign ceased operations in 2000. Similar work is currently carried out by the non-profit Wild Virginia (www.wildvirginia.org).

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Abstract:

The Appalachian Restoration Campaign (ARC) is dedicated to the restoration and protection of Central Appalachian wildlands by developing an interconnected system of reserves in which human activity is compatible with ecological recovery and health. The core of this project is the Central Appalachian Assessment (CAA), focusing on a regional study area that encompasses portions of six states throughout the Central Appalachians. Part I of this Assessment includes an examination of the current landscape within the study area and its suitability for supporting the eastern cougar (*Puma concolor couguar*). Suitable cougar habitat still exists within the Central Appalachians, yet prior studies have not examined the location or availability of habitat. The cougar stands out as an umbrella species for habitat management due to its extensive home range. If we protect the habitat that falls under this protective "umbrella", we could effectively provide for the habitat needs of a number of other species throughout the region. Using GIS software, this analysis identifies suitable cougar habitat based on the landscape characteristics of prey density, road density, human population density, and land use. The data for each layer was reclassified and ranked from 1 to 10 according to its suitability as cougar habitat. The highest suitability rating (10) was given to the categories of lowest road density, lowest human population density, highest deer density, and forest habitat. The reclassified data layers were added using ArcView to create a final composite map, with a total score calculated for each cell of 5.5 mi^2 (14.2 km^2). The composite scores for the CAA study area range from 8 to 40, with 40 being those cells most suitable as cougar habitat. The greatest density of high suitability cells within the CAA study area (total score 37 - 40) is located within the central to northwest section of West Virginia. There are also smaller areas of dense cells with a high suitability rating (total score 34-40) located in northeastern West Virginia and in northwest Pennsylvania. In addition, a large portion of cells which received a high suitability rating (total score 32-40) are located along the Appalachian mountain chain and within the northern Allegheny plateau. Additional research is necessary to further identify specific areas of suitable habitat on a smaller scale and to examine these areas in terms of property ownership and current protection status.

Introduction

There is a growing recognition among the scientific community that in order to effectively conserve biological diversity in the long term, conservation plans need to encompass large areas, on the order of tens to hundreds of thousands of square kilometers (Noss et al. 1996, Noss & Cooperrider 1994). It is not likely that governments will initiate regional conservation planning since there are few legislative precedents and multi-state planning is not in keeping with American political traditions. The Appalachian Restoration Campaign (ARC) utilizes geographic information systems (GIS), for large-scale conservation planning throughout the Central Appalachian mountains and plateaus.

Through ecological research, education, and advocacy, ARC works to develop and forward an interconnected system of reserves where human activity is compatible with ecological recovery and health. The core of this project is the Central Appalachian Assessment (CAA), focusing on a study area that encompasses all of West Virginia and portions of Virginia, Maryland, Kentucky, Ohio, and Pennsylvania (Figure 1).

Part One of the CAA, entitled "Assessing Current Ecological Conditions in Central Appalachia," examines a defined study area through a Geographic Information Systems spatial database. Representation of native biodiversity and current ecological conditions are examined using both coarse and fine filter approaches. Elemental occurrences of all rare, threatened and endangered species were overlaid with ecological regions (Keys et al. 1995, Omernik 1987, 1995) to provide a fine filter examination of existing conditions. Additional layers will be added as the analysis reveals new questions and new results. Our coarse filter includes the present examination of the central Appalachian landscape and its suitability for supporting the eastern cougar (*Puma concolor couguar*). The results will enable Part Two of the Central Appalachian Assessment, and an evaluation of current protected lands.

Once roaming throughout the eastern United States and beyond, the cougar stands out as an umbrella species for habitat management due to its extensive home range. Depending on the prey density, location of other cougars, and type of landscape, the home-range for an individual adult male can range anywhere between 15 to 125 mi^2 (~40-325 km^2) (Anderson 1983, Hornocker 1970, Seidensticker 1973, Wright 1972, USFWS 1991). The data for home range size is based on male cougars because males typically have larger home ranges than resident females and male territories generally do not overlap, whereas females share some common areas (Anderson 1983, Linzey 1987). According to studies done in the western US, the minimum habitat area needed to support a cougar population of about 15-20 adults lies between 390 and 850 mi^2 (1000-2200 km^2) (Beier 1993). Although there are no documented viable populations of cougars in the Appalachians, theoretically, if we protect what suitable cougar habitat is left, this landscape "umbrella" would theoretically benefit and support the habitat needs of many other species throughout the region (Noss & Cooperrider 1994, Noss et al. 1996, Havlick 1998).

The Eastern Cougar Habitat Suitability Analysis is a tool for identifying those areas within the Central Appalachians that could fulfill the habitat requirements for the largest obligate carnivore in the east. Before the early 1900's, cougars roamed throughout the eastern forests. Excluding the Florida panther (*Puma concolor coryi*), cougars are now considered extirpated from the east and, as discussed above, there are currently no documented viable populations of cougars in the Appalachians. As a result, there is very little data available on the biology and habitat requirements of the eastern cougar (*Puma concolor couguar*). The only large collection of scientific data available on *Puma concolor* comes from studies done in the western U.S. Although the native temperate ecosystems of the east are quite different from many western environments, the western data can be used as a guideline to help identify characteristics of suitable habitat in the east (Bolgiano 1995, Brocke 1981, Wright 1972). As such, the biology and habitat requirements for the cougar are generally defined within this analysis based on western data.

The information gained from this analysis can then be used in conjunction with additional CAA priority restoration criteria to identify and map linkages between these areas to insure animal and plant migration corridors. The proposed reserve network would represent native ecosystems, support native plant and animal populations, and allow for natural evolutionary processes and disturbance regimes within a network of protected lands (Noss & Cooperrider 1994).

Background on the Eastern Cougar

"There is no such thing as a good or bad species. A species may get out of hand, but to terminate its membership in the land by human fiat is the last word in anthropomorphic arrogance." Aldo Leopold-*A Sand County Almanac*

Commonly known as cougar, puma, catamount, mountain lion, panther, or painter, *Puma concolor* once thrived throughout Appalachia and beyond. Its home range originally covered ground from the Yukon territory, Canada, across North America, to the southern tip of South America. With habitat requirements that allow for such a diversity of climate and ecosystems, the cougar is considered one of the most adaptable large mammals in existence (Bolgiano 1995, Brocke 1981, Wright 1972). Yet, as recent history has shown, the cougar's adaptability and range throughout the east have been severely threatened by extirpation and habitat loss due to human development.

As European settlers moved into the vast wilderness throughout the East and cleared the land, the cougar faced unrelenting persecution. Such a large predator was viewed as a personal threat and completely incompatible with raising livestock. Widespread bounty hunting of cougars, a severe decline in deer populations, and the loss of forested habitat during the 1800's and early 1900's, led to the virtual extinction of the eastern cougar by the turn of the century (Bolgiano 1995, Downing 1981, Parker 1998, Wright 1972, Young & Goldman 1946).

As cougar populations declined, so did the habitat necessary to support a viable population in the east. The development of roads, agricultural lands, and urban expansion fragmented once contiguous natural communities. Such development and loss of habitat continues largely unabated today as human population increases throughout the east.

Yet all suitable habitat is not lost. Over the last century, abandoned agricultural fields and cleared land have slowly converted back into forest, and many continue to believe that the rugged mountains and forested valleys of the Appalachians provide sanctuary for small, isolated populations of eastern cougars (Parker 1998). Such claims are given further credence by the fact that cougar sightings and sign have continued throughout the Appalachians even as cougar habitat has grown more fragmented and developed.

Following the decline of eastern cougar populations in the early 1900's, cougar sightings did not increase significantly until after the white-tailed deer population was restocked and protected in the 1930's (Bolgiano 1995, Downing 1981). By the 1950's and 1960's, the number of cougar sightings had increased dramatically. This increase in sightings gained the attention of wildlife agencies and the eastern cougar subspecies (*Puma concolor couguar*) was listed as a protected animal in the 1973 Endangered Species Act (Bolgiano 1995).

By the late 1970's, a number of cougar sightings were reported in and near the Nantahala National Forest of the Great Smoky Mountains in North Carolina. Several groups threatened to sue the U.S. Forest Service unless it protected the habitat and halted all timber extraction on a 112 mi^2 (290 km^2) tract of land within the Nantahala National Forest (Downing 1981, Bolgiano 1995). The U.S. Fish and Wildlife Service responded to this threat by joining with the Forest Service to sponsor a field study to officially determine the status of the cougar in the southern Appalachians. The study was lead by wildlife biologist, Robert Downing. After three years of snow and dirt tracking along the Blue Ridge Mountains and within various national forests, the study produced only one track and one scat suspected to be cougar (Downing 1981). Yet according to Downing, tracking conditions were rarely ideal, and few areas were searched intensively enough to say with high certainty that cougars were not present (Downing 1996). But due to a lack of indisputable sign, Downing had to report that he was unable to confirm self-sustaining populations of cougars (Downing 1981). For federal and state wildlife agencies, this report settled the controversial matter of the eastern cougar and concerns for the cougar could no longer justifiably affect federal policy.

The release of Downing's study in 1981 did nothing to quell the number of cougar sightings throughout the east. Yet many wildlife biologists do not consider sightings to be proof of cougar presence since there are numerous cases of reports mistaking animals such as bobcat, deer, or large dogs, as cougars (East 1979). Unless the sightings are reported by a credible source, such as a trained biologist, or are coupled with hard evidence, most state wildlife agencies dismiss them.

The most convincing evidence of cougar presence is clearly when a live cougar is captured or killed. In 1967 an immature female cougar was killed in northwestern Pennsylvania (Parker 1998, Wright 1972). Although opinions of the details vary, in April of 1976, a young male cougar was killed by a farmer in Pocahontas County, West Virginia. Two days later, a female cougar (some reports say she was pregnant) was captured by the WV Department of Natural Resources in the same vicinity (Pocahontas Times 1976). The female cougar was later brought to the French Creek Game Farm in Buckhannon, WV, and ultimately sold to a zoo in Pennsylvania (Ashe 1976, Vanscoy 1999). The mystery and lack of paper trails surrounding the Pennsylvania and West Virginia cougars typify the treatment of such situations by state and federal agencies. Freedom of Information Act requests to pertinent agencies revealed little more than newspaper accounts.

Of the remaining states within the Central Appalachian study area, the last documented cougar kill or capture took place in Ohio in the 1960s, Maryland in the 1920s, Virginia in 1882, and Kentucky in 1863 (Bolgiano 1995, Danz 1999, Downing 1981, East 1979, Parker 1998, Wright 1972, Young & Goldman 1946).

Within the past five years, the Extension Wildlife Specialist at the University of California has confirmed two sets of tracks found in West Virginia. One set, found in Wyoming County, West Virginia in 1996, was confirmed as the right front foot of an adult male. The second set was found in the summer of 1998, in Mingo County, West Virginia, and was confirmed as an adult female (Lester 1999).

All the cougar captures and sign that have occurred since the mid 1900s have raised important, yet difficult, questions among cautious wildlife biologists. How many of these animals were born in the wild as free-roaming cougars, or how many were bred in captivity and released by their owners? For the cougars captured and killed in West Virginia in 1976, it was assumed that both had been released from captivity since they appeared to be tame and showed no fear of humans (Ruckel 1976). For the cougar killed in Pennsylvania, there was no evidence that it had ever been in captivity (Wright 1972).

Currently, if any cougar is found outside of captivity, state wildlife agencies must determine whether or not the cougar is of the eastern cougar subspecies, *Puma concolor couguar*. Only the native eastern subspecies and the Florida Panther, *Puma concolor coryi*, are protected under the Endangered Species Act. Based on this classification system, any cougar that is determined to be within another subspecies is considered unprotected (Bolgiano 1995). For some state and federal wildlife agencies, this is reason enough to dismiss the need to further study particular cougar findings and offer no protection if the cougar is not an "eastern" cougar (Bolgiano 1996, Parker 1998, Tischendorf 1999).

Under the current taxonomic classification, there are 32 subspecies of *Puma concolor* (Culver 1999). The subspecies designation of the eastern cougar was created a half century ago, primarily based on skull measurements (Anderson 1983, Bolgiano 1995, Parker 1998, Wright 1972). With a home-range that can encompass over a hundred square miles, there has been a wide dispersal of genetic material throughout the region and across the US (Brocke 1981, Linzey 1987, Noss 1996, Parker 1998). Although small regional variations may occur among certain populations of cougars, there are no obvious differences in physical characteristics of *Puma concolor* to support the need for 32 subspecies (Parker 1998).

Recent cougar studies of Felid systematics based on genetic data rather than physical characteristics show a need to reclassify the subspecies designations for *Puma concolor*. Melanie Culver, working under feline geneticist Stephen O'Brien at the University of Maryland, recently finished her dissertation addressing the genetic geographic variation among cougar populations, taking into account evolutionary mechanisms, population structure and ecology (Culver 1996,1999). The study collected and examined biological samples from 315 cougars throughout their entire range and the samples included 1 to 35 animals from each of the 32 subspecies (Culver 1999). Each sample went through genetic analyses and based on the results she concluded,

> there is no basis for maintaining 32 subspecies. Instead the use of six subspecies is recommended, adopting the oldest name among the subspecies that are combined. All temperate North American subspecies (north of Nicaragua) should be recognized as different populations of a single subspecies. Since *Puma concolor couguar* is the oldest named subspecies among the 15 North American subspecies, it is further recommended that all pumas north of Nicaragua be recognized as *Puma concolor couguar*. The DNA analyses also showed one subspecies occurring in Central America and four others in South America. The similarity within and among the six groups is perhaps more important to consider than the differences (Culver 1999).

The release of Culver's dissertation has led to an increased interest in systematic revisions for all subspecies of *Puma concolor*. As more research is done on the cougar subspecies designations, the need to revise the current designations will potentially gain more support. The reclassification of all temperate North American cougar subspecies into a single subspecies, *Puma concolor couguar*, could have both positive and negative effects in terms of eastern cougar protection.

The term "eastern" would no longer signify a distinct subspecies, but more accurately, a specific geographic population. With a large viable population of cougars currently living in the west, a single subspecies designation could spur an attempt to take the eastern cougar off of the Endangered Species list. US Fish and Wildlife Service officials currently want to delist the "eastern" cougar. If left on the Endangered Species List, the animal, regardless of its anthropogenic name, could still be protected as a distinct population segment if more cougars were to recolonize the east. This change in classification would not allow state and federal wildlife agencies to make the popular claim that any cougar in the east is a released or escaped western cat, thereby avoiding protection under the Endangered Species Act.

Justified or not, most federal and state wildlife agencies are unwilling to do a long-term study of cougar populations, or the potential for them, in the Appalachians. At this time ARC does not recommend any reintroduction effort; public and agency sentiment towards the cougar seems too hostile. It is our hope that this study will initiate further research and, along with the important work of others like the Eastern Cougar Foundation, spark renewed interest and support for cougars in the east.

Whether cougars residing in the east are native, biologically distinct, eastern cougars, or animals pushing back into their former range, or even captively bred free cats, we must learn to respect and protect one of North Americas most important predators. The importance of education on cougars and other predators cannot be overstated.

Central Appalachian Study Area Description

The habitat suitability analysis is a regional study, focused on an area encompassing all of West Virginia, the plateaus and ridges of Pennsylvania, southeastern Ohio, eastern Kentucky, and western Virginia; we call this area "Central Appalachia." The Central Appalachian study area is a total of 107,644 mi^2. The region hosts a range of forest ecosystems and topography. Spanning north to south along the western edge of the study area is the Appalachian plateau, made of the Allegheny plateau in the north and the Cumberland plateau in the south. East of the plateau, the region rises in elevation to form the folding Ridge and Valley province. Dry and rocky ridges are the norm throughout this province, coupled with deep and narrow stream valleys (Mueller 1994, 1986). Along the eastern most edge of the CAA study area lie the Blue Ridge mountains. Elevations throughout the entire region range from about 300 to 5800 ft (90 to 1740 m) with the highest elevations found in West Virginia and southwest Virginia.

The study area includes the headwaters of two major eastern watersheds, the Chesapeake and the Ohio, the former being the largest freshwater estuary in North America. Their major drainages are the economic and ecological lifeblood of this region. The James, Potomac, Patuxent and Susquehanna make the Chesapeake. The major tributaries of the Ohio River, including the Monongahela, Allegheny, Kanawha (New), Scioto, Muskingum, Big Sandy and Kentucky, all flow from within the study area.

The wide range of landscape characteristics and topography throughout the Central Appalachians has led to a diversity of forest types within the CAA study area. Forests make up 72.9% of the land cover within the CAA study area, (Table 1). The most diverse forest type present within the CAA is the mixed mesophytic. The mixed mesophytic forest is predominant within the Cumberland and Allegheny plateau region at elevations below 2500 ft (760 m) (Bailey 1995, Braun 1950, Mueller 1994). This forest type is most developed throughout West Virginia, yet it also extends northward with attenuated diversity. Widespread dominants of the mixed mesophytic forest include a number of species of oaks, hickories, maples, basswoods, birches, ashes, poplars, and pines.

Oak-pine forests characterize the Ridge and Valley province of the Central Appalachians. The dominant oaks are white, black, scarlet, northern red, and chestnut. The pines are predominant on the drier sites and they include Virginia, pitch, shortleaf or yellow, and table mountain pine (Braun 1950, Mueller 1994). Into the higher elevations, as well as northward into Maryland, Pennsylvania, and Ohio lie the northeastern hardwood forests. Maple, beech, and birch species with a mixture of hemlock and white pine characterize these forests. Among the highest elevations of the Blue Ridge and Allegheny mountains, between 3500–5800 ft (1000-1740m), the northeastern hardwoods gradually yield to forests dominated by spruce and fir species, meadows, and balds (Bailey 1995, Braun 1950, Mueller 1994).

Table 1.
Land Use/Land Cover: Percent of CAA Study Area
Source:USGS Landsat TM Data, 1993.
EROS Data Center, Sioux Falls, SD

Forest	72.86 %
Agriculture	22.99 %
Developed	2.09 %
Water	0.86 %
Transition	0.84 %
Wetlands	0.37 %

Methods

We compiled four spatial data sets of landscape characteristics for the Central Appalachian study area to identify potential cougar habitat: land cover/land use, human population density, prey density, and road density. Each data set was selected based on previous studies of cougar habitat, which utilized some or all of the layers to determine suitable habitat locations.

Jordan (1994) defined suitable sites for the reestablishment of the Florida panther based on the variables: site size, vegetation, population density, and road density. Additional research supports the use of prey density in determining suitable cougar habitat. Such studies have also shown that ungulate-size prey serves as the primary food source for the cougar (Anderson 1983, Brocke 1981, Hornocker 1970, Linzey 1987,1994, Riley 1998, Seidensticker et al. 1973, Toweill 1977). Within the Central Appalachians, the predominant ungulate is the white-tailed deer (*Odocoileus virginianus*). For the purposes of this analysis, prey density is defined in terms of deer density.

Actual road data was obtained from USGS as 1:100,000 digital line graphs and includes all highways, paved roads, and improved unpaved roads passable by auto, but excludes unimproved forest roads and trails. Road density was calculated for the CAA study area as miles of roads per square mile (mi/mi^2) (Figure 2).

Human population data was obtained from the U.S. Bureau of the Census, Annual Time Series data. Total population was recorded and averaged for each county within the CAA study area for the years 1994 – 1997. The average population for the four years was calculated to provide an estimate of human population. Human population density was determined per county by dividing the average population of each county by the total county area, and is recorded as average population per square mile (pop/mi^2) for each county (Figure 3).

Land use/land cover data for the CAA study area was derived from digital Landsat Thematic Mapping ™ data at a 30m resolution from USGS EROS Data Center. The original Landsat ™ data recorded the land use/land cover in terms of the variables listed in Table 2.

category includes quarries, strip mines, and gravel pits. Although this variable would not normally be considered transitional, it accounts for 0.5% of the total land use for the CAA study area. It was therefore considered acceptable to include it within the transitional category.

Table 2: USGS Landsat TM Data Variables
Source: 1993.EROS Data Center, Sioux Falls, SD

Water	11 Open Water 12 Perennial Ice/Snow
Developed	21 Low Intensity Residential 22 High Intensity Residential 23 High Intensity (Commercial/Industrial/Transportation)
Barren	31 Bare Rock/Sand/Clay 32 Quarries/Strip Mines/Gravel Pits 33 Transitional
Natural Forested Upland (non-wet)	41 Deciduous Forest 42 Evergreen Forest 43 Mixed Forest
Natural Shrubland	51 Deciduous Shrubland 52 Evergreen Shrubland 53 Mixed Shrubland
Non-Natural Woody	61 Planted/Cultivated (orchards, vineyards, groves)
Herbaceous Upland Natural/ Semi-Natural Vegetation	71 Grassland/Herbaceous
Herbaceous Planted/ Cultivated	81 Pasture/Hay 82 Row Crops 83 Small Grains 84 Bare Soil 85 Other Grasses (Urban/recreational; e.g. golf courses, lawns)
Wetlands	91 Woody Wetlands 92 Emergent Herbaceous Wetlands

The total number and type of variables included in the original Landsat ™ data (Table 2) was not used within the habitat suitability analysis. A justifiable ranking system could not be devised to distinguish between areas such as "Non-Natural Woody" and "Herbaceous Planted/ Cultivated" in terms of their suitability for cougar habitat. For this reason, each related category was grouped together to create the final land use categories: Water, Developed, Wetlands, Transitional, Agriculture, and Forest (Figure 4).

Transitional includes the original categories: Barren, Natural Shrubland, and Herbaceous Upland Natural/Semi-Natural Vegetation. It is important to note that the Barren

Agriculture includes the original categories of Non-natural Woody and Herbaceous Planted/Cultivated. The remaining categories of water, developed, wetlands, and forest, match the original category listed within Table 1 (Water, Developed, Wetlands, and Natural Forested Upland (non-wet), respectively).

White-tailed deer (*Odocoileus virginianus*) harvest data for each county within the CAA study area was used to determine deer density. Deer harvest statistics do not provide a precise measure of deer populations, yet these measures are generally robust enough to follow population trends over time and provide the only consistent measure of deer abundance throughout the study area (Evans et al. 1999, Pike et al. 1999, Roseberry and Woolf 1991). Total deer harvest data for the years 1994-1997 was obtained from state wildlife agencies for each county within the CAA study area and averaged for the four years. Deer density was calculated by dividing the average harvest per county by the total area of each county, and is recorded as average deer harvest per square mile (deer/mi^2) for each county (Figure 5).

A GIS data layer, or coverage, was generated for each data set (Figures 2-5) using ArcView Version 3.1. Each coverage was converted from vector to raster, or grid, format to allow for further analysis. The data for the road density, deer density, and human population density layers were classified into ten categories using the Natural Breaks classification within ArcView. This classification method identifies breakpoints between classes using a statistical formula, Jenk's optimization, which minimizes the sum of the variance within each of the classes (ESRI-ArcView GIS Version 3.1 1992-1998). A more traditional method of classification, such as equal intervals, would have skewed the data for road density and human population density due to high values associated with these layers in the largest city of the study area, Pittsburgh, Pennsylvania. The Natural Breaks classification allowed for more distribution within the data categories by classifying each layer based on groupings and patterns inherent in the data itself. The land use layer was classified into six qualitative categories based on the original data set: Water, Developed, Wetlands, Agriculture, Transition, and Forest.

To create the final composite analysis all categories within each layer were assigned a particular value, ranging from 0 to 10, based on its suitability as cougar habitat. The highest suitability rating (10) was given to the categories of lowest road density, lowest human population density, highest deer density, and forest habitat, based on the results of the following studies. Van Dyke et al. (1986a) discussed how cougars crossed improved dirt roads and hard-surfaced roads less than smaller dirt roads and suggested that they avoided areas with an abundance of improved roads. In a subsequent study, Van Dyke et al. (1986b) found that cougars selected home areas with no recent timber sales and few or no sites of human residence. Logan and Irwin (1985) studied habitat use by cougars in Wyoming and found their primary habitat to be within mixed forest vegetation.

Following the highest suitable category, each category decreases in value down to 1, with the exception of the land use layer, which has six categories and decreases based on even values down to 0 (Figures 2-5). Without a quantitative classification scheme, the remaining land use categories were ranked and assigned values based on suitability. The following values were assigned to the land use categories, based on the knowledge that cougar prefer covered habitats and areas with low human and road interaction: (Brocke 1981, Riley 1998, Jordan 1994, Logan and Irwin 1985, Tischendorf 1999):

0 = Water
2 = Developed
4 = Agriculture
6 = Wetlands[1]
8 = Transitional
10 = Forest

Using ArcView, the reclassified data layers were added to create a composite map (Figure 6). To conduct the composite analysis, the CAA study area was divided into cells of approximately 5.5 mi^2 (14.2 km^2) and a total composite score was calculated for each cell. In theory, the composite scores could range from 3 to 40, with 40 representing those cells most suitable as cougar habitat. Composite scores for this analysis range from 8 to 40.

Results

Figure 6 is the full composite map for the Central Appalachian study area. The composite map displays the total score for the layers as a color range, with yellow areas representing cells that received the lowest suitability rating and darker blue/black areas representing cells that received the highest suitability rating. The total score was calculated for each cell of approximately 5.5 mi^2 (14.2 km^2). The high scores represent areas most suitable for cougar habitat based on highest deer density, lowest human population density, lowest road density, and forestland.

The values 33 to 40 represent the top 25% of the 32 composite scores (8-40) (Figure 7). The cells within this range are located predominantly within northeast and central West Virginia, and follow the western edge of the

[1] The primary range of the Florida panther (*Felis concolor coryi*) is within the swamp forest and marsh/wetland vegetation of southern Florida (Maehr 1990). Since the Florida panther population is the only documented large feline population in the eastern U.S., it could be considered appropriate to study wetland ecosystems north of Florida as potential cougar habitat. Yet an important discrepancy lies in the fact that the ecosystems of southern Florida are significantly different than the higher elevation, varied topography of the Central Appalachians. Wetlands make up only 0.4% of the landscape within the CAA study area. It is for this reason that the transitional category was given a higher suitability rating than the wetlands category.

Appalachian mountain chain north through Maryland into south-central Pennsylvania. The cells continue to extend into northwest Pennsylvania, with other small pockets located in eastern Ohio and southwestern Virginia.

It is important to note that the top 25% composite scores (33-40) do not necessarily represent the only suitable habitat for cougars within the CAA study area. Cougars are extremely adaptable and able to survive over a wide range of habitats. As such, it is more useful to focus the results and analysis on those areas that exhibit the highest density and connectivity among cells. Such areas could potentially fulfill the large-scale habitat requirements of the cougar. The areas of dense cells within this analysis were identified based on Figures 6 and 7, and include all cells with a composite score of 32-40. The focus on this range of composite scores does not exclude the possibility that other clusters of cells with a lower score could fulfill the habitat requirements for the eastern cougar. Future site specific studies which take into account more variables will provide a higher level of certainty regarding suitable habitat.

As mentioned above, the minimum habitat area necessary for a cougar population to survive in the absence of immigration in the western US is between 390 and 850 mi^2 (1000-2200 km^2) (Beier 1993). The home range for an individual adult male can range between 15 and 125 mi^2[2] (~ 40-325 km^2) (Anderson 1983, Hornocker 1970, Seidensticker 1973, Wright 1972, USFWS 1991). The greatest density of high suitability cells within the CAA study area is located within the central to northwest section of West Virginia (Figure 6 and 7). Within this section, the cells with highest suitability rating (total score 37-40) are in the West Virginia counties of Ritchie, Gilmer, Tyler, Doddridge, and Wirt, and cover an area of approximately 1470 mi^2 (3810 km^2).

There are also smaller areas of dense cells with a high suitability rating (total score 34-40) located in northeastern West Virginia, near the Virginia border, and in northwest Pennsylvania. In northeastern West Virginia, the cells are in the counties of Hardy, Hampshire, and Tucker, and cover an area of approximately 1,455 mi^2 (3770 km^2). In northwest Pennsylvania, the cells are in the counties of Warren and Forest, and cover an area of approximately 1,210 mi^2 (3134 km^2).

Discussion

Additional Landscape Comparisons

The results of the eastern cougar habitat suitability analysis serve as a coarse identification of suitable cougar habitat within the Central Appalachians. To further identify and define suitable habitat areas within the CAA study area, the results were compared to additional data and landscape characteristics that have been associated with cougar habitat. These data layers are: topography, cougar sightings, and public lands. These layers were not used in the initial habitat suitability analysis due to incomplete or unjustifiable data as a basis for cougar habitat.

Previous studies of cougars in the western U.S. discuss the importance of terrain in identifying cougar habitat (Hornocker 1970, Logan and Irwin 1985, Riley 1998, Seidensticker 1973). These studies associate cougar habitat with steep, rugged, and variable terrain. Although there are significant differences in elevation between the topography of the eastern and western U.S., the general habitat descriptions of the western U.S. are important to consider in relation to the Central Appalachians. The Appalachian mountains were once heavily populated by cougars and are part of historic cougar range (Bolgiano 1995, Parker 1998, Wright 1972).

In addition to studies done on cougar habitat in the western U.S., it is important to consider the habitat of the only documented *Puma concolor* population in the east, the Florida panther, *Puma concolor coryi*. Its main habitat is in southern Florida and is predominantly within low elevation mixed swamp forest (Maehr 1990). The variation in habitat between western cougars and the Florida panther demonstrates that the cougar's habitat is not necessarily confined to steep terrain. The topography of the CAA study area was not used as a data layer in the habitat suitability analysis due to the cougar's shown adaptability to a range of habitats.

Figure 8 displays the topography of the CAA study area as a color scheme with red representing the highest elevations and violet representing the lowest elevations. The high elevation areas are clearly represented along the eastern range of the CAA study area, which includes the

[2] McNab (1963) examined how mammals determine home range size and found that, in general, higher prey density results in a smaller home range. During recent years, deer populations have been increasing throughout the eastern US, particularly within the state of Pennsylvania (Barber 1984, Bowers 1997, Storm & Palmer 1995). Such increases in prey density could potentially decrease the home range area necessary for an individual cougar within the Central Appalachians. Yet since there is currently no exact data available on total deer populations in the east or the home range size of eastern cougars, we did not attempt to estimate a different home range from the numbers available for western cougars.

highlands of the Appalachian mountains (Bailey 1995, Mueller 1986). A large portion of the cells which received a high suitability rating in the final composite map (total score 32-40) are located along the Appalachian mountain chain and specifically within the northern Allegheny plateau (Figure 7).

The majority of the cougar sightings recorded for the CAA study area are located throughout high elevation areas and in proximity to high suitability cells (Figures 6-9). Figure 9 displays the sightings data as a color scheme with dark blue representing the counties with the highest number of sightings and light yellow the lowest number of sightings. Based on the actual sightings data, approximately 60% of the total recorded sightings are located along the Appalachian mountain chain.

Sightings data was obtained from the Eastern Cougar Foundation, the Eastern Puma Research Network, and Shenandoah National Park. The Eastern Cougar Foundation and the Eastern Puma Research Network provided sightings data as totals per county from the mid 1970's to 1998. The Shenandoah National Park data was originally classified based on location and/or milepost numbers along Skyline Drive. When possible, milepost numbers were estimated based on location descriptions. The milepost numbers were used to classify each sighting within one of the following counties in Virginia: Warren, Rappahannock, Page, Madison, Greene, Rockingham, Albemarle, and Augusta. The sightings from each source were totaled per county and transferred into an ArcView coverage for comparison with the final composite map.

Cougar sightings data was not incorporated within the initial habitat suitability analysis for two reasons. First, the data itself is incomplete within the study area and second, sighting reports are largely considered unreliable among trained biologists and wildlife officials unless they are coupled with physical evidence. Yet scattered among the misidentified sightings are reliable reports that are frequently unnoticed and uninvestigated by wildlife agencies (Tischendorf 1996). Due to data and time limitations, the reliable and/or confirmed sightings of cougars in the central Appalachians could not be separated from unconfirmed reports for use within the habitat suitability analysis. Cougar sightings data was available as overall totals per county for the following states within the CAA study area: West Virginia, Virginia, Maryland, and Pennsylvania.

As a final comparison, the results of the habitat suitability analysis were analyzed with the location of state and federal public lands in the Central Appalachians (Figure 10). The highest density of public lands within the CAA study area is along the Appalachian mountain chain along the Virginia/West Virginia border and in the northern Allegheny plateau, specifically northwest Pennsylvania.

With comparatively low human population and paved road densities, the public lands complex potentially includes some of the most suitable cougar habitat in the east. Yet these publicly owned forests are surrounded by private landowners, many of whom own large tracts of forestland. Since it cannot be assumed that suitable cougar habitat is confined within public lands, the state and federal public lands data was not included within the habitat suitability analysis. It will be necessary to include the land ownership data in subsequent studies as core habitat areas become further defined and prioritized in order to accomplish ARC's large-scale conservation proposals.

Final Composite Map

The above comparisons show a high correlation of suitable habitat cells with the Appalachian mountain chain. It is important to discuss these results in relation to the final composite maps (Figure 6 and 7). Two clusters of cells with high suitability ratings (total score 34-40) are located in this region. They are located in northeastern West Virginia, near the Virginia border, and in northwest Pennsylvania and cover an area of approximately 1455 mi^2 (3770 km^2) and 1210 mi^2 (3134 km^2), respectively (Figure 7). As discussed above, there are habitat cells with a total score of 32-34 located around these areas and extending throughout the Appalachian mountains. In future studies it will be useful to extend beyond the dense areas of high suitability cells to examine the potential for connectivity with other areas in the Appalachians (Beier et al. 1998, Noss et al. 1996).

The cells with the highest suitability rating (total score 37-40) are located in central to northwest West Virginia, along the southern Allegheny plateau (Figure 7). The road density, human population density, and land use values in this section of West Virginia are comparable to those along the Appalachian mountain chain (Figures 2-4). The main difference lies in the deer density values in this region of West Virginia as compared to the rest of the study area. The deer density in central and northwest West Virginia are all within the top 50% of values. The highest deer density values in the study area located west of the mountains in the West Virginia counties of Lewis, Wirt, Tyler, and Ohio (17-19 deer/mi2) (Figure 7).

White-tailed deer are an indicator species of land fragmentation and disturbance, and as such, deer populations are generally smaller in the mountains than in the Piedmont and plateaus where fragmentation and edge are greater (Alverson et al. 1988, Augustine & Frelich 1998, Shrauder 1984). Although deer densities are typically higher near "edge" habitat, studies have shown that cougars have an affinity for forested habitat over fragmented and populated areas (Logan & Irwin 1985, Van Dyke 1986b). Based on this information, it is important to consider the possibility that areas of highest deer density do not necessarily represent the most suitable cougar habitat. Due to data limitations, the values assigned to the deer density data could not be changed to reflect different habitat preferences. However, further study could challenge the ranking system of prey density, that is highest deer density is best for cougar, by reclassifying the data based on documented cougar preference for forested habitat.

An important deer population trend to consider for the entire study area is the possibility that in recent years deer populations have been high enough that prey availability should not be considered a limiting factor in determining suitable cougar habitat (Barber 1984, Bowers 1997, Storm & Palmer 1995). Deer density for the CAA study area ranges from 0-19 deer/mi^2 (0-7 deer/km^2) (Figure 5). Although deer harvest statistics are generally considered the best data available to analyze deer population trends over time, these statistics tend to underestimate actual population numbers (Evans et al. 1999, Riley 1998, Roseberry & Woolf 1991)[3]. For the six states within the study area, annual harvest data is obtained via mandatory check stations and/or harvest report cards sent into state game departments (State Wildlife Agencies). The success of these methods of data collection is dependent on hunter effort and participation.

White-tailed deer studies which have compensated for low harvest statistics estimate deer density to be between 13-50 deer/mi^2 (5-20 deer/km^2) throughout much of the eastern U.S. (Bowers 1997, Storm & Palmer 1995). Estimated frequencies of deer kills by cougar in the western U.S. range from 1 deer/10-14 days to 1 deer/3.1 days for females with cubs (Anderson 1983, Hornocker 1970, Linzey 1987, Young & Goldman 1946). Kill rates vary based on the energy demands of the cougar, the contribution of other foods to the diet, and the rate of spoilage (Linzey 1987). Cougars have also been observed to travel 25 miles or more a night in search of food (Young & Goldman 1946).

In comparing prey availability to estimated kill rates for cougars, it appears as though the population of deer throughout the east is sufficient to support a small breeding population of cougars. To further substantiate this claim, additional studies are necessary to more accurately determine deer densities within the Central Appalachians.

Additional, though indirect, evidence of high deer densities is the millions of dollars in agricultural damage and the negative affects deer browsing has had on forest regeneration for a number of tree species (Alverson et al. 1988, Bowers 1997, Shrauder 1984, Stout, Tzilkowski et al. 1997). Tzilkowski et al. (1997) conducted a study on agricultural damage within Pennsylvania for the Department of Agriculture and found that, "based on questionnaire responses average levels of crop damage across the state ranged from six to ten percent depending on the crop and the economic value of crop loss from wildlife and in particular white-tailed deer exceeded 70 million dollars". In terms of forest regeneration, white-tailed deer have a very generalized diet and deer density as low as 10 deer/mi^2 (4 deer/km^2) may inhibit the growth of a number of herbaceous plants (Alverson et al. 1988, Bowers 1997, Stout).

With growing deer populations despite high hunter harvests, and no substantial large predator populations in the east, effective deer management has become an important issue for both agricultural and wildlife agencies (Barber 1984, Tzilkowski et al. 1997). Deer hunting is legal throughout the Appalachians to help control local populations and prevent overabundance. Yet there is a recognized need for additional long-term population control measures throughout different areas in the east. (Augustine & Frelich 1998, Beasom 1974). Beasom (1974) conducted a study on the relationship between predators and white-tailed deer net productivity and found that predation was responsible for substantial juvenile deer mortality. Predation was identified as the major factor stabilizing the dense deer herds (Beasom 1974). With suitable habitat still available throughout the central Appalachians, a renewed presence of cougars could potentially help stabilize the growing deer populations. This could lessen direct agricultural damage, allow forest regeneration in high deer density areas and allow the cougar to return to part of its original range.

[3] Figure 5, "Central Appalachian Study Area - Deer Density", reflects deer densities in eastern Kentucky of less than 1 deer/mi^2 as 0 deer/mi^2. There clearly are deer in eastern Kentucky, but because the statistics were literally represented as whole numbers in the analysis, a density of 0.5 deer/mi^2 is shown as 0 deer/mi^2 on the map. However, the densities in eastern Kentucky are generally lower than in other areas of the study area, and therefore these numbers are useful for comparison.

Conclusion

The results of this analysis can serve as a general guideline of suitable cougar habitat within the Central Appalachian region. Large areas of suitable habitat were identified within central West Virginia and along the Appalachian mountains from western Virginia to the northern Allegheny plateau. Further research on a smaller scale is necessary to help identify specific suitable areas, taking into account additional land characteristics such as the location of riparian systems and the specific type of forested habitat within each area (patchy forest near developed areas vs. contiguous forest).

This initial analysis, along with future studies, will be used to help accomplish part two of ARC's Central Appalachian Assessment. Part Two will examine the current ability of public and private protected areas to serve ARC's large-scale conservation goals by contrasting the distribution of unique ecoregions, as defined by areas such as suitable cougar habitat, and rare, threatened, and endangered species hotspots with the locations of currently protected lands. Based on these findings, the report will identify linkages between these areas to insure animal migration corridors, and present implications for public land management and private land stewardship to achieve our conservation goals. The Assessment will conclude with a preliminary description of the needed restoration work within the Central Appalachians.

Recommendations for Federal and State Wildlife Agencies

The U.S. Fish and Wildlife Service lists the eastern cougar (*Puma concolor couguar*) and the Florida panther (*Puma concolor coryi*) as endangered and threatened, respectively. The official status of the eastern cougar is endangered, but the recovery plan has not been approved. According to Paul Nickerson, of the US Fish & Wildlife's endangered species program in the northeast region, the USFWS is not actively pursuing approval because, "there's nothing left to debate, eastern cougars are gone"(Nickerson 1999).

Politically, the cougar is not recognized as part of the eastern US. Dozens of conversations with individuals who have sighted cougars or actually found evidence, detail a long history of denial of the cougar's presence by wildlife agencies. At a minimum, recognition of this species as an integral part of eastern ecosystems, and a serious treatment of sighting reports would help advance the debate on cougars. Regardless of the legal status and the taxonomic classification, state and federal wildlife managers are not doing their jobs with respect to cougars. Evidence of this can be found in a recent USDA Office of Inspector General's Report, "Forest Service Timber Sale Environmental Analysis Requirements," which states in regards to timber sales analyses on the Marlinton District of the Monongahela National Forest in West Virginia,

> We concluded that the district was improperly using the table to exclude some threatened, endangered, and sensitive [species] from detailed analysis. For example, the district did not discuss the eastern cougar in its biological evaluations despite the fact that suitable habitat was available and the presence of a "catlike" creature had been reported in the area. District personnel stated that they had been unable to confirm any of the reported sightings and to the best of their knowledge, the eastern cougar had to be expatriated from the area. However, at least one appellant had used the lack of discussion and surveys for the eastern cougar in an appeal regarding timber sales on this forest. We believe that, at a minimum, the above facts concerning the eastern cougar should have been discussed in the biological evaluation (USDA 1999).

The Marlinton District is the same area where the aforementioned 1976 cougars were shot and captured.

Wildlife managers have a duty to protect all wildlife regardless of the ownership status of the land. Ignoring the cougar as an existing or potentially viable population in the east is an unacceptable wildlife management policy. Public agencies such as the US Forest Service have a legal obligation to search for and manage all wildlife species, regardless of personal beliefs.

Future wildland protection and ARC's conservation goals can be further supported through the commitment of the US Fish and Wildlife Service to protect all wild cougars in the East. The first step towards such protection could be through the implementation of the Eastern Cougar Recovery Plan. Robert Downing developed the Eastern Cougar Recovery Plan following his study on the status of the eastern cougar in the Southern Appalachians (Downing 1981,1982). The Plan includes a seven step outline, calling for research and search training, and systematic field searches in all likely locations throughout the cougar's former range. If a population is found, a detailed study, interim protection, habitat management, and public education are intended to follow (Downing

1982). Unfortunately, seventeen years have passed and, like many recovery plans, the Eastern Cougar Recovery Plan has yet to be implemented.

The 1982 Eastern Cougar Recovery Plan was a satisfactory report for its time, but much has been learned over the past seventeen years. Revisions to the plan are needed and should not be limited solely to the listed subspecies eastern cougar (*Puma concolor couguar*). The recovery team needs to examine new information, such as sightings and genetic studies.

Unfortunately, moving these agencies toward a legitimate cougar recovery plan many involve future legal action. Indeed, “conservation by litigation,” as termed by Reed Noss, is the dominant, but not necessarily the best way of protecting species (Noss & Cooperrider 1994). Any plan forwarded by state or federal agencies must include significant public involvement.

Public involvement in agency policy is an important aspect of wildlife management. If public pressure for cougar recovery is strong and consistent, the agencies should respond accordingly.

ARC recommends all pertinent state and federal wildlife managers be trained in cougar tracking by outside experts, such as Sue Morse of Keeping Track, Inc. Further, we recommend a unified and uniform method of dealing with sightings at the state and federal level. ARC recommends increasing funding for the Federal Endangered Species Program. There are many opportunities for cost sharing arrangements or multi-agency, public-private partnerships to address this important issue. Although these agencies are important, protecting wildlife does not have to depend on government regulations and tax dollars.

In addition to state and federal education and training programs, cougar advocates in the east need to build understanding, respect, and tolerance for cougars in rural communities located in and near cougar habitat. A proactive campaign of education and outreach to people who live in existing and potential cougar habitat will empower them with knowledge about the animal and the ecosystem and help build an attitude of respect and tolerance. Without such acceptance, wild cougars will never have a chance of surviving.

Beyond the classification questions and the resistance of agencies, is a deeper, more important issue. In recent years, the role of conservation biology in wildlife and land-use management issues has increased significantly. Conservation biology asserts that the overall health of the ecosystem is best served by allowing the natural food chain and native species populations to run their natural course. Fundamental to conservation biology is the understanding that human existence is dependent on healthy and functioning ecosystems. Many important species native to central Appalachia have been extirpated. The timber wolf, the elk (there are reintroduction efforts underway), the badger in the north, and the river otter in many places, are no longer affecting evolution in Appalachia. Protection of umbrella species like the cougar can help ensure protection of many species and the complex ecosystems upon which we all depend.

Ultimately, the mystery of the eastern cougar will be solved by open and candid discussion at all levels. Suitable habitat and a sufficient prey base clearly exists for the cougar in the Central Appalachians. Public approval and agency acceptance are the major barriers facing cougar recovery in the east. Increased pressure from concerned citizens and more public education may set the stage for the return of a thriving cougar population in the east.

Acknowledgements

We are extremely grateful to Andy Mahler, Phil Berck, Karen Tuerk, Tom Rooney, Charlie Sullivan, Sherman Bamford, Steve Krichbaum, M.A. Jones, Rick Landenberger, R.F. Mueller, and others for their dedication to the idea and the actualization of the Appalachian Restoration Campaign. Than Hitt, ARC's first Coordinator, initiated the Central Appalachian Assessment, of which this study is an integral part.

We received advice and assistance from Jay Tischendorf, David J. Mladenoff, Dr. Ranier H. Brocke, Sunny Bass, Troy Merrill, Carlos Carroll, Shawn Riley, and Chip Harvey. The manuscript benefited from thoughtful reviews provided by Chris Bolgiano, Tom Rooney, Melanie Culver, William H. "Marty" Martin, Susan Morse, and Steve Krichbaum. We thank Todd Lester, Sherry Blanchette, and John Lutz for providing us with sightings data and their undying faith in the eastern cougar. All eastern cougar enthusiasts who continue to collect sightings data throughout the east and dedicate valuable time towards cougar protection also deserve thanks.

We thank the U.S. Dept of the Interior for providing us with digital land use and road density data, the US Census Bureau for data on human population, the Environmental Systems Research Institute (ESRI) for nationwide county data, and state wildlife and natural resource agencies for information on county deer harvests. ESRI also provided

software and training grants to ARC, without which this and other projects would not be possible.

This project and publication were produced with generous funding provided by **The Summerlee Foundation**, **The Norcross Wildlife Foundation** and **The George Gund Foundation**.

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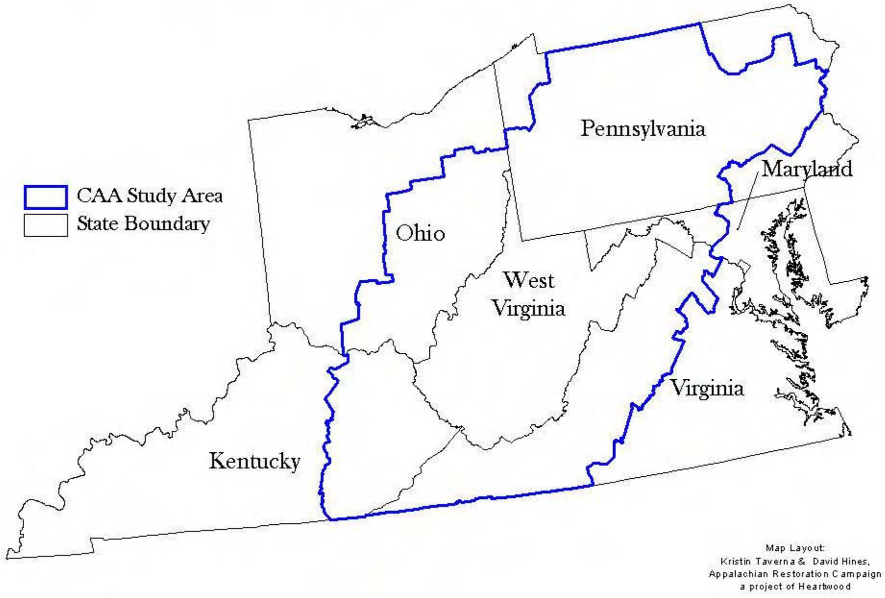
FIGURE 1

Central Appalachian Study Area



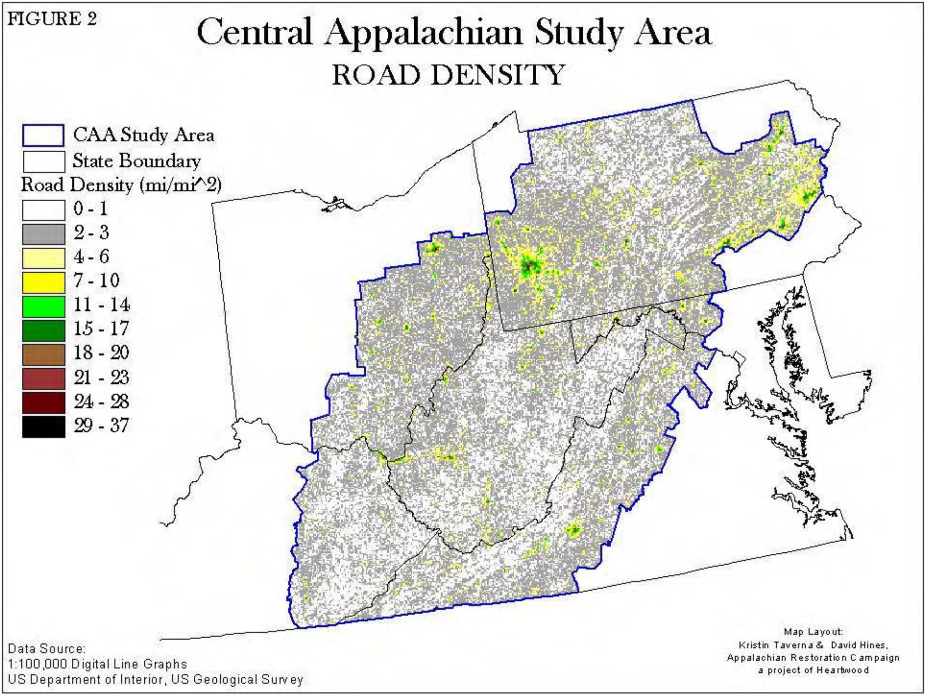


FIGURE 2
Central Appalachian Study Area
ROAD DENSITY
CAA Study Area
State Boundary
Road Density (mi/mi^2)
0 - 1
2 - 3
4 - 6
7 - 10
11 - 14
15 - 17
18 - 20
21 - 23
24 - 28
29 - 37
Data Source:
1:100,000 Digital Line Graphs
US Department of Interior, US Geological Survey
Map Layout:
Kristin Taverna & David Hines,
Appalachian Restoration Campaign
a project of Heartwood

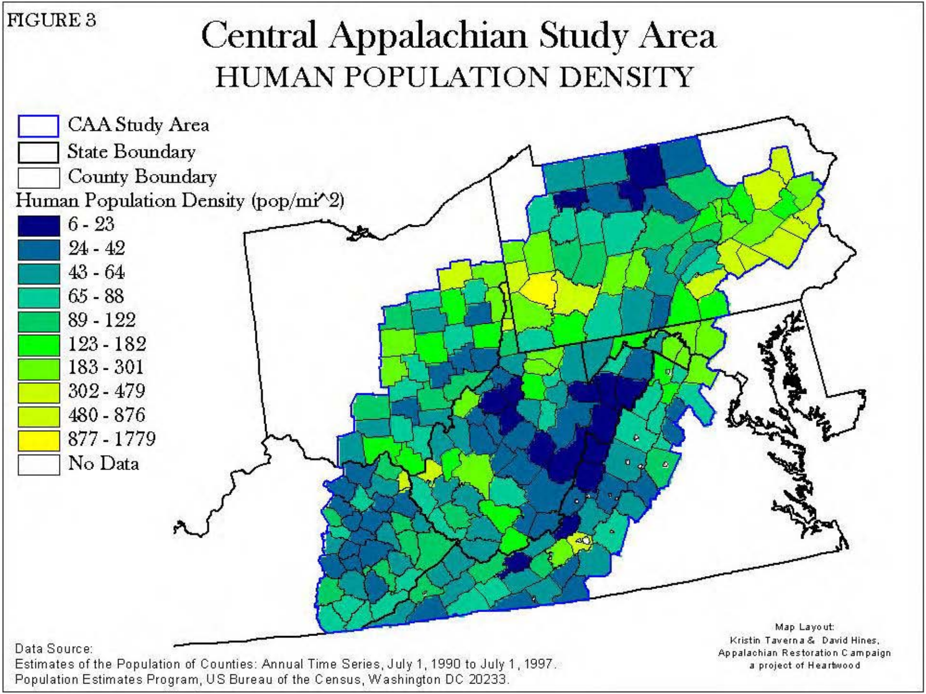
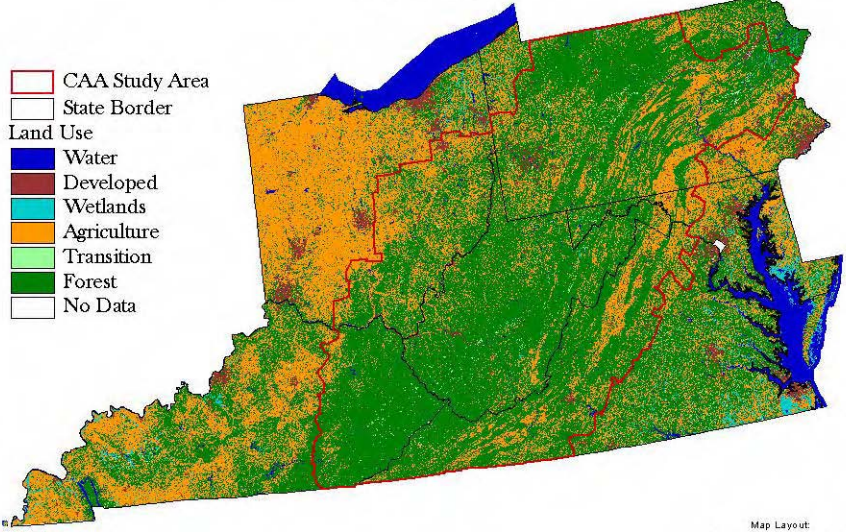


FIGURE 3
Central Appalachian Study Area
HUMAN POPULATION DENSITY
CAA Study Area
State Boundary
County Boundary
Human Population Density (pop/mi^2)
6 - 23
24 - 42
43 - 64
65 - 88
89 - 122
123 - 182
183 - 301
302 - 479
480 - 876
877 - 1779
No Data
Data Source:
Estimates of the Population of Counties: Annual Time Series, July 1, 1990 to July 1, 1997.
Population Estimates Program, US Bureau of the Census, Washington DC 20233.
Map Layout:
Kristin Taverna & David Hines,
Appalachian Restoration Campaign
a project of Heartwood

FIGURE 4

Central Appalachian Study Area

LAND USE



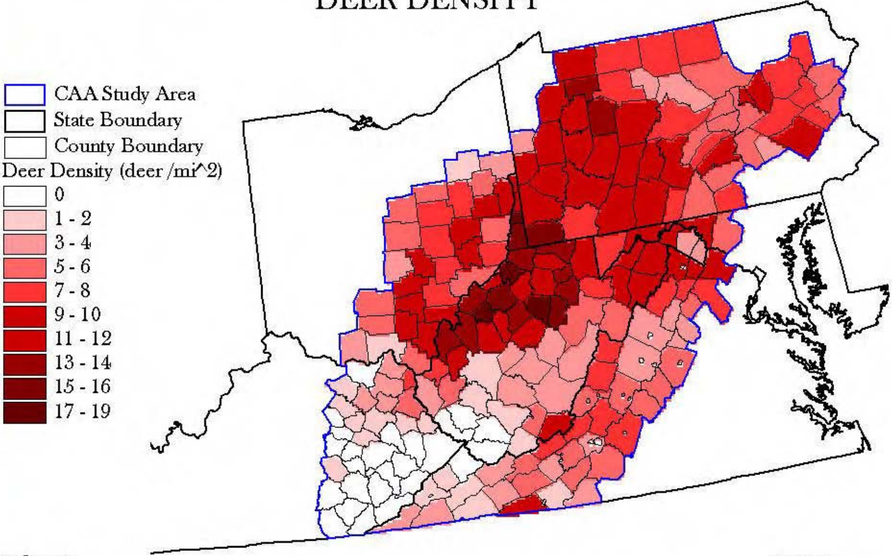
Data Source: Landsat TM Data - 1986-1993,
US Department of Interior, US Geological Survey.
EROS Data Center, Sioux Falls, SD.

Map Layout:
Kristin Taverna & David Hines,
Appalachian Restoration Campaign
a project of Heartwood

FIGURE 5

Central Appalachian Study Area

DEER DENSITY



Data Sources:
PA Game Commission-Bureau of Wildlife Management, OH Dept. of Natural Resources-Division of Wildlife, MD Dept. of Natural Resources-Wildlife and Heritage Division, VA Dept. of Game and Inland Fisheries, WV Division of Natural Resources-Wildlife Resources Section, KY Dept. Fish and Wildlife-Deer Enforcement Office

Map Layout:
Kristin Taverna & David Hines,
Appalachian Restoration Campaign
a project of Heartwood

FIGURE 6

Central Appalachian Study Area

COUGAR HABITAT SUITABILITY COMPOSITE MAP

Deer Density - Human Population Density - LandUse - Road Density

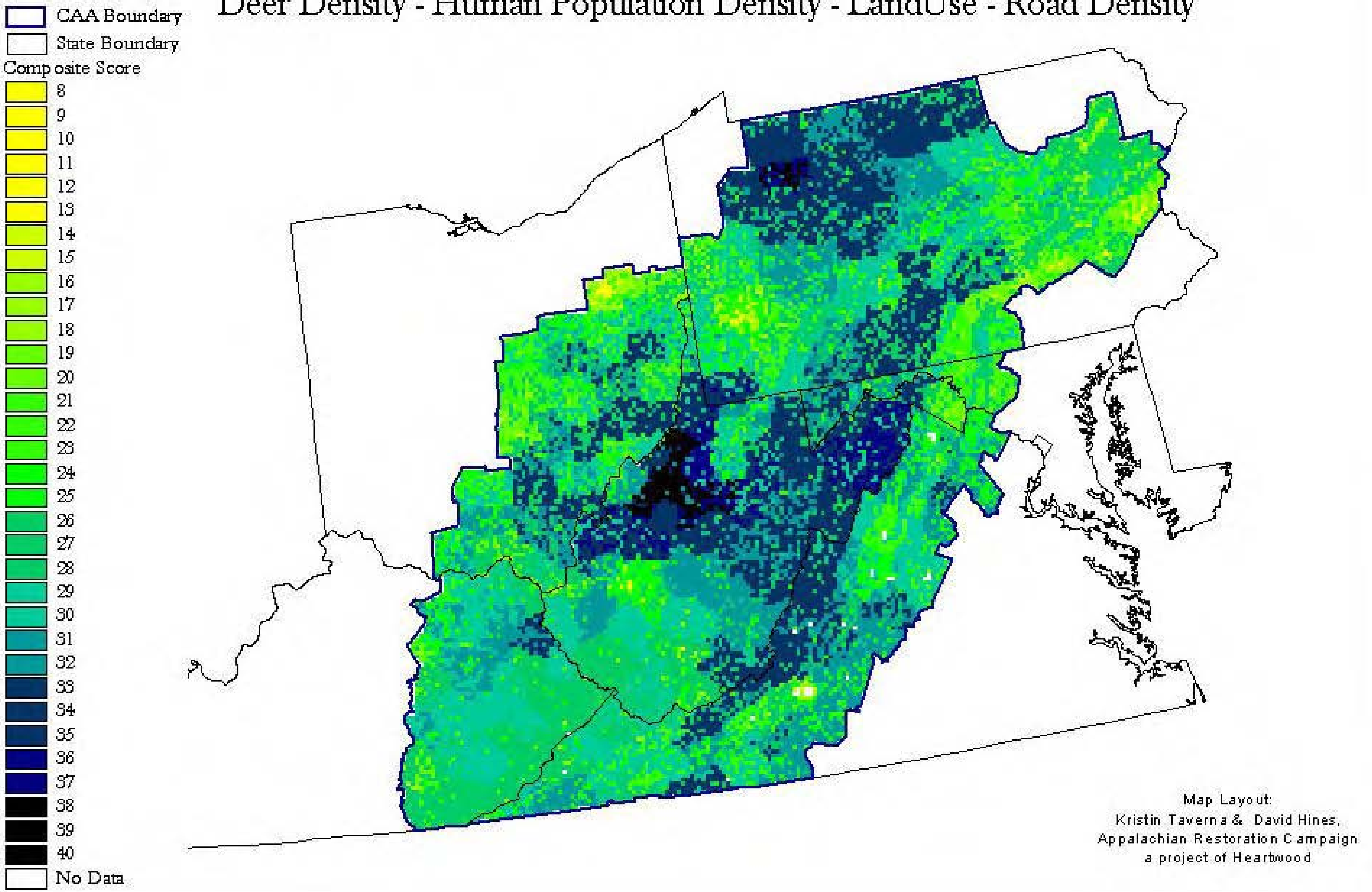
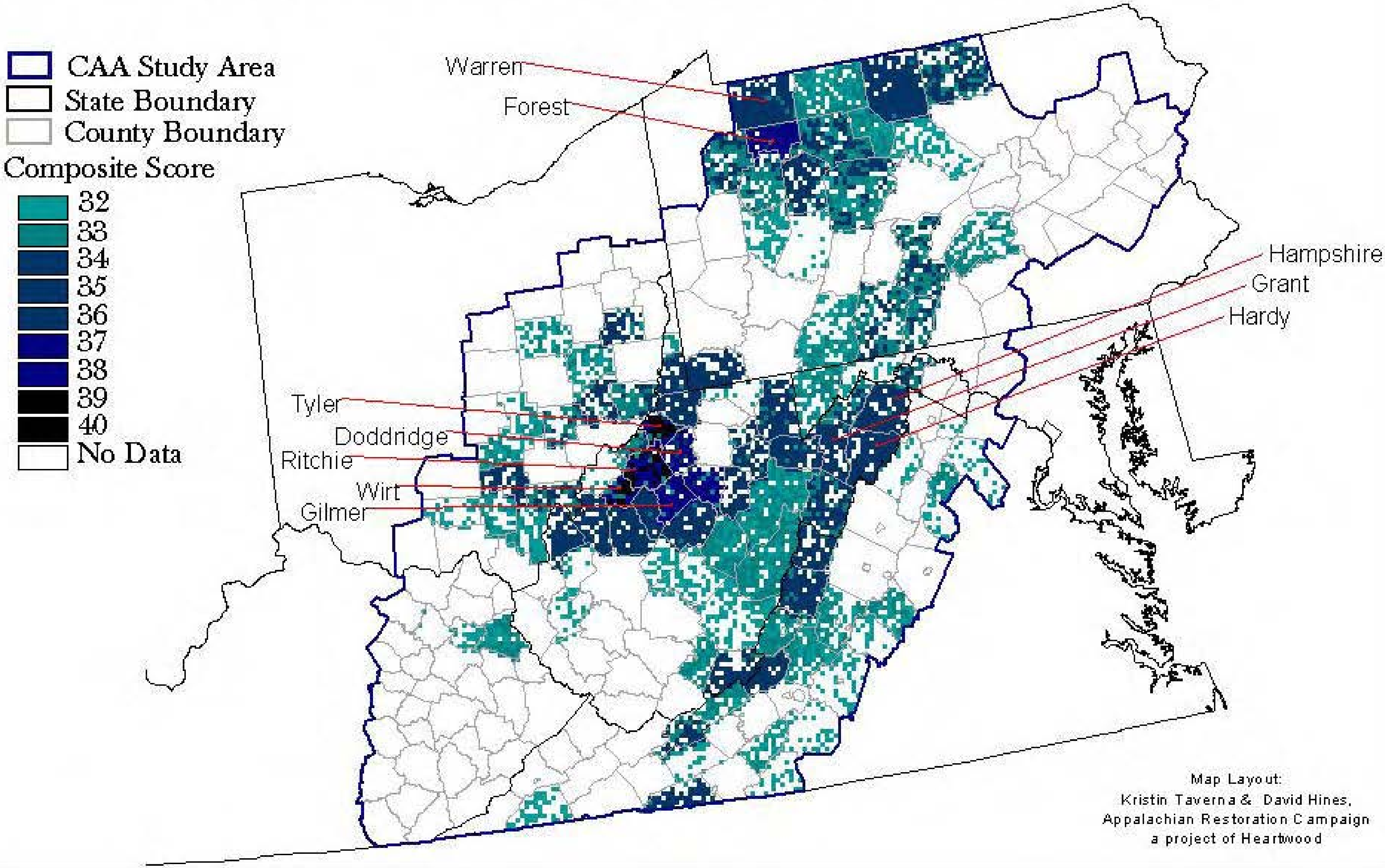


FIGURE 7

Central Appalachian Study Area

HIGHLY SUITABLE HABITAT for COUGAR

Deer Density - Human Population Density - Land Use - Road Density

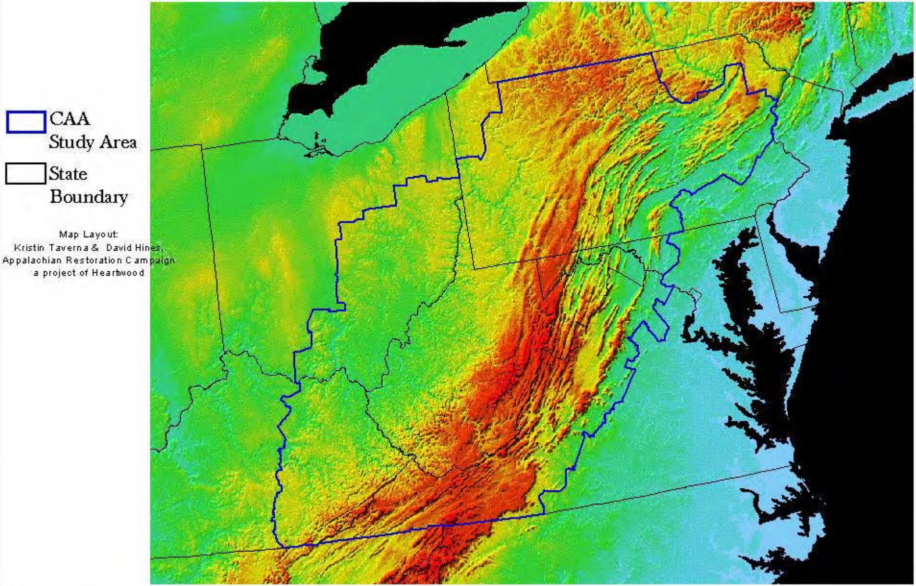


Map Layout:
Kristin Taverna & David Hines,
Appalachian Restoration Campaign
a project of Heartwood

FIGURE 8

Central Appalachian Study Area

TOPOGRAPHY



Map Layout:
Kristin Taverna & David Hines,
Appalachian Restoration Campaign
a project of Heartwood

Data Source: Compiled at 1:100,000 scale. Ecological Units of the United States CD-ROM, USDA Forest Service, 1995.

FIGURE 9

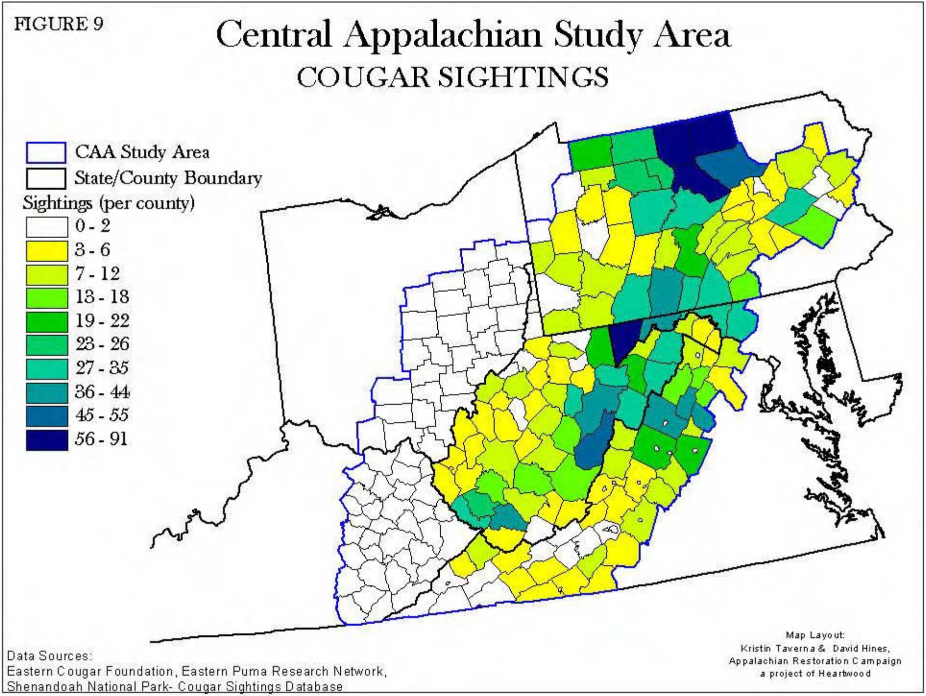
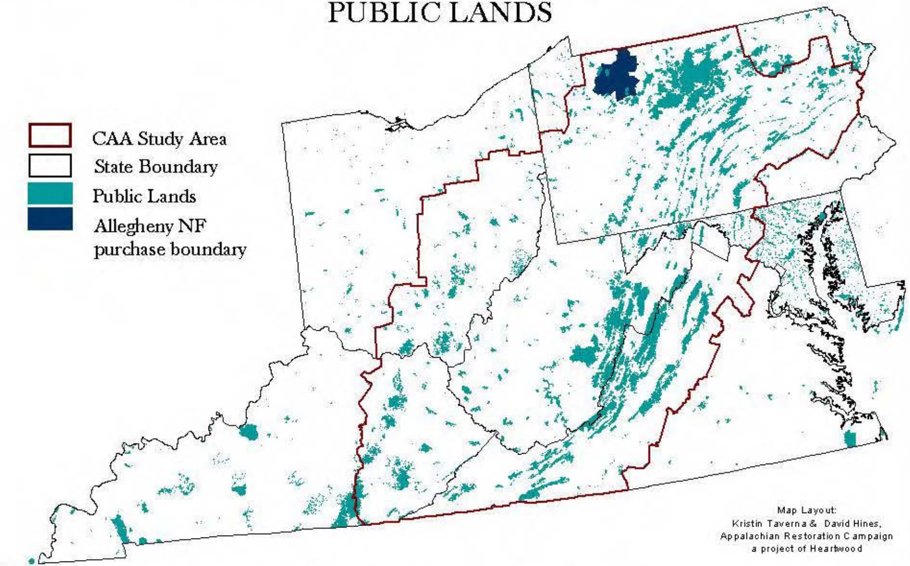

Central Appalachian Study Area
COUGAR SIGHTINGS
CAA Study Area
State/County Boundary
Sightings (per county)
0 - 2
3 - 6
7 - 12
13 - 18
19 - 22
23 - 26
27 - 35
36 - 44
45 - 55
56 - 91
Map Layout:
Kristin Taverna & David Hines,
Appalachian Restoration Campaign
a project of Heartwood
Data Sources:
Eastern Cougar Foundation, Eastern Puma Research Network,
Shenandoah National Park- Cougar Sightings Database

FIGURE 10

Central Appalachian Study Area

PUBLIC LANDS



Data Sources:
KY Natural Resources and Environmental Protection Cabinet Office of Information Services, MD Dept. of Natural Resources-Protected Lands Data,
OH Dept. of Natural Resources, Real Estate and Land Management Data, PA Spatial Data Access: The PA Geospatial Data Clearinghouse,
WV Dept. of Natural Resources, VA Dept. of Conservation and Recreation
McGhie, R.Gavin.1996. Comprehensive Managed Areas Spatial Database for the Conterminous United States. NCGIA Technical Report 96-4. NCGIA, University of California Santa Barbara, California.