ASSESSING RED WOLF CONSERVATION BASED ON ANALYSES OF HABITAT SUITABILITY AND HUMAN PERCEPTION OF CARNIVORES

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LAUREN K. TOIVONEN

Dr. Matthew E. Gompper, Thesis Supervisor

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The undersigned, appointed by the dean of the Graduate School,
have examined the Thesis entitled

ASSESSING RED WOLF CONSERVATION BASED ON ANALYSES OF HABITAT SUITABILITY AND HUMAN PERCEPTION OF CARNIVORES

Presented by Lauren K. Toivonen

A candidate for the degree of
Master of Science

And hereby certify that, in their opinion, it is worthy of acceptance.

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Matthew E. Gompper, Ph.D.

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Hong S. He, Ph.D.

_____

Charles Nilon, Ph.D.

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TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 1

CHAPTER 2

LIST OF FIGURES

CHAPTER 1

ASSESSING RED WOLF CONSERVATION BASED ON ANALYSES OF HABITAT SUITABILITY AND HUMAN PERCEPTION OF CARNIVORES

Lauren K. Toivonen

Dr. Matthew E. Gompper, Thesis Supervisor

ABSTRACT

The red wolf (*Canis rufus*) is a critically endangered species endemic to the southeastern United States. Currently the world's only wild population resides in a single locale on the Albemarle Peninsula in northeastern North Carolina. Thus, it is imperative to identify potential sites that may be suitable for additional wild populations. We analyzed available data to identify and rank suitable habitat and sites across the historic range of the species. The goal of this study was to examine available data to identify and rank suitable habitat sites across the historic range of the species. Because presence points obtained within the RWRA are not translatable to the varied broader landscape of the southeastern United States, and because scant research was published on the original wild red wolf population, a literature review of red wolf landscape use and suitability analyses was conducted to identify primary habitat metrics for inclusion.

We examined how much of the overall landscape of the red wolf historic range is suitable for them based on landscape, prey density, human population, and road type factors. Further, we examined public landscapes that are presumably large enough (>1,000km^2) to sustain a red wolf population. We found that suitable landscape is available across the historic range, with large areas of suitable lands

occurring in National Forests throughout the range of the species. Several National Forests repeatedly ranked high, independent of model choice, and may thus represent appropriate localities for population restoration efforts.

However, even though large areas of suitable landscape does exist for the red wolf, it is important to factor in the perception and attitudes of stakeholders. While attitude and perception of specific large carnivore species is prevalent in the literature, we examined how people perceive carnivores as a generalized, basic level. Understanding perceptions of a basic concept aides in building a foundational framework. Public perception of carnivores was assessed from over 1,100 surveys distributed across a spectrum of natural resource and general events in Missouri and Arkansas, two regions that ranked high in habitat suitability. The majority of respondents had positive views based on their expressed opinions and experiences with carnivores. For those who expressed negative view of carnivores, the greatest concerns were in regard to safety of pets and livestock. When asked about specific carnivore species and particularly about the red wolf entering the state via natural recolonization or through a organized reintroduction program, respondents were in favor for both methods, but natural recolonization had a higher percent support. While most responses were positive across the spectrum, logistic regression was utilized to identify predictor variables that correlated with agreement.

Additionally, educational outreach programs are a tool commonly used in conservation management as a way for biologists and managers to educate and connect with the public and stakeholders. Immediate and long-term effects of educational outreach were also evaluated from over 560 surveys distributed at

carnivore-centered outreach programs. Effects were measured comparing responses before, immediately after, and one month, three months, and five months after the program. Results indicated that educational outreach programs inspired change in and the deepening of previously-held perceptions. It also showed an increase in support for red wolf reintroduction efforts.

This research shows that if red wolf reintroduction were to occur, there are large portions of its historic range considered to be suitable habitat. However, it is imperative to assess and be inclusive of local communities. This research shows baseline data from a region deemed as suitable, but could be used as an aide in predicting perceptions of other regions and areas deemed as suitable.

CHAPTER 1

A HABITAT SUITABILITY ANALYSIS FOR THE RED WOLF ACROSS ITS HISTORIC RANGE

ABSTRACT

The red wolf (*Canis rufus*) is a critically endangered species endemic to the southeastern United States. Currently the world's only wild population resides in a single locale. Thus, it is imperative to identify potential sites that may be suitable for additional wild populations. We analyzed available data to identify and rank suitable habitat and sites across the historic range of the species. A geographic information system approach was used to develop habitat suitability models based on indices of landscape type (i.e. cropland, forest) and metrics based on distance from a point to nearest road-types (i.e. highways, interstate) and to human populations. A land use index was created based on information on habitat suitability, preference, and use extracted from the literature. We then incorporated human population measures and distances to major roads to create twelve models of ranked suitability throughout the study area. Modelled landscape suitability varied subtly as a function of parameter weights, but the 12 models could be reduced to three based on the similarities of results. These three models were used to further identify suitability of large (>1000km^2) parcels of federally managed lands. Results indicate suitable landscape is available across the historic range, with large areas of suitable lands occurring in several National Forests. These National Forests repeatedly ranked high

independent of model choice and may thus represent appropriate localities for population restoration efforts.

INTRODUCTION

In North America, the wolf is viewed as a cultural icon of the "Great American Wilderness", yet within the continental United States, both the gray wolf *Canis lupus* and the red wolf *C. rufus* occupy a small percentage of their historic range. The red wolf is endemic to the southeastern region of the United States. Little was known about the red wolf until the 1960s, when research efforts focused on determining the status of the wild population and on identifying individuals to place into captive management for breeding and restorative intentions (Phillips et al. 2003). Much of what we know today about the red wolf stems from the restoration efforts produced by the Red Wolf Recovery Program (RWRP), which is overseen by the US Fish and Wildlife Service (USFWS). A population of 30-35 red wolves currently exists as a nonessential experimental population (NEP) on the Albemarle Peninsula of northeastern North Carolina (USFWS 2018). The USFWS has expressed continuous interest in establishing additional populations of this keystone species within their historic range (USFWS 1990, 2007, 2016, 2018).

Within the Red Wolf Recovery Area (RWRA), where the current population of red wolves lives within the Albemarle Peninsula, habitat use has been well studied. Red wolves have selected for agricultural fields over other available habitat types (Hinton & Chamberlain 2010). This selection could be because agricultural fields offer high-quality foraging habitat, provide cover, and may influence pup survival because there are less biting insects and parasites (Hinton 2010). Chadwick et al. (2010) noted seasonality among red wolf habitat use: red wolves used agriculture fields between July and October while

they selected forested and grass-brush areas from November to May. Dellinger et al. (2013) suggested that red wolves select agricultural land and early successional fields as well as areas near secondary dirt roads and areas with low human presence. If fields are near areas where a high density of people are located, red wolves may select forests and marshes in areas where human populations are low (Dellinger et al. 2013). However, Dellinger et al. (2011) also documented a pack that successfully raised a litter of pups when their home range was primarily upland forest surround by areas with higher human density. Thus while red wolves have preferred habitat, they can successfully use other habitat types.

Karlin et al. (2016) created a MaxEnt model based on telemetry locations from 178 red wolves and noted that the variables most predictive of red wolf presence were human population density, secondary road density, and agricultural area. These findings further buttress the argument that while red wolves tend to select agricultural landscapes in the RWRA, they are also able to persist within other landscapes. The low density of human populations was a more dominating variable than landscape type, as red wolves will shift their landscape usage based on human presence (Dellinger et al. 2013). Additionally, red wolves use secondary roads for movement (Karlin et al. 2016) but will move further from those roads as human density increases (Dellinger et al. 2013).

There is abundant information on individual use of the landscape within the RWRA. However, it is important to note that the landscape of the RWRA is a small subset of the entirety of habitat features found throughout the southeastern United States. The dominant habitat features within the RWRA include agricultural fields, pine plantations, woody

wetlands known as pocosin, pine hardwood forests, and salt marsh (Wildlife Management Institute 2014). These habitat types do not translate directly across the 17-state study site.

Reintroduction efforts outside of the single current site have occurred within the Great Smoky Mountains National Park (GSMNP), Tennessee. The GSMNP restoration effort was deemed unsuccessful and terminated in 1998 (USFWS 1998). Nonetheless, Mauney (2005) modeled habitat use of the GSMNP population combining geographic information systems (GIS) and telemetry locations from radio-collared red wolves. Mauney found that red wolves selected deciduous forests, pastures, and woody wetlands. It was noted that the use of forest may be a function of availability, as deciduous forest was the predominant habitat type in the GSMNP. Large open areas are also a predominant landscape feature of Cades Cove, one of three sections within GSMNP where red wolf reintroductions occurred, and home ranges established within that portion of the park were centered among the open areas. Woody wetland areas were predominant along Abrams Creek and its tributaries within GSMNP, which were used for hunting and for places of seclusion as human-use density in that area of the park is low compared to other areas, such as Cades Cove, which receive a high number of park visitors. It is important to note that the woody wetlands of the GSMNP are not as dense as the pocosin woody wetlands of the RWRA (Toivonen, personal observation).

Prior to the 1987 red wolf reintroduction, the majority of red wolf research was conservation-based rather than landscape use-based and thus research on how the red wolf utilized its entire historic range is meager. There are a few historical accounts of red wolves on the landscape, however. Russell and Shaw (1971) found that red wolves in Texas used three broad habitat types: marshlands, prairie grasslands, and woodlands (although

woodlands were noted to have the lowest density of red wolf occupation, and also contained a higher number of coyotes). Paradiso and Nowak (1972) noted that red wolves rested in open habitats such as weedy fields, grass, or brush pastures. Red wolves may have occupied bottomland forests and wetlands along rivers throughout their historic range (Paradiso & Nowak 1972, Riley & McBride 1972). The last stronghold of red wolves were marshes and coastal prairies within counties along the coastlines of southeastern Texas and southwestern Louisiana (Phillips et al. 2003; USFWS 2007). Although these areas may have been marginal for red wolves (USFWS 2007), a canid (*C. latrans*) population who live on an island along the coast of Texas were recently found to have red wolf alleles resulting from introgression (Heppenheimer et al. 2018).

Habitat suitability analysis (HSA) is a primary method of identifying potential landscapes that can accommodate reintroduced populations and address other issues centered around conservation planning and habitat management by using environmental data to identify areas suitable for the species of target (Pearce & Ferrier 2000, Carvalho et al. 2012, Martin et al. 2012, Reza et al. 2013). Development methods and HSA functionality are customizable based on the data researchers have available (Carvalho et al. 2012, Reza et al. 2013). Four HSAs have been conducted for the red wolf. In the late 1990s, the USFWS provided a list of 31 prospective release areas for van Manen et al. (2000) to analyze. This has been the most complete historic range-wide study of red wolf habitat suitability. Van Manen et al. created models to predict red wolf release success in each county of interest in and around each prospective release area. A composite index was then created for each area , and areas were ranked based on their composite index score. Their findings indicated that the top-five most suitable habitats from the 31 potential sites were 1) northwestern

Alabama, 2) eastern West Virginia, 3) southwestern Mississippi, 4) northern Mississippi, and 5) southern Missouri.

At a more regional scale, three additional HSAs have been conducted. An HSA for the red wolf was performed for Daniel Boone National Forest (DBNF), Kentucky (Jacobs 2009) as well as for central costal North Carolina (Shaffer 2007), and coastal North Carolina (Desmul 2013). Jacobs (2009) identified nine potential restoration sites within DBNF based on a gray wolf logistic regression model created by Mladenoff et al. (1995) and revised it to better reflect how the study area's road network is used. Shaffer (2007) utilized GIS to examine the amount of suitable landscape available in protected areas within his study region as well as connectivity between patches of suitability. With these criteria, he identified three patches of suitable areas in which 75% of these areas were located in protected landscapes. Desmul (2013) conducted a connectivity analysis for the NEP's potential to disperse to inland North Carolina using features that are putatively avoided by red wolves. Desmul (2013) suggested that bottlenecks within the population might form due to several human-related developments and rising sea levels. However, construction aimed at maintaining corridors such as highway underpasses and greenways might help to slow or prevent the bottleneck. Overall, these studies have suggested that there remain areas of suitable habitat on both public and private landscapes within portions of the red wolf historic range.

The USFWS continues to express interest in the potential opportunities to restore additional red wolf populations within their historic range (USFWS 1990, 2007, 2016, 2018). While previous studies have identified areas of suitable habitat in particular locations, and contrasted particular landscapes, none have examined the historic range in

its entirety. The goal of this study was to use available data to identify and rank suitable habitat and sites for the red wolf. Because presence points within the RWRA are not translatable to the varied broader landscape of the southeastern United States, and because scant research was published on the original wild red wolf population, a literature review of red wolf landscape use was conducted to identify primary habitat metrics for inclusion (Appendix 1). Further, individuals who have been involved in the red wolf program and who have studied red wolf space-use were informally contacted to gain their opinions on red wolf landscape-use. Here we examine how much of the overall landscape of the red wolf historic range is suitable for them given a variety of biotic and abiotic acceptability factors. Further, we examine public landscapes that are presumably large enough to sustain a red wolf population, and rank these landscapes based on results of the HSA.

METHODS

Study Area

The study area stretches 2,040,925 km^2 across 17 states within the southeast United States (Figure 1). This area constitutes the majority of states that comprise the hypothesized red wolf historic range. Currently, the red wolf historic range is thought to include all or parts of Level II Ecoregions as designated by the EPA (USFWS 2018). Seven states (New Jersey, Maryland, Delaware, New York, Kansas, Oklahoma, Texas) were excluded because either (1) the majority of the excluded state's land area was not part of the red wolf historic range or (2) the state lacked tracts of National Forest that were large enough for the assessment of this study (size = >1,000km^2). Importantly, given recent evidence of residual red wolf alleles in a putative coyote population (Heppenheimer et al. 2018) and given that red wolves were known to also inhabit the Gulf Coast of southeastern

Texas (Paradiso 1965), we excluded Texas from the analyses, as the bulk of the state was not inhabited by red wolves and the putatively inhabited areas represent a very small portion of the state.

Habitat Suitability Analysis

To identify suitable habitat, a total of 22 theses, dissertations, government documents, and published articles were examined and reported for observations on red wolf habitat preference (Appendix 1). Once suitable habitat characteristics were identified, we evaluated landscape characteristics in the 17-state region to identify modern red wolf habitat suitability. Ecological conditions and human influence (Table 1.1) were examined utilizing ArcGIS. Variables chosen for inclusion in the analyses have been commonly used in carnivore HSAs (Taverna et al. 1990, Schadt et al. 2002, Martin et al. 2012) and provide a general understanding of suitable habitat availability based on landscape type and human disturbance. Data layers were sourced from the U.S. Census Bureau TIGER Database (Human Populations, Roads; U.S. Census Bureau 2016), USGS Gap Analysis Protected Areas Database (Land Ownership Patterns, Agency Oversight; U.S. Geological Survey 2016), and National Land Cover Database (Landscape Type; Homer et al. 2015).

Geographic information system (GIS) is commonly used in conservation research as a tool that allows multiple layers of data to be visualized, combined, and analyzed for purposes such as identifying and predicting species movement and habitat use. The National Landcover Database (NLCD) layer was uploaded into ArcMap (v 10.3.1), clipped to the 17-state study area, and resampled to a 300mx300m cell size (Figure 1.1). The detailed NLCD layer was reclassified into distinct, generalized categories: forest, grassland, shrubland, wetland, cropland, and pasture. Interstate and highway data were added as well

as human population data in the form of towns and cities. Towns were determined to be any human population under 100,000 while cities were defined as a human population >100,000. Euclidean distance was utilized to identify how far each individual 300mx300m cell was from road types and human populations. We assume that as a red wolf moves closer to these particular variables, there is an increased risk of mortality. Therefore, cells located 0 - 1km from a highway (Shaffer 2007) and 0 - 2km from an interstate were deemed unsuitable. Cells located <2km from a town (Shaffer 2007) and < 5km from a city were also deemed unsuitable. To account for this, buffers were added around each road type and human population type and expanded to cover the appropriate distance.

Focal Statistics and Map Algebra functions were used to add weight to each landscape, road type, and population variable, and an equation was derived to create the base for the habitat suitability analyses. Larger weighted values associated with the specific landcover, road type, or population variable indicated more favorable habitat (Malczewski 2004, Belongie 2008, Gong et al. 2012; Table 1.1) for the red wolf. In this study, each weighted value consists of two numbers (e.g. 37). The number in the tens position indicates rank; the higher the number the more suitable that habitat characteristic may be for the red wolf. The number in the ones position indicates range (the difference that remains when the tens-position number is subtracted from 10). All weighted variables are on a scale from 19 to 91. The idea of applying weighted values to each variable is based in multi-criteria decision-making analysis (MCDA). When used with GIS (GIS-MCDA), this process combines geographical data and valued judgements to construct hypothesized habitat valuations (Malczewski 2004, 2006). This approach is commonly utilized across disciplines (Meyer et al. 2009, Janke 2010, Kabir et al. 2014, Kremer et al. 2016, Maanan et al. 2018).

Landscape variables were assigned multiple weighted values in different models to take into account the types of information found within the literature and gained from personal communications with those knowledgeable in the field of red wolf space use (Table 1.1). Historically, red wolves were documented using open habitats such as prairies, grasslands, savannas, open woodlands, and coastal plains. Current usage shows a preference for cropland, which is an open landscape type. Red wolves also utilize forest landscapes to den, welp, and generally occupy. Space use typically occurs within the forest edge more so than the entirety of forests, but forest use increases as the red wolf gets closer to human populations and forest landscape type is ranked favorably in movement studies. Shrubland was viewed as a landscape beneficial to the red wolf as it provides cover and the potential to be a source of prey. However, while red wolves have been documented using upland shrubs within the recovery area, detailed information on shrubland-use is limited. Wetland landscape is both used and avoided by red wolves. Wetlands provide a prey source and cover but can be difficult for movement. Cropland is an open-space habitat that provides cover and prey and has been heavily used by the population residing in the RWRA. However, cropland is also a non-natural landscape that is managed by humans, which represent the biggest source of red wolf mortality (Hinton et al. 2017). Conversely, cropland is a preferred habitat and if localized persecution in these habitats doesn't occur, the habitat type should rank highly. Even though pasture is an open landscape and was used by the GSMNP population (Mauney 2005), there is little documentation about how red wolves utilize a landscape that is managed by humans for livestock, so it got a low ranking.

Twelve models were formulated (e.g. Model 2 = Forest_91 + Grassland_82+ Shrubland_82 + Wetlands_73 + Cropland_64 + Pasture_64 + Oakmast_91 - Interstate_91 - Highway_37 - City_19 - Towns_28; Table 1.2). Weighted landscape type, distance to nearest highway and interstate, and distance to nearest human populations were described for every 300m x 300m cell in the study area. The models were similar to equations in that each cell resulted in a numbered value, and numbered values were organized into three classes, or thresholds, of suitability as determined by natural breaks classification, which takes the frequency within the data and breaks those values into inherent classes (Carvalho et al. 2012). This was replicated with each model.

Initial results included the entire landscape of the 17-state study area. Three representative models were then chosen to contrast large (>1,000km^2), federally-managed areas across this landscape: models 4, 11, and 12. Model 4 has the lowest weighted cropland value compared. Model 6 has the highest weighted forest variable, and the cropland variable is midrange. Model 12 has the highest weighted cropland variable. These three models reflect alternative quasi-hypotheses regarding the relative importance of croplands and forested lands. Results of these three models were overlaid to identify areas of agreement, as assessed by cells identified as suitable, moderate, or unsuitable for all three models.

Given that any reintroduction effort would require identifying suitable lands to support a self-sustaining population, we conducted a second analysis contrasting the suitability of large federally managed lands. We established an arbitrary need for a landscape that would support a minimum of 10 wolf packs to mitigate potential conflicts that might occur on private lands and to mitigate potential inbreeding concerns (Robinson

et al. 2018). Red wolves have variable home range sizes as documented in historic records (Riley & McBride 1972, Phillips et al. 2003), the current RWRA (Hinton et al. 2016sa), and for the GSMNP restoration effort (Mauney 2005). An estimated mean home range size of 100km^2 was chosen with the recognition that under ideal circumstance, ten non-overlapping home ranges can be established within a 1,000km^2 area. We therefore identified federally managed landscapes >1,000km^2, and contrasted the percent of each management unit that was identified as suitable habitat, as well as the absolute amount of habitat identified as suitable per management unit.

RESULTS

Overall, the majority of the landscape was classified into class 1 (suitable) or class 2 (moderate), and differences in threshold classes among each model were small (<20% difference; Table 1.3). The range of difference for threshold class 1, suitable habitat, was 11.6% (high = 46.9%; low = 35.3%), the range of difference for threshold class 2, moderate habitat, was 7.8% (high = 49.3%; low = 41.5%), and the range of difference for threshold class 3, unsuitable habitat, was 13.8% (high = 22.0%; low = 8.2%). Three groups of models were identified based on similarities of overall percentages of suitable, moderate, and unsuitable habitats, with similarities of percent unsuitable habitat being the biggest factor differentiating the groups (Figure 1.2). One model from each group was identified as a representative to highlight the main differences in habitat suitability for each the model set: 4 (Table 1.4, Figure 1.3), 6 (Table 1.5, Figure 1.4), and 12 (Table 1.6, Figure 1.5). Other model results (as maps) are found in Appendix 3. Overlaying the three representative models (Figure 1.6) revealed that 34.9% of the entire study area's cells were recorded as suitable across all three models, 29.9% of the entire study area's cells were recorded as

moderate across all three models, and 7.5% of the entire study area's cells were recorded as unsuitable across all three models. This means that 72.3% of total cells matched in suitability thresholds across all three representative models.

Further analyses contrasted habitat suitability of >1000km^2 federally-managed landscapes (Tables 1.4, 1.5, 1.6) for each of the representative models. Based on percent suitability, all three models ranked Talladega National Forest (NF) as having the highest proportion of suitable habitat, followed by Ozark NF (Figure 1.7). Chattahoochee NF was ranked third for models 4 and 6 but ranked fifth in model 12. Conversely, Ouachita NF was ranked as third for model 12 but ranked fifth in models 4 and 6. While most landscapes were similarly ranked for each of the three models, several differed greatly, including Wayne NF and Cherokee NF. Daniel Boone NF had a >50% decrease in suitability in model 12 when compared to models 4 and 6.

Of the five landscapes with the greatest suitable habitat, three are located in northern Arkansas and southern Missouri. The amount of suitable land available within each management unit based on models 4 and 6 ranked 1.) Ouachita NF, 2.) George Washington & Jefferson NF, 3.) Mark Twain NF, 4.) Ozark NF, and 5.) Wayne NF (Figure 1.8). While models 4 and 6 were identical through all the rankings, model 12 matched only 50% of the time. Uniquely, model 12 ranked Nantahala NF and Pisgah NF as 9 and 10, respectively, and Daniel Boone NF was not included among the top ten. The top two rankings were unanimous among all three models, indicating Ouachita NF and George Washington and Jefferson NF have the largest space available. While these NFs are similar in overall size, Ouachita had at minimum 1,000km^2 more land deemed suitable across all three models compared to George Washington and Jefferson NF. Furthermore, each of

these NFs have another high-ranking, both in overall quality and in size, NF contiguous to them (Monongahela NF to Washington and Jefferson NF) or within a few 100 km (Ozark NF to Ouachita NF).

DISCUSSION

General habitat preference of the red wolf has been suggested by Paradiso and Nowak (1972) to be "warm, moist, and densely vegetated habitats, including virgin pine and lowland hardwood forests, coastal prairies, and marshes." However, this description is not reflective of the landscape found throughout the entirety of their historic range. Because of its large historic geographic distribution, it is probable that red wolves "utilized a large suite of habitat types" (Kelly et al. 2004). Based on what we know about historic use in small portions of the total range, it is suggested that red wolves are habitat generalists (USFWS 2007). However, while the NEP use a variety of landscapes, they show a preference for open landscapes as demonstrated by their high usage of agricultural habitat (Chadwick et al. 2010, Hinton et al. 2010, 2016, Dellinger et al. 2013, Karlin et al. 2016).

Our HSA indicates large suitable landscapes are available to red wolves across their historic range. Given that the majority of total landscape (72.3%) matched in suitability thresholds across all three representative models suggest that, even though 12 models were created to account for differences found in the literature and opinion, these customizations ultimately have similar results. This is unsurprising given that large carnivore usage of developed landscapes is well recognized. For instance, mountain lions persist in a natural landscape fragmented by urbanization in southern California (Riley et al. 2014, Vickers et al. 2016, Benson et al. 2017), and coyotes persist in urban environments (Murray et al. 2016, Poessel et al. 2017, Mueller et al. 2018). Red wolves are

no exception; they can use roads as movement corridors (Dellinger et al. 2013, Karlin et al. 2016; Hinton et al. 2016), and agricultural areas. Thus, as predictors of habitat use by a generalist species, the nuances of the models should be less important than the broader results.

We treated the federally managed lands as independent of one another. Importantly, however, there are landscapes within the study area that allow for natural red wolf expansion with relatively low movement barriers, namely northern Arkansas/southern Missouri and western Virginia/eastern West Virginia. While there are human populations and highways throughout these areas, most populations are <100,000 and the only major interstate present in these areas are Interstate 40 that divides Ozark and Ouachita NFs in northern Arkansas and Interstate 64 that bisects Washington and Jefferson NF in western Virginia. Additionally, each of these forests within these areas rank among the top ten in regard to amount of suitable landscape available and one federal agency, the Forest Service, has managerial oversight over each of these forests, despite being located across four states.

The challenge of NFs being surrounded by private land and the addition of highways and interstates plays a crucial role in population movement. Collisions with vehicles have accounted for 34% of red wolf mortality within the NEP (Hinton et al. 2017). The analyses conducted in this study are relatively simplistic in the context of treating adjacent cells. If restoration efforts progress to the point of contrasting landscapes, further refinement of the models might address the correlations of adjacent cells and the connectivity of patches of suitable habitat. For example, if two NFs have a high ranking of suitability within the forest boundary, but the surrounding landscapes vary considerably, the overall

consideration for suitability for each NF may change. In addition, we focused on federally managed lands. Future work could include a connectivity analysis between NFs and other public landscapes.

An additional consideration is fragmentation of these forests themselves, independent of road networks. Mark Twain National Forest and Wayne National Forest are comprised of multiple large patches. It is important to consider the ownership of the landscape surrounding the fragments (i.e. what portions of the landscape are privately-owned and what portions are managed by a state or federal agency or non-governmental organization?). When different management agencies fragment an area, a lack of organized effort potentially causes negative effects for broad-scale ecosystem management (Dallimer and Strange 2015). USFWS (2018) has addressed the importance of stakeholders as a part of reintroduction success. Thus, to effectively manage restoration efforts, it is important to consider agency ownership of landscapes surrounding parcels of federally-owned land and how likely partnerships and "buy-in" would be among those differing agencies and land-holders.

These models allow for customization of variables based on ranking preference. Nonetheless, results indicated that while there are differences in suitability ranking depending on each model's weighted values, these changes are relatively minor. Overall, a little over one third (34.9%) of the study area is ranked as suitable habitat for the red wolf among representatives of all three groups. This includes top regions identified by van Manan et al. (2000). Even though the southeastern United States has undergone heavy development, there are still large swaths of landscape deemed suitable for red wolf populations. Additionally, even though this region is mostly privately-owned, there are

publicly-owned landscapes large enough to hold multiple packs of red wolves. As restoration efforts progress, once specific potential locations have been identified for reintroduction, further research should examine those locations more closely to capture additional measures of suitability that are difficult to assess on a range-wide scale. Characteristics such as prey (specifically deer) density, hunting pressure, and the attitudes and inclusion of the local community could be incorporated into the models to further refine site rankings.

LITERATURE CITED

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Table 1.1: Data layers used for habitat suitability analysis, including reasoning as determined by a literature review, and suitability index ranking. The higher the index value, the more beneficial the variable is to the red wolf.

Ecological Variable	**Reasoning**	**Index Value(s)**
Oak forest mast	Oak mast produced used as food source for prey species	91
Forest	Utilized for denning, whelping, and pup-rearing Use forest edge for transportation; hunting Adapt to forest use when near human population or disturbance Ranked highest value possible in cost movement ranking studies	91 82
Grassland	Historically used prairies and coastal plains; early successional fields Current preference for cropland and utilizing road networks suggests historically occupied grassland and open-type habitats Ranked highest value possible in cost movement ranking studies	91 82
Shrubland	Utilized in RWRA Provide cover, associated with den sites Ranked mid-range in cost-movement ranking studies Lack of space-use and historical data	82 73
Wetland	Used for hunting; human avoidance Tended to avoid otherwise Rated mid value in cost movement ranking studies	82 73
Human-influenced Variables		
Population	Use human-associated landscapes but decrease use as human population increases Red wolves were consistently documented in actively avoiding human population and disturbance Increase in human density affected reintroductions Variable was divided into cities (populations > 100,000) and towns (populations < 100,000)	Towns = 28 Cities = 19
Roads	Used secondary dirt roads in RWRA for travel and hunting Roads in general contribute to red wolf mortality Variable examined interstates and highways as they are the road types most frequently traveled	Highways = 28 Interstates = 19
Cropland	Most utilized landscape in RWRA and GSMNP Utilized for hunting, pup-rearing, cover Decreased exposure in biting insects and parasites when compared to forest Managed by humans, the prime factor in red wolf mortality Rated low value in cost movement ranking studies	91 82 73 64

Table 1.2: Habitat models with associated landscape rankings. The higher the number, the more suitable the landscape is for the red wolf. All models have Oakmast_91, Interstate_19, Highway_37, Towns_28, City_19

Model	1	2	3	4	5	6	7	8	9	10	11	12
Forest	91	91	82	82	91	91	82	82	91	91	82	82
Grassland	91	82	91	91	91	91	91	91	82	91	91	91
Shrubland	82	82	82	73	82	82	82	73	73	73	82	73
Wetland	73	73	73	82	73	82	82	73	73	73	73	73
Cropland	64	64	64	73	73	73	73	82	82	82	91	64
Pasture	64	64	64	64	64	64	64	64	64	64	64	64

Table 1.3: Suitability percentages of the total landscape of each model broken down by percent type.

Model Number	Percent Landscape Suitable	Percent Landscape Moderate	Percent Landscape Unsuitable	Group Number
1	42.5	49.3	8.2	1
2	42.4	49.3	8.3	1
3	46.9	44.4	8.7	1
4	46.9	44.4	8.7	1
5	42.2	42.2	15.7	2
6	36.6	47.9	15.5	2
7	36.6	48.2	15.2	2
8	42.3	42.1	15.5	2
9	42.2	43.0	14.8	2
10	36.5	41.5	22.0	3
11	36.6	41.5	21.9	3
12	35.3	42.9	21.8	3

Table 1.4: Suitability of public landscapes over 1,000km^2. Rankings are based on the percent suitable habitat as output by model 4.

State	Name of Target Landscape	Size (km^2)	% suitable/moderate/unsuitable	Total size of suitable habitat (km^2)
Alabama	Talladega National Forest	1,588	97.2/2.7/0.1	1,544
Arkansas	Ozark National Forest	4,856	95.8/4.0/0.2	4,652
Georgia	Chattahoochee National Forest	3,306	95.0/4.4/0.6	2,884
Ohio	Wayne National Forest	4,349	93.5/6.1/0.4	4,066
Arkansas	Ouachita National Forest	7,284	93.3/6.6/0.1	6,796
North Carolina	Nantahala National Forest	2,150	92.6/6.6/0.8	1,991
North Carolina	Pisgah National Forest	2,075	91.9/7.4/0.7	1,907
West Virginia	Monongahela National Forest	3,727	90.8/8.8/0.4	3,384
Tennessee	Cherokee National Forest	2,652	89.7/8.7/1.6	2,379
South Carolina	Francis Marion National Forest	1,046	89.3/10.4/0.3	934
South Carolina	Sumter National Forest	1,502	86.8/11.8/1.4	1,304
Louisiana	Kisatchie National Forest	2,445	84.3/15.3/0.4	2,061
Missouri	Mark Twain National Forest	6,070	82.9/16.2/0.8	5,032
Mississippi	DeSoto National Forest	2,098	80.9/18.3/0.8	1,697
Kentucky	Daniel Boone National Forest	2,865	79.8/18.4/1.8	2,286
Virginia	Washington & Jefferson National Forest	7,247	78.5/19.8/1.7	5,731
Pennsylvania	Allegheny National Forest	2,077	68.3/31.2/0.5	1,418
Illinois	Shawnee National Forest	1,075	56.8/38.6/4.6	610
Georgia	Okefenokee National Wildlife Refuge	1,771	35.1/64.8/0.1	622

Table 1.5: Suitability of public landscapes over 1,000km^2. Rankings are based on the percent suitable habitat as output by model 6.

State	Name of Target Landscape	Size (km^2)	% suitable/moderate/unsuitable	Total size of suitable habitat (km^2)
Alabama	Talladega National Forest	1,588	91.9/7.9/0.3	1459
Arkansas	Ozark National Forest	4,856	89.0/10.6/0.4	4322
Georgia	Chattahoochee National Forest	3,306	86.4/12.5/1.0	2623
North Carolina	Nantahala National Forest	2,150	85.9/12.4/1.7	1847
Arkansas	Ouachita National Forest	7,284	85.7/12.5/1.9	6242
West Virginia	Monongahela National Forest	3,727	85.6/13.5/0.9	3190
North Carolina	Pisgah National Forest	2,075	84.7/14.2/1.1	1758
Tennessee	Cherokee National Forest	2,652	81.4/16.2/2.4	2159
South Carolina	Francis Marion National Forest	1,046	79.0/19.0/2.0	827
Ohio	Wayne National Forest	4,349	79.0/20.2/0.8	3436
South Carolina	Sumter National Forest	1,502	78.7/17.5/3.9	1182
Louisiana	Kisatchie National Forest	2,445	78.4/19.5/2.1	1917
Mississippi	DeSoto National Forest	2,098	74.8/23.2/2.0	1569
Missouri	Mark Twain National Forest	6,070	72.8/24.8/2.4	4419
Virginia	Washington & Jefferson National Forest	7,247	71.2/26.2/2.6	5198
Kentucky	Daniel Boone National Forest	2,865	70.4/25.6/4.0	2017
Pennsylvania	Allegheny National Forest	2,077	65.1/33.2/1.7	1352
Illinois	Shawnee National Forest	1,075	48.8/43.4/7.8	525
Georgia	Okefenokee National Wildlife Refuge	1,771	32.9/61.9/5.2	583
Florida	Apalachicola National Forest	2,562	9.5/83.9/6.6	243

Table 1.6: Suitability of public landscapes over 1,000km^2. Rankings are based on the percent suitable habitat as output by model 12.

State	Name of Target Landscape	Size (km^2)	% suitable/moderate/unsuitable	Total size of suitable habitat (km^2)
Alabama	Talladega National Forest	1,588	89.7/9.7/0.7	1424
Arkansas	Ozark National Forest	4,856	88.5/10.2/1.3	4298
Arkansas	Ouachita National Forest	7,284	82.5/15.2/2.3	6,009
West Virginia	Monongahela National Forest	3,727	81.4/16.4/2.3	3,034
Georgia	Chattahoochee National Forest	3,306	80.8/17.8/1.4	2,453
Ohio	Wayne National Forest	4,349	78.1/19.4/2.5	3,397
North Carolina	Pisgah National Forest	2,075	77.6/20.0/2.5	1,610
North Carolina	Nantahala National Forest	2,150	76.7/21.1/2.2	1,649
South Carolina	Francis Marion National Forest	1,046	75.6/21.7/2.6	791
Louisiana	Kisatchie National Forest	2,445	74.7/22.1/3.1	1,826
South Carolina	Sumter National Forest	1,502	74.0/20.3/5.6	1112
Mississippi	DeSoto National Forest	2,098	73.4/23.1/3.5	1540
Missouri	Mark Twain National Forest	6,070	70.8/22.8/6.4	4298
Virginia	Washington & Jefferson National Forest	7,247	68.2/26.3/5.5	4979
Pennsylvania	Allegheny National Forest	2,077	61.0/35.6/3.4	1267
Illinois	Shawnee National Forest	1,075	48.4/34.6/17.0	520
Kentucky	Daniel Boone National Forest	2,865	35.3/42.9/21.8	1011
Tennessee	Cherokee National Forest	2,652	35.3/42.9/21.8	936
Georgia	Okefenokee National Wildlife Refuge	1,771	32.9/61.5/5.6	583
Florida	Apalachicola National Forest	2,562	9.3/82.6/8.1	238

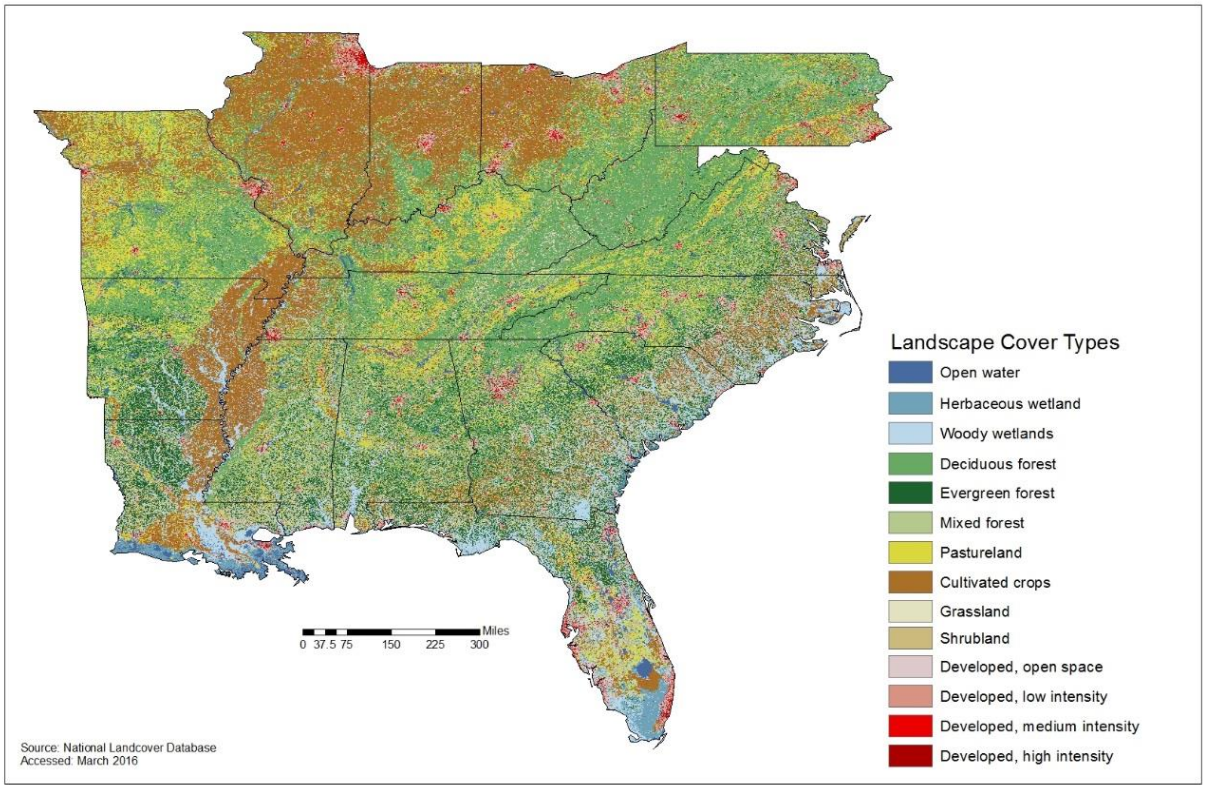

Figure 1.1: Map of landscape cover for the 17-state study area. Source: National Landcover Database

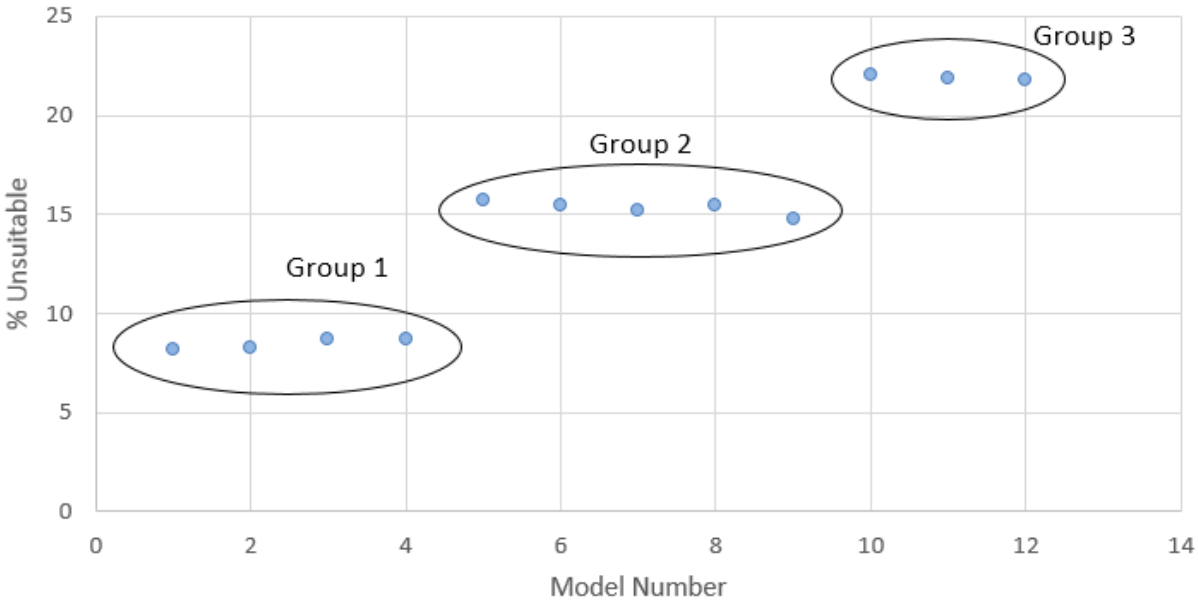

Figure 1.2: Habitat model groupings based on likeness of percent unsuitable habitat available. Models 1-4 are in group 1; models 5-9 are in group 2; models 10-12 are in group 3.

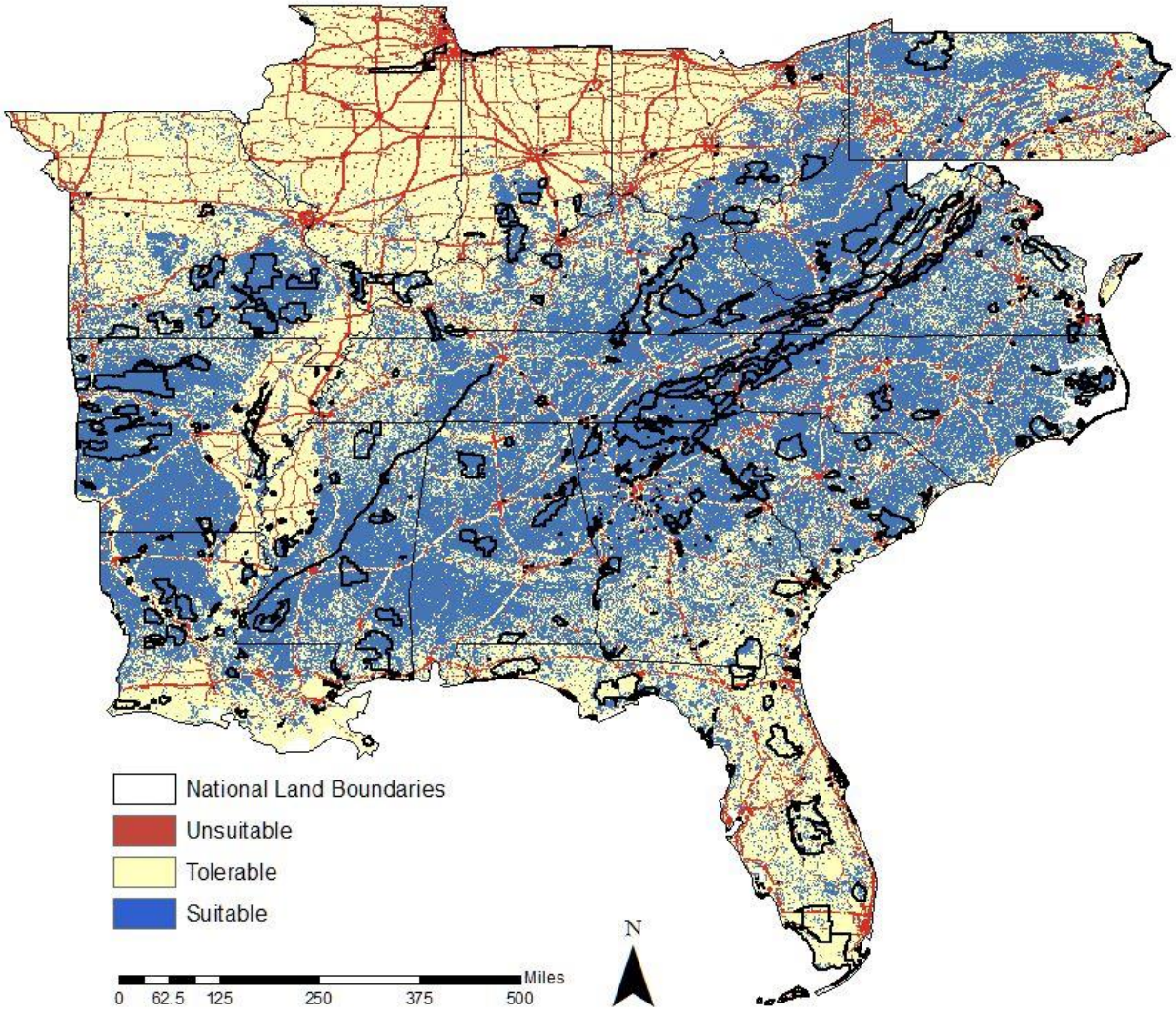

Figure 1.3: Map of habitat suitability derived from model #4. Included is the entirety of the study area along with boundary marks that indicate the location of publicly-owned landscapes. Blue represents habitat identified as suitable, tan represents habitat identified as moderate, red represents habitat identified as unsuitable.

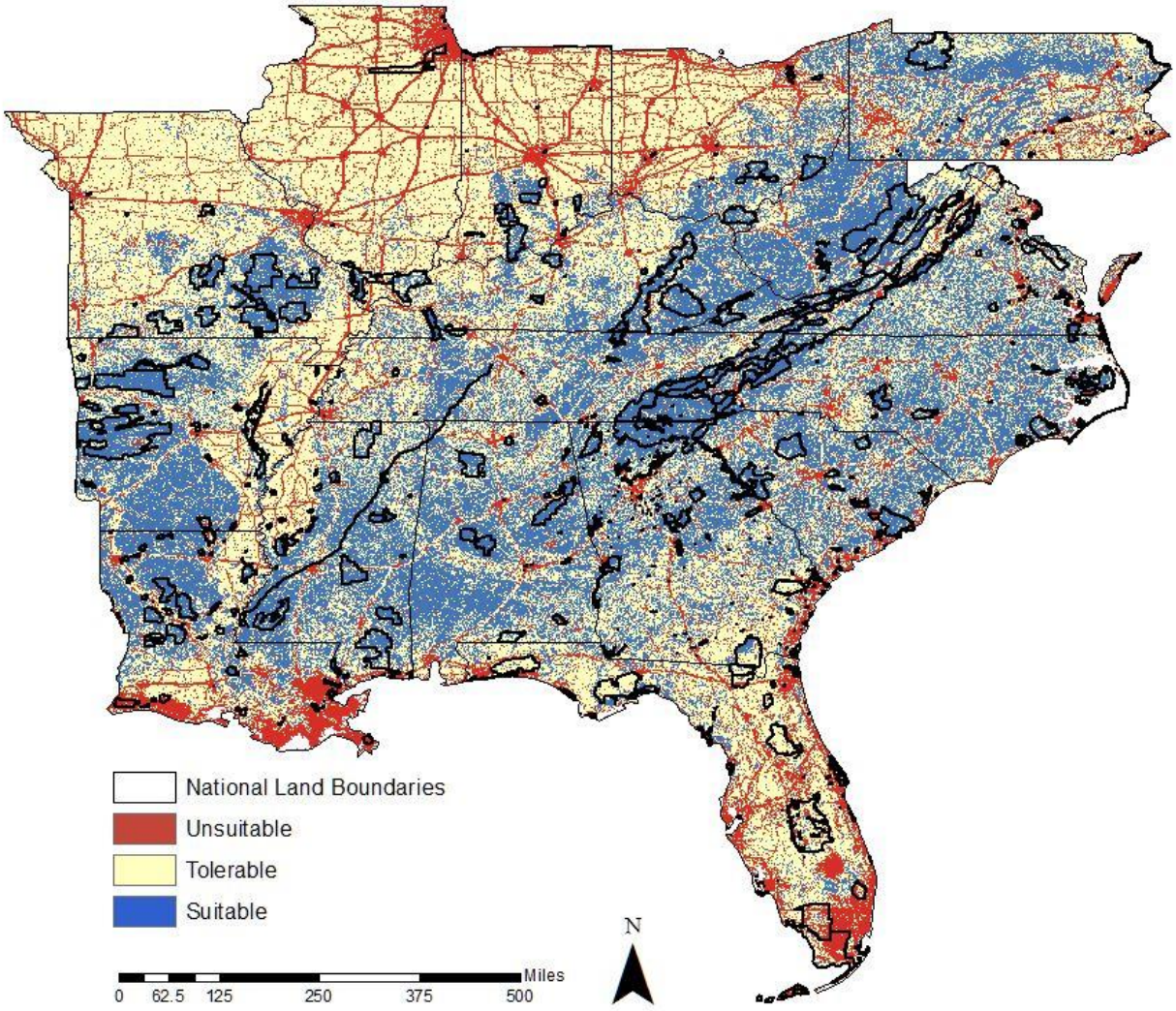

Figure 1.4: Map of habitat suitability derived from model #6. Included is the entirety of the study area along with boundary marks that indicate the location of publicly-owned landscapes. Blue represents habitat identified as suitable, tan represents habitat identified as moderate, red represents habitat identified as unsuitable.

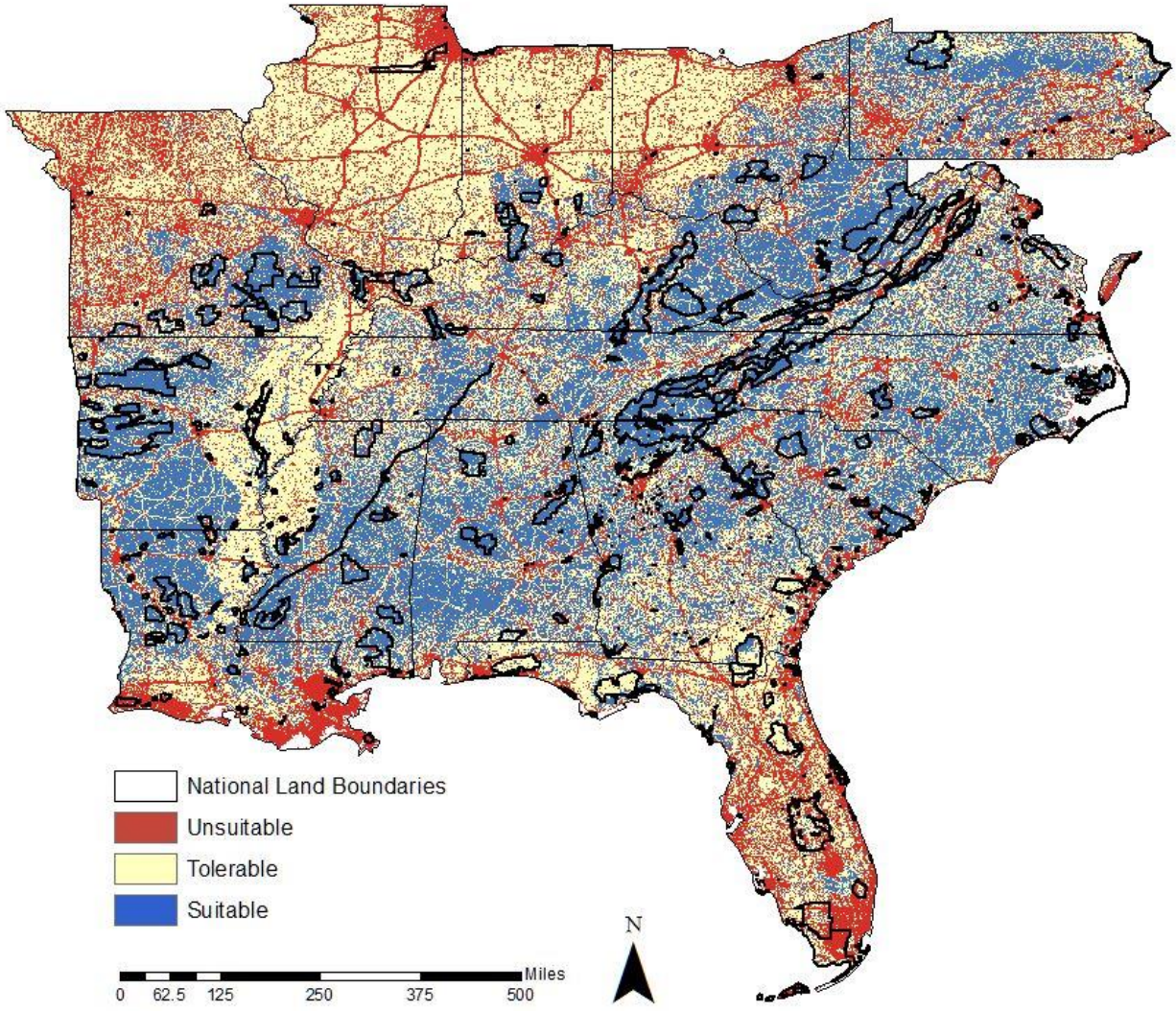

Figure 1.5: Map of habitat suitability derived from model #12. Included is the entirety of the study area along with boundary marks that indicate the location of publicly-owned landscapes. Blue represents habitat identified as suitable, tan represents habitat identified as moderate, red represents habitat identified as unsuitable.

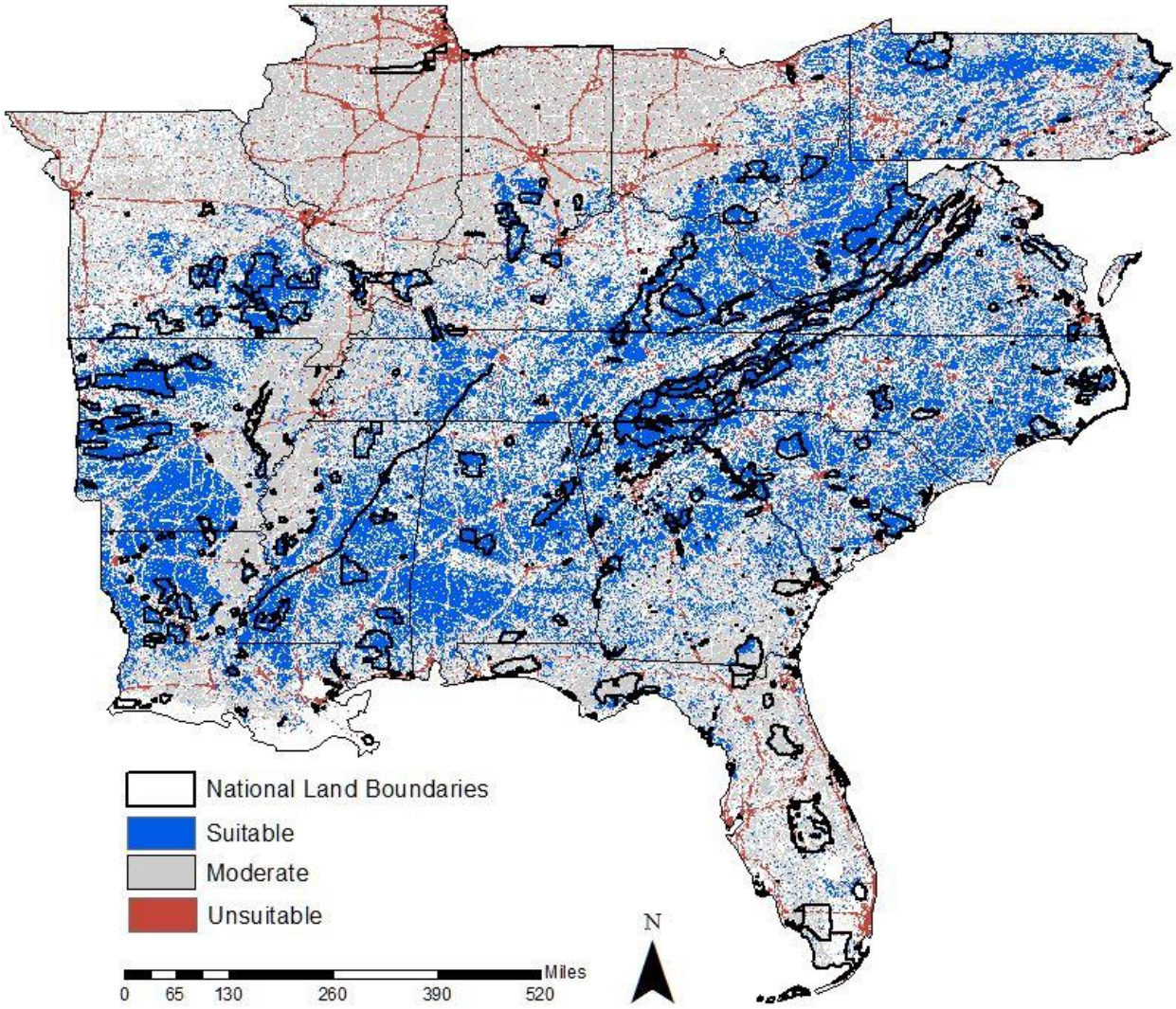

Figure 1.6: Overlay analysis results of models 4, 6, and 12. Included is the entirety of the study area along with boundary marks that indicate the location of publicly-owned landscapes. Blue represents habitat identified as suitable in all three models. Gray represents habitat identified as moderate in all three models. Red represents habitat identified as unsuitable in all three models. White indicates that suitability ranking among all three models for that habitat were not in agreement.

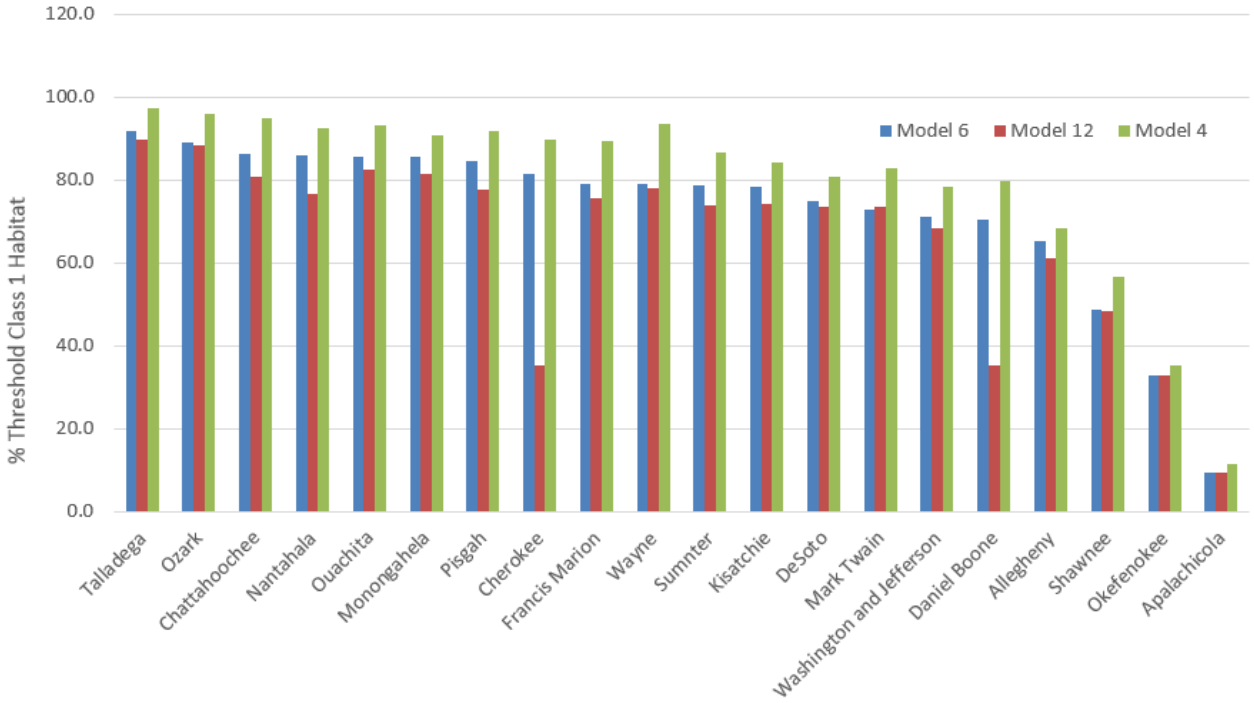

Figure 1.7: Suitability of public landscapes over 1,000km^2. Rankings are based on the percent suitable habitat as output by models 4, 6, 12 and are organized by public landscape.

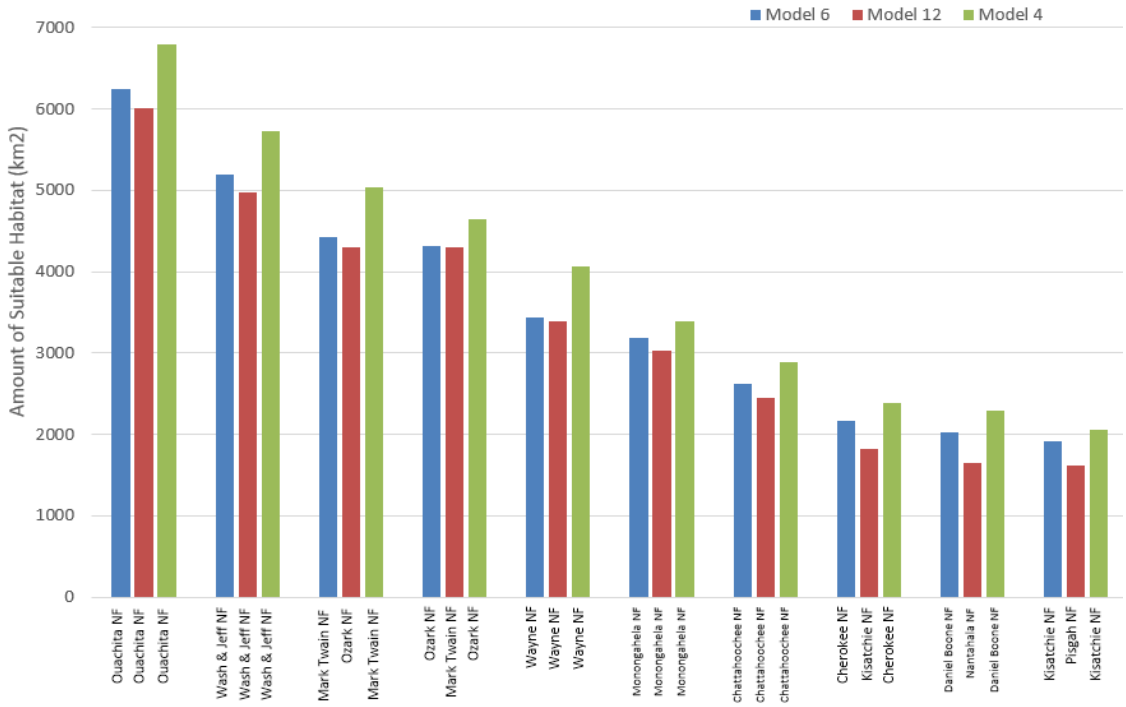

Figure 1.8: Amount of threshold class 1 (suitable) habitat available in public landscapes, measured by size (km^2). Rankings are based on the amount of suitable habitat as output by models 4, 6, 12 and are organized by public landscape.

Chapter 2

HUMAN-PERCEPTION OF CARNIVORES AT A GENERALIZED LEVEL, WITH RELEVANCE TO EDUCATIONAL OUTREACH AND RED WOLF CONSERVATION

ABSTRACT

While attitude and perception of specific large carnivore species has been described, how people perceive carnivores at a more generalized, basic level is less studied. Public perception of carnivores was assessed from over 1,100 surveys distributed across a spectrum of general and natural resource-related events in Missouri and Arkansas from October 2016-October 2017. The majority of respondents communicated positive views of carnivores based on their expressed opinions and experiences with carnivores. For those who expressed negative view of carnivores, their greatest concerns were related to pets and livestock safety. When asked about five specific carnivore species (black bear, mountain lion, coyote, red fox, red wolf) entering the state via natural recolonization or through a reintroduction program, respondents were in favor for both methods for all five species, but natural recolonization had higher levels of support. Logistic regression revealed that gender, age, education level, occupation, how often that person visited a public landscape, and what that person did in a public landscape influenced an individual's response, but these variables were dependent on the specific question. Immediate and long-term effects of educational outreach were also evaluated from over 560 surveys distributed at carnivore-centered outreach programs in Missouri and Arkansas. Effects were measured comparing responses before, immediately after, and one month, three

months, and five months after the program. Results indicated that educational outreach programs affected change, in a mostly positive or constructive way, but it is important to build and maintain working relationships with stakeholders if educational programming is going to have a lasting effect and be included in conservation management actions

INTRODUCTION

Conservation of wildlife is a multi-faceted effort that requires government agencies, private organizations, and public stakeholders to work cooperatively. In particular, large carnivore conservation must engage the public on issues related to the management and reintroductions of large carnivores on the landscape (Andersone 2004, Ericsson et al. 2008, Thornton & Quinn 2009, Gray et al. 2018, Hovardas 2018). Assessing stakeholder views is important for carnivore conservation efforts as understanding public perception has been shown to improve management effectiveness (Lute & Gore 2014) and, overall, stakeholder involvement has been increasing in crafting policies (Reed 2008). Some agencies anticipate stakeholder involvement when planning for future conservation management efforts (USFWS 2018). With this increase in stakeholder involvement, it is important to assess stakeholder perception and attitude towards carnivores, especially in a landscape where human-carnivore interactions might occur. Mitigation measures focused on coexistence can be developed if stakeholder perception and attitude can be identified (Gebresenbet et al. 2018). Stakeholder assessment is one of many useful tools that can be utilized for determining if a location is suitable for reintroduction efforts (Qin & Nyhus 2017, Gray et al. 2018) and for evaluating the impact of reintroduction efforts within a community (Serenari et al., 2018). Mitigation measures focused on coexistence can be developed if stakeholder perception and attitude can be identified (Gebresenbet et al. 2018).

Assessment can be used to understand stakeholders' concerns, improve management techniques, allow for stakeholders to become more involved, enhance communication between agency and stakeholders, decrease conflict between humans and carnivores, and increase public understanding of carnivores (Chase at al. 2000, Jim & Xu 2002).

It is important to assess perception and attitude towards carnivores, especially in a landscape where human-carnivore interactions might occur. One way to engage the public in the management process is by assessing their attitudes and perceptions with social science surveys. For decades, public attitude and perception surveys have been conducted on specific large carnivore species, including wolves (Kellert 1985, 1987, Kellert et al. 1996; Ericsson et al. 2003, Bruskotter et al. 2007, Karlsson & Sjöström 2007, Sponarski et al. 2013, Treves et al. 2013, Dressel et al. 2015, Hogberg et al. 2016), mountain lions (Wolch et al. 1997, Davenport et al. 2010, Smith et al. 2014, Rucker 2015, Engel et al. 2017), and bears (Kellert 1994, Morzillo et al. 2007, Campbell & Lancaster 2010, Smith et al. 2014, Dressel et al. 2015, Heneghan & Morse 2018). Public attitude and perception surveys have also been conducted on a suite of large carnivore species in a specific area (Kellert et al. 1996, Andersone & Ozoliņš 2004, Røskaft et al. 2007, Lagendijk & Gusset 2008, Lucherini & Merino 2008, Dar et al. 2009, Carter et al. 2010, Smith et al. 2014, Mkonyi et al. 2017a), but there is little research on how people perceive the generalized, non species-specific term 'carnivore' itself. Understanding basic perceptions of carnivores can be useful when discerning how to incorporate stakeholders into carnivore restoration plans. Knowing how people think about and understand carnivores may direct wildlife managers towards approaches to use when determining how a carnivore can be restored in a community.

Human perception is formed based on learning, experience, process and attention (Bernstein 2010). 'Carnivore' can be an attention-grabbing term. Interactions that people have with carnivores, such as in zoos, when hunting or hiking, or when watching documentaries, help to shape their perception of this term. This term may incite a sense of pride, connection, or resourcefulness when thinking about catching a rare glimpse of a mountain lion quietly strolling through the edge of a family's property. Conversely, feelings of nuisance, irritation, and fear may arise for a farmer whose livestock have been targeted by that same mountain lion. Others might not feel affected by this term at all. Knowing what people think about carnivores at a basic level may provide insight into how accepting they might be in regards to large carnivore reintroduction programs. While specific carnivore species might arouse different emotional responses, does the general term 'carnivore' provoke a more generalized response?

Reintroduction programs, particularly for large carnivores, are sometimes considered controversial because, while the intention is to return a species to a portion of its historic range, reintroduction efforts can be disruptive to local human communities and conflict can occur (Dickman 2010). For example, the reintroduction of the river otter to Missouri was heralded as a success with regard to the reintroduction effort itself. However, many residents expressed negative opinions about the program because of the river otter's predation on stocked fish in private ponds and management areas (Serfass et al. 2014). For large carnivore reintroductions, there can be conflicting priorities between agencies and stakeholders, as well as conflicting views among agencies (Lute et al. 2018). Understanding conflicting views, cultivating partnerships if they were once weak or non-existent, and

understanding drivers for stakeholder involvement and consideration are all factors that can aide in recovery efforts (Don Carlos et al. 2009, Frank 2016, Treves et al. 2017).

Particularly for large carnivores, buy-in from local communities is imperative to the success of a reintroduction program. Three communities bordering the Manyeleti Game Reserve (adjacent to Kruger National Park in South Africa) had overall favorable opinions about the large carnivore species in the area due to viewing the species as part of their natural heritage and conservation management approach (Lagendijk & Guesset 2008). Because of this cultural tolerance, human-carnivore coexistence occurs within the communities, despite the relatively high human population densities (Lagendijk & Gusset 2008). Understanding perceptions that people have towards carnivores at a generalized-level is a foundational step that is crucial to developing successful carnivore management plans.

Along with learning about perception and attitudes, educational outreach programs are a tool that scientists and educators use to connect stakeholders and members of the public with scientific concepts and research. Historically, programs in conservation education have been shown to increase knowledge, cultivate positive perception, and promote natural resource conservation (Jacobson 1991). These types of programs are typically unidirectional with the educator attempting to connect with the audience (Brewer 2002) by presenting accurate information and answering questions. Educational outreach programs can be a powerful tool in developing knowledge and perception about carnivores. In northern Tanzania, schoolchildren evaluated before and after an educational project about African wild dogs (*Lycaon pictus*) showed improved knowledge and recognition of the local carnivore community and recognized perceived threats towards

this species (Lyamuya et al. 2016). Because of the program, children's knowledge, recognition, and perceptions, of the local carnivore community improved. While children are often the target for educational outreach, programs are developed for adults as well. A five-year program for adults that focused on Andean bear (*Tremarctos ornatus*) conservation in an Ecuadorian community found that support for an Andean bear project was correlated with participation in the educational program, although attitudes and behaviors were mixed when participants had a conflict with the species (Espinosa & Jacobson 2012).

While the general term of 'carnivore' was the focus of this study, most of the education programs that were assessed spent a portion of time focused on the red wolf (*Canis rufus*), a critically endangered species endemic to the southeastern region of the United States. Due to prolonged human persecution, this species was on the brink of extinction before given federal protections. The U.S. Fish and Wildlife Service currently manages this species and has expressed interest in identifying areas of habitat suitability for the potential release of additional red wolf populations throughout its historic range (USFWS 1990, 2007, 2016, 2018), Given that humans are the biggest mortality factor for this species, successful reintroduction would likely require an incorporation of stakeholder perspectives and repeated meetings with stakeholders(USFWS 2018).

Objectives of this study were two-fold. First, we assessed perceptions of the term 'carnivore' at a generalized, basic level. Secondly, we asked how people respond to an outreach program that is carnivore-centric. How do the perceptions of carnivores change after an education program? Are there immediate and lasting effects on perception? We

also examined how perceptions towards carnivores might influence attitudes towards carnivore restoration, and in particular, restoration of red wolves.

METHODS

Carnivore perception surveys

We conducted a mixed methods study using convenience sampling of individuals working or visiting within a geographic area identified as suitable habitat for red wolves (Chapter 1). We selected locations in these areas to capture two populations of participants: (1) locations with people who may be more likely to partake in outdoor activities and use public lands; and (2) locations that would allow access to the general population. A survey (Appendix 3) was created and distributed between October 2016 and October 2017 at 7 locations in Missouri, 5 locations in Arkansas, and 1 location in Kentucky, USA (Table 2.1).

Respondents were asked to indicate what word(s) comes to mind when they think of the word 'carnivore' and if respondents had any personal interaction with a carnivore. If there was a personal interaction, respondents were asked to share their experience along with the emotion(s) that came to mind when they reflected upon that experience. Additionally, respondents were asked of their agreement with statements regarding carnivores (5-point Likert scale, 1 = Strongly Disagree, 2 = Somewhat Disagree, 3 = Neutral, 4 = Somewhat Agree, 5 = Strongly Agree). The statements were: 1.) Carnivores are a necessary part of the ecosystem. 2.) Humans and carnivores can coexist. 3.) I am concerned about carnivores near me. Throughout the survey there was no definition provided for the term 'carnivore', as we did not want respondents' answers to be influenced by any predetermined definition. To assess respondent support for species reintroduction efforts,

we asked respondents to indicate if they supported a particular method(s) used for hypothetical reintroductions of black bears, mountain lions, coyotes, red fox, and red wolves to the state we were collecting data in, or if they did not support any method. Answer options were: "when a population has returned to our state on their own", "when a population is placed in our state", both, or neither.

We asked several questions about the respondent's socio-demographic characteristics, occupation, gender, age, and highest completed level of education. Respondents were also asked how often they visited public land (e.g. state parks, national forests, and conservation areas). Answer options were: once a week, once a month, once a year, other (open-ended), and what types of activities they did within these landscapes (open-ended).

We examined factors influencing agreement responses to the three different carnivore statements and to methods of return for red wolves on the landscape. Each socio-demographic characteristic was subdivided into 2-3 levels:

- GENDER: Male, Female, Other (other was excluded from analysis due to n=3)
- EDUCATION: Completed high school or university (university encompasses any degree obtained starting at the Associate level)
- AGE: 18-34 (young), 35-59 (middle-aged), 60+ (older)
- OCCUPATION: does the respondent work at a job related to 1.) Agriculture, 2.) Natural Resources/on a Public Landscape, or 3.) Other/anything else
- Public land VISITING frequency: Infrequent (once a year, never/rarely), Occasional (seasonal), Frequent (once a week, once a month, live/work)
- ACTIVITIES within public landscape: Hunt, Work/Live, Recreation

Multiple logistic regression was used for binary variables. For variables with three categories, a Wald test and Bonferroni adjustment were utilized after the multiple logistic regression was executed. R Studio (version 3.4.3) was used to conduct all analyses using the dplyr (Wickham et al. 2017), MASS (Venables 2002), and aod (Lesnoff 2012) packages.

Educational outreach programs

Participants at educational outreach events were asked to complete a questionnaire before and after an educational program (Table 2.1). Educational outreach events were organized and presented by staff from the Endangered Wolf Center (located in Eureka, Missouri) and the Missouri Department of Conservation (MDC). The events addressed the role of carnivores within the ecosystem and how humans and carnivores can coexist. The events began broadly about carnivores, then the focus narrowed to wolves. The biology and social dynamics of wolves were addressed along with wolf-human interactions. Finally, with the red wolf used as a species of focus, the program concluded with information and a short video about the red wolf. The presentation was followed by a question and answer session. Programs lasted 60-90 minutes.

Two survey opportunities differed from this procedure, however they were both educational and involved carnivores. The first opportunity was an open-house event at the Endangered Wolf Center known as Wolf Fest. This event is the only time of the year the public can visit without prior reservation. This event includes attendance by families who would not normally visit this facility during other parts of the year, the opportunity to see live red wolves and Mexican wolves (*Canis lupus baileyi*) in enclosures with docents stationed at each enclosure, and hear educational presentations by Animal Care staff members throughout the day. The second opportunity was a fur-trapping workshop co-

hosted by the Missouri Trappers Association (MTA) and MDC. Here, members of the public who were interested in trapping for fur were able to attend this educational event that featured a short presentation, demonstrations of processing methods by members from MTA, opportunities to handle equipment and furs, and members of MTA and staff from MDC were available to answer questions and share their expertise. Overall, audience members for all programs were typically people who utilized the outdoors, from conservation docents to trappers. However, some events also attracted a general audience, or university students who attended as part of a required class.

We administered a survey immediately before and after the outreach program to determine the effect of the educational outreach event. We asked participants to volunteer to participate in follow-up surveys, which were sent out via email one-month, three-months, and five-months following the initial program to assess the longer-term impacts of the educational outreach program. Respondents who chose to participate filled-out the survey in Qualtrics (Qualtrics, Provo, UT).

Survey instrument

Quantitative survey questions can be used to assess general trends and qualitative survey questions provide insight into specific thought processes regarding knowledge, concerns, and individual opinions (White et al. 2005). Because both survey methods are valuable in understanding stakeholder perceptions, we used both to assess this perception of carnivores. The carnivore perception survey contained a total of 11 questions (Appendix 3). Four questions addressed topics related to carnivores while remaining questions addressed socio-demographic information such as occupation, gender, age, highest completed level of education, and public-land visiting frequency and usage. Pre-surveys for

the educational outreach programs were identical to carnivore perception surveys (Appendix 3). Post-surveys were similar but had minor revisions to better capture follow-up responses (Appendix 4). We promoted design validity of the study with review from experts from the University of Missouri and Clemson University, and with a pretest of undergraduate-level students from the University of Missouri who were enrolled in a wildlife management course during the Fall 2017 semester (n=50). IRB project number 2006785.

RESULTS

Human perceptions of carnivores

In total, 1,151 valid in-person surveys were collected for the carnivore perception surveys (Table 2.1). Respondents were primarily male (52.2%) and between the ages of 18-34 (48.1%). Most respondents (87.4%) had some college-level education, and the majority (79.5%) worked in an occupation that was not in agriculture or outdoors. Another 10.2% of respondents worked in a career that involved outdoor work, 5.2% of respondents worked in an agriculture-based career, and the remaining 4.9% chose not to answer. Most respondents visited public areas occasionally (47.0%), while 35.8% visited infrequently, and 17.1% visited frequently. In regard to activities people did while on public land, most respondents (82.8%) listed some form of recreation, 13.1% listed hunting, and 4.0% of respondents worked on public landscapes.

Respondents most-associated the term 'carnivore' with 'meat eater' (32.8%), 'meat' (20.8%), and 'predator' (7.5%) (Table 2.2). In the case of respondents whose answer included a specific species, 'wolves' were the most listed species-related response (4.5%). The majority of respondents (55.1%) indicated having an interaction with a carnivore

(Table 2.3), but most indicated that their interactions were with pets (19.3%). Another 17.0% indicated their interaction as viewing a carnivore in the wild (e.g. seeing black bear while hiking) and 9.7% indicated they had a physical interaction with a carnivore in the wild (e.g. having a black bear break into a respondent's car while camping). When describing an emotion that was associated with the respondent's recalling of the interaction, most emotions described were positive (Table 2.3). Fear, one of the few negative emotions communicated, was often coupled with excitement. When both these emotions were described together, they were typically associated with an unexpected encounter with a carnivore in the wild; in such cases, most indicated that they initially felt fear, but that fear turned to excitement once they realized they were safe.

On average, respondents indicated agreement that carnivores are a necessary part of the ecosystem ($\bar{x}$=4.79; SD=0.55)(Table 2.4). They also indicated agreement that humans and carnivores can coexist ($\bar{x}$=4.6; SD=0.76). However, respondents expressed a moderate level of concern about carnivores living near them ($\bar{x}$=2.59; SD=1.30). Most respondents were concerned about pets, livestock, and general safety when it came to carnivores near them (Table 2.5). EDUCATION (University) and OCCUPATION (Other) were predictors that were positively correlated to the statement 'carnivores are a necessary part of the ecosystem' (Table 2.6) No predictors were identified to positively correlate with the statement 'carnivores and humans can coexist' (Table 2.7). GENDER (Female), AGE (Older), and OCCUPATION (Agriculture) were predictors found to positively correlate with the statement 'I am concerned about carnivores living near me' (Table 2.8).

The vast majority of respondents appeared to support the return of the red wolf; 88.4% supported one or both methods versus only 11.4% who supported neither method

(Table 2.9). Generally, respondents were more supportive of natural recolonizations than reintroductions of predators as part of a program (Table 2.9). More respondents were supportive of reintroductions of red wolves as part of a program, but least supportive of a natural reintroduction of red wolves as compared to any other species we asked about. GENDER (Female), EDUCATION (University), OCCUPATION (Other), VISITING (Frequent, Occasional), and ACTIVITY (Recreation) were all predictors of support for red wolves on the landscape (Table 2.10).

Educational outreach programs

In total, 564 valid, paired education program surveys were completed (Table 2.1). 'Meat eater' and 'meat' were the predominant words associated with the term 'carnivore' for both pre- and post- surveys. The top ten responses associated with this term in the educational outreach pre-survey were nearly identical to responses seen in the carnivore perception survey (Table 2.2). However, the top responses associated with this term in the educational outreach post-survey included 'red wolf', 'necessary', and 'endangered' (Table 2.2). Additionally, there was an increase in the number of people who associated 'carnivore' with 'wolf' (Table 2.2). Most respondents did revise their association, and overall responses from the post-program survey were focused more towards the roles that carnivores have within the ecosystem (Table 2.2). When respondents were asked on the post-survey if the educational program changed how they felt about their interaction with a carnivore, most indicated it did not because their experience with the carnivores was positive (74.0%)(Table 2.3). For those who did indicate a change, most either became positive or became more positive about that interaction, or the respondent indicated that due to the educational outreach, they now had a better understanding of their interaction.

In the pre-survey, most respondents strongly agreed (necessary pre: $\bar{x}$=4.87; SD=0.46 & coexist pre: $\bar{x}$=4.70; SD=0.62) that carnivores are a necessary part of the ecosystem and that humans and carnivores can coexist (Table 2.4). This strong agreement increased for both statements in the post-survey (necessary post: $\bar{x}$=4.93; SD=0.32 & coexist post: $\bar{x}$=4.81; SD=0.51). Pre-survey results indicated that most respondents either disagreed with or were neutral about carnivores near them being a cause for concern (pre: $\bar{x}$=2.41; SD=1.22). However, while the number of respondents who indicated they strongly disagreed increased post-program, the amount of strongly agree responses increased by 3% (post: $\bar{x}$=2.32; SD=1.35). Respondents' main concern about carnivores near them, as indicated in the post-program survey, was the well-being of the carnivores themselves. The number of listed concerns decreased by 50% in the post-survey (n=79) when compared to the pre-survey (n=158) (Table 2.5).

There was strong support for the red wolf on the landscape both before and after the educational outreach programs (96.0% pre; 98.0% post)(Table 2.11). Post-program responses revealed an increase in support for red wolves returning to the landscape as part of an organized program and for both methods of return, but also showed a 50% decrease in support for 'neither' natural or human-facilitated reintroductions (pre n=18; post n=9).

Participation in educational outreach follow-up surveys was relatively low. A total of 52 respondents participated in the one-month follow-up, 33 respondents in the three-month follow-up, and 47 respondents in the five-month follow-up. When asked about information retained from the carnivore program, most respondents stated they remembered most or some of the information one- and three-months post-program (91.3% for month one where total n = 23, and 100% for month three where total n = 9).

While most respondents remembered most or some of the information five-months post program (60.7%; n=17), 39.2% of respondents also stated they remembered little or nothing of the program at the five-month mark (n=11). Respondents indicated that the most memorable portions of the educational outreach program were the enthusiasm and presentation of knowledge from the panel of presenters, presented information specific to red wolves, and, in the event of Wolf Fest, being able to see a live wolf. All but one respondent spoke about the program to friends and family (one-month: n=52, 100%; three-month: n=32, 96.9%; five-month: n=47, 100%).

'Meat eater' and 'meat' remained the words most often associated with the term 'carnivore' (Table 2.2). Even though they were mentioned on the post-survey right after the program, 'red wolf', 'necessary', and 'endangered' were no longer mentioned in the follow-up surveys, however, 'important' was mentioned by three individuals in the one-month follow-up. Additionally, the majority of respondents were supportive of both reintroduction types for the red wolf at the one-month follow-up (47.0%) and 'human-facilitated reintroduction' for the red wolf at the three-month and five-month follow-ups (51.5% and 46.6% respectively)(Table 2.11).

There was strong agreement with the statements of 'carnivores are a necessary part of the ecosystem' (one-month=98%, n=50; three-month=97%,n=32; five-month=100%,n=45) and 'humans and carnivores can coexist' (one-month=88%, n=45; three-month=93%,n=28; five-month=91%,n=41) for each follow-up. Most respondents strongly disagreed that they were concerned about having carnivores near them at the one-month follow-up (42%, n=21), were largely neutral at the three-month follow-up (31%, n=10), and mostly strongly disagreed at the five-month follow-up (33%, n=15). Dangers to

pets (n=16), livestock (n=9), carnivores themselves (n=7), and children/family(n=5) remain the greatest concerns for each of the follow-up surveys.

DISCUSSION

Our survey respondents have a generally positive view about carnivores. When asked what comes to mind upon hearing the term 'carnivore', responses focused primarily on the basic meaning of the term, characteristics that stand-out specific to the term, or on a specific species that was viewed by the respondent as a carnivorous animal. All three of these main response-types are accurate to the definition of a carnivore in terms of ecological role, nutrition-mode, anatomical significance, or taxonomic meaning. This suggests that respondents have a relatively good general understanding of what carnivores are.

When sharing a story about a carnivore interaction, pet stories were the most reported. The prevalence of stories of interactions with carnivores being related to pets is unsurprising given that our respondents likely interact with pets frequently, and likely have a positive interaction with pets. This perspective is most typical for that of developed countries, such as the United States (Gray & Young 2011, Blouin 2015). In other parts of the world, it is common for cats and dogs to be thought of as free-roaming animals who predate on native wildlife, spread disease, and could threaten human health and safety (Hughes & Macdonald 2013).

Human attitude is strongly influenced by perceptions and personal experience (Pinheiro et al. 2016, Dickman et al. 2013, Espinosa & Jacobson 2012) as well as cultural norms and societal beliefs (Dickman 2010). While attitudes towards some carnivore species may be complex (Røskaf et al. 2007), the positive emotions conveyed by most

respondents in this study suggest that an encounter with a carnivore is generally viewed as favorable. Negative emotions regarding experiences with carnivores were typically associated with 1.) the destruction of livestock or property or 2.) unexpected sightings, which typically turned into a more positive emotion. However, it is important to note that not everyone who had a seemingly negative encounter with a carnivore had a negative response; some emotions were associated with understanding of various levels of acceptance.

Support for carnivores on the landscape was overwhelmingly positive for each for the five identified species. However, the natural reintroduction mode received more support than these species returning via an organized program. When examining support of red wolves and coyotes on the Albemarle Peninsula in North Carolina, Serenari et al. (2018) noted more community support for predator species who came into the area on their own, versus predator species who entered an area due to direct anthropogenic interference. Each species, except the red wolf, had over 50% support for naturally returning to the landscape. Conversely, when compared to the other species, the red wolf had the highest percentage response in support for organized reintroduction (Table 2.9). Reintroduction attempts of African wild dogs revealed an array of conflicting interests in attitudes among stakeholders, but reintroduction could be viable if certain needs (e.g., financial, educational, and livestock management) were addressed or improved (Gusset et al. 2008). A reintroduction of wolves in an area of Scotland garnered support by all public stakeholders except farmers (Nilsen et al. 2007). However, the farmers themselves were not as strongly opposed as the organizations that represented them expressed (Nilsen et al. 2007). It is imperative for reintroductions to be well-planned so that the concerns of local

residents can be met. If there is a negative encounter with the reintroduced species, such as predation.

While there was broad support for red wolves and other carnivores on the landscape, and surveys were conducted in areas that represent suitable habitat for the red wolf (Chapter 1), it is important to note that those who are more likely to not support red wolves on the landscape are those living near areas red wolves could potentially inhabit. The "not in my backyard" sentiment in carnivore conservation dates at least to Yellowstone wolf reintroductions (Paystrup 1993) and remains common (Whitaker &Beazley 2016). Many respondents who did support carnivores on the landscape indicated that they were okay with their presence in the area as long as the species did not destroy property and livestock, or cause harm to themselves and family. These two views indicate concern and fear of harm or loss, and need to be acknowledged and addressed in planning reintroduction efforts. Otherwise, these views could turn into a stronger negative factor and could perhaps override, or at the very least conflict with, any positive or neutral attitudes (Whitaker and Beazley 2016).

While, overall, respondents agreed that carnivores are necessary and that it is possible for humans and carnivores to coexist. This might suggest that people have an intuitive understanding carnivores and their general role within the ecosystem. According to results of the logistic regression, those with the most concern about carnivores were women, those over the age of 60, and those who worked in an agricultural occupation. The latter is not surprising as conflict tends to increase when livestock and carnivores share the same landscape (McManus et al. 2015, Mkonyi 2017b, van Eeden et al. 2018, Mbise et al. 2018). Those who are older may be more inclined to think negatively of carnivores because

of changes in how educational outreach programs have exposed people to carnivores (Scasta at al. 2017, Bergstrom 2017) and sustainability issues (Lerner et al. 2017).

For respondents who had concern about carnivores, those biggest concerns were with pets, livestock, and general safety. Interestingly, most respondents used pets to define their interactions with carnivores. Pets within the United States are valued as companions and can be utilized for different tasks. Despite viewing their pets as carnivores, the presence of a wild carnivore in the area could indicate that the well-being and safety of their pet is at risk. Even though the pet may be perceived as a carnivore, they may not be able to survive an encounter with a wild counterpart. Livestock generates income for many people and it is common knowledge that carnivores predate on livestock. The loss of that income because of predation impacts producers. Mitigation programs may lower this risk and increase understanding for both livestock producers and population managers (Treves & Karanth 2003, Bradley et al. 2005, Woodroffe et al. 2007, Baker et al. 2008). Additionally, having experiences in which carnivores harm personal property causes general concern. Concern also occurs for those who have no direct experiences with carnivores but know someone who has, as well as, if an individual's understanding of a carnivore is based upon perceived negative images and information (Røskaf et al. 2007).

We found that our educational outreach efforts had an effect on human perceptions of carnivores. This is also apparent in the literature, particularly with education programs related to wolves (Troxell et al. 2009, Kuhl 2016). Following the educational outreach programs, there was an increase in support for red wolf return to the landscape (via methods of reintroduction and natural recolonization), particularly with reintroduction efforts, and a decrease in support for the red wolf absent from the landscape. For Wolf Fest,

an event that surveyed people after they saw live wolves and were able to talk with docents, 68% of respondents reported support for either reintroduction efforts or both methods. Other studies have found similar results in that when a topic is presented, participants tend to become more aware of the knowledge they acquired, and attempts are made to put that knowledge into some form of action (Foster 2016). Additionally, those who have more knowledge about a particular issue are more likely to have a positive viewpoint about that issue (Penn et al. 2018).

There was already strong agreement about the statement 'carnivores are a necessary part of the ecosystem' before the educational program began. In regard to the statement 'humans and carnivores can coexist', again there was overwhelming strong support for agreement before the program began. However, strong agreement was noted to increase when respondents were surveyed after. The last statement, "I am concerned about carnivores near me" did show a small increase of agreement in post-program response. However, there was also a slight increase of disagreement in post-program response. When looking at the follow-up question of 'what concerns you', people most noted safety for the carnivore after the program. This correlates with the increase in overall concern post-program: attendees became more concerned for carnivores themselves. Espinosa and Jacobson (2012) found that participants in an Andean bear conservation program made behavioral adjustments to decrease conflict with bears more so than those who did not participate in the program.

Additionally, a number of concerns decreased post-program. Main concerns before the outreach program were more about human safety while after, main concerns were for the carnivores themselves or danger about a specific species and pets. This suggests that

when people learn that carnivores do not serve an immediate danger to personal safety, their concern decreases. However, where there is concern due to a danger in either personal or property safety, mitigation efforts need to be put into place to reduce effect. One such example is that of compensation programs. Even though compensation programs do not prevent negative interactions, they can be effective in supporting maintenance (Morehouse et al. 2018).

Most respondents after the educational program did not have a change in response toward their story experience. However, stories were mostly about pets and carnivores that were seen in the wild and emotions were mostly positive. While 'meat eater' and 'meat' were the top two words thought of when respondents were asked to associate words with carnivore, overall response shifted from that of species-specific, utilitarian, negative associations to more ecological-minded responses. Species that were specifically named were red wolf, wolf, and coyote. These were species that were named within the presentation itself. However, follow-up surveys showed that 'carnivore' association went back to more utilitarian terms.

Overall, a change in perception was noted among education programs, even for those who were already volunteering as a docent at a zoo or conservation center. In regard to cultivating deeper meaning and connection for the participant, Brewer (2002) outlined benefits of partnerships between biologists and participants (in this case, residents of a community adjacent to threated and endangered species and their habitats) by having participants learn first-hand the point of the biologist's role in regards to the 'what', 'how', and 'why' of their research. Additionally, biologists can gain deeper understanding of how the participants relate to the species of focus and the habitat that they use (Brewer 2002),

thus creating a bi-directional connection between educator and audience and opening up avenues towards community-based conservation. For management purposes, it is important to include stakeholders who are already "on board" as well as those who are not already predisposed to the topic (Penn et al. 2018) or may have a negative view on the topic. It is also important to move beyond the uni-directional presentational format and engage in action and continual evaluation of program effect (Hillard et al. 2016).

Our study found that educational outreach programs do have an effect on the respondent, in a mostly positive or constructive way, but it is important to build and maintain working relationships with stakeholders if educational programming is going to have a lasting effect and be included in conservation management actions. Two participants made comments that summarize this statement. One noted, "I wish more people were able to hear this information! Even though I was already in favor of (red wolf) reintroduction, it made me even more aware of how important this is and what an uphill struggle it is." The second respondent noted, "It is one thing to hear someone else say what works and another thing to try it and see that it works. I have not had the opportunity to test out what I learned to discover if it does in fact work as well as they (the presenters) stated."

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Table 2.1: Locations of individual surveys and educational outreach programs

Location	Description	Survey Number
Onondaga Cave State Park[1]	Park visitors and participants attending a BioBlitz	57
South Farm[1]	A public event for those who are interested in agriculture and natural resource topics	35
Daniel Boone National Forest[1]	Park visitors in the Gladie Visitor Center	55
Missouri Cattlemen Conference[1]	Annual meeting of Missouri ranchers	80
Arkansas State University Student Union[1]	General college student population	76
Missouri Natural Resources Conference[1]	Annual meeting of natural resources professionals and students across Missouri	83
Conservation Federation of Missouri Meeting[1]	Annual meeting of natural resources professionals and students across Missouri with a focus on legislature	80
Town Square in Bentonville, AR[1]	General population of a small community	25
Ouachita National Forest region[1]	General population of towns within Ouachita National Forest, Arkansas	63
Mark Twain National Forest region[1]	General population of towns within Mark Twain National Forest, Missouri	58
University of Arkansas campus[1]	General college student population	107
Arkansas Academy of Science[1]	Annual meeting of scientific professionals and students across Arkansas	94
University of Missouri-Columbia	An undergraduate natural resources course taken by students who have predominately business majors	70
St. Louis Science Center[2]	General population of an urban community who listened to a panel discuss topics pertaining to wolves, specifically the red wolf, and then watched a 20-minute red wolf documentary	46; 27 indiv
Runge Nature Center[2]	Volunteers at a conservation center who listened to a panel discuss topics pertaining to living among carnivores, generalized wolf topics, and the red wolf and then watched a 2-minute red wolf video clip	30; 14 indiv
Arkansas State University[2]	Optional student event where students listened to a panel discuss topics pertaining to living among carnivores, generalized wolf topics, and the red wolf and then watched a 2-minute red wolf video clip	30; 21 indiv
Springfield Nature Center[2]	Volunteers at a conservation center who listened to a panel discuss topics pertaining to living among carnivores, generalized wolf topics, and the red wolf and then watched a 2-minute red wolf video clip	26; 3 indiv
Dickerson Park Zoo[2]	Docents at a zoo who listened to a panel discuss topics pertaining to living among carnivores, generalized wolf topics, and the red wolf and then watched a 2 minute red wolf video clip	34; 7 indiv
Arkansas State University FYE event[2]	Mandatory student event where students listened to a panel discuss topics pertaining to living among carnivores and the red wolf and then watched a 2-minute red wolf video clip	284; 184 indiv

Wolf Fest[2]	Open house event at a wolf conservation center where members of the public were able to view live wolf species and interact with docents at each enclosure	102
Fur Handling Workshop[2]	Attendees interested in wanting to learn more about fur trapping and handling techniques; low attendance due to snowstorm	12; 12 indiv

[1] = Individual survey locations
[2] = Educational outreach program survey locations. Some locations had individual surveys collected, this is marked by # indiv (number of individual surveys collected at program).

Table 2.2: Response to survey question "What word(s) come to mind when you think of carnivore?" Responses include individual surveys, educational program surveys, and educational program follow-up (one-month; three-month; five-month) surveys.

Individual		*Pre-program*		*Post-program*		*One-month*		*Three-month*		*Five-month*	
Meat eater	322	Meat eater	197	Meat eater	127	Meat eater	14	Meat eater	14	Meat eater	24
Meat	204	Meat	101	Meat	91	Meat	8	Meat	5	Meat	11
Predator	74	Predator	32	Wolf	36	Predator	7	Animals	3	Predator	6
Animals	51	Wolf	24	Predator	23	Big cat species	6	Wolves	3	Teeth	3
Wolf	45	Bear	21	Red/American Wolf	20	Wolves	4			Animals	2
Bear	40	Animals	18	Animals	20	Dogs	3			Food	2
Lion	38	Lion	12	Necessary	15	Important	3				
Dinosaur	31	Hunt/Hunter	10	Endangered	10						
Coyote	28	Dinosaur	9	Bear	9						
Teeth	24	Teeth	8	Coyote	9						

Table 2.3: Response to survey questions "If you've had any personal interaction with a carnivore, please share your story." and "What emotion(s) come to mind when you tell this story?" Responses include individual surveys and educational program surveys.

Individual surveys				*Educational outreach programs surveys*			
Themes	**Number of Respondents**	**Top Emotions**	**Number of Respondents**	**Themes**	**Number of Respondents**	**Top Emotions**	**Number of Respondents**
Pets	123	Happy	62	Pets	62	Happy	34
Viewed carnivores in the wild	108	Excitement	61	Viewed carnivores in the wild	40	Excitement	33
Interaction with carnivores in the wild	62	Neutral	35	Working or volunteering at a captive management facility	31	Love	25
Referring to humans as carnivores	51	Fear	34	Visiting a captive management facility	26	Fear	18
People who have seen carnivores on their property	47	Love	34	Interaction with carnivores in the wild	22	Awe	14
Hunting or trapping carnivores	46	None	31	People who have seen carnivores on their property	16	Sadness	11
Visiting a captive management facility	34	Scared	26	Interaction with a wild carnivore held as a pet or captivity	15	None	10
The respondent referring to themselves	33	Positive	24	Referring to humans as carnivores	11	Positive	9
Working or volunteering at a captive management facility	24	Sad	23	Hunting or trapping carnivores	11	Joy	7
Respondent was not clear in story	23	Awe	18	The respondent referring to themselves	11	Neutral	7
Wild animals attacking domestic animals/pets	22	Nostalgic	14	Wild animals attacking domestic animals/pets	9	Cool	6

Interaction with a wild carnivore held as a pet or captivity	20	Interesting	13	Respondent was not clear in story	3	Fun	5
Research on carnivores	20	Respect	12	Education	2	Respect	5
Domestic animals attacking wild animals or humans	18	Amazing	11	Domestic animals attacking wild animals or humans	1	Pride	4
Movies or TV shows	3	Factual (statement)	11				
Education	1	Awesome	10				

Table 2.4: Response to educational outreach survey question "To which extent to you agree or disagree with the following statements?"

Statement	Strongly Agree		Somewhat Agree		Neutral		Somewhat Disagree		Strongly Disagree		Total Response
	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-	Pre-	Post-	
Carnivores are a necessary part of the ecosystem	91.2% (418)	94.1% (431)	6.1% (28)	3.0% (14)	1.9% (9)	1.9% (9)	0.2% (1)	0% (0)	0.4% (2)	0% (0)	458
Humans and carnivores can coexist.	76.9% (350)	86.3% (393)	16.0% (73)	10.1% (46)	5.0% (23)	3.0% (14)	1.0% (5)	0.6% (3)	0% (0)	0% (0)	455
I am concerned about carnivores living near me.	7.0% (32)	11.0% (50)	9.9% (45)	7.9% (36)	31.0% (141)	23.1% (105)	20.0% (91)	18.0% (82)	31.0% (141)	40.0% (182)	454

Table 2.5: Response to survey question "If you are concerned about carnivores living near you, please share why." Responses include individual surveys and educational program surveys.

Theme ***Individual***	**Description**	**% of respondents**	**Number of respondents**	**Theme** ***Pre (n=158)***	**% of respondents**	**Number of respondents**	**Theme** ***Post (n=79)***	**% of respondents**	**Number of respondents**
Pets	Depredation of dogs and/or cats.	18.4	78	Pets	17	27	Carnivore concern	18.9	15
Livestock	Depredation of cattle and/or chickens.	17	72	Carnivore concern	15.1	24	Species specific	15.1	12
General safety	Safety concern; feeling that a carnivore is dangerous	13.7	58	Personal safety	13.2	21	Pets	13.9	11
Personal property	Damage a carnivore might do to one's property.	7.8	33	Other	9.4	15	General safety	11.3	9
Children	Harm a carnivore might bring to children's safety.	7.8	33	General safety	8.8	14	Other	8.8	7
Specific species	Respondents named a species that they were particularly concerned about	7.3	31	Species specific	8.8	14	Livestock	7.5	6
Other	General statements	6.4	27	Livestock	7.5	12	Not concerned	6.3	5
Personal safety	Concern for respondent's own	6.6	28	Not concerned	6.9	11	Personal safety	6.3	5

	personal safety								
Carnivore safety	Well-being of carnivore species is at threat	6.6	28	Children	3.7	6	Lack of education	3.7	3
General animals	The safety of animals (not specified what kind) is at risk	3.3	14	Lack of education	3.7	6	Wildlife impact	3.7	3
Not concerned	Respondents who specifically wrote not concerned	2.8	12	Generic animals	2.5	4	Children	1.2	1
Wildlife impact	Concern about the impact carnivore presence might bring to already established wildlife populations	2.1	9	Wildlife impact	0.6	1	Personal property	1.2	1

Table 2.6: Estimated coefficients and standard errors of a model predicting respondent agreement to the statement "carnivores are a necessary part of the ecosystem" (n = 984) from surveys distributed through Missouri, Arkansas, and Kentucky, USA (Oct. 2016-Oct. 2017). The resulting p-value of a Wald's test is applied for variables analyzed with three categories ($p < 0.05$ is significant). All three categories are examined if $p < 0.05$. Consult Methods for variable descriptions.

Variable	Coeff.	SE	Wald's
GENDER	-0.0004	0.4426	-
EDUCATION	1.661***	0.4957	-
AGE- Young	0.0085	1,131	0.98
AGE- Middle	17.86	-0.9827	0.98
OCCUPATION- Other	1.592*	0.6762	0.048#
OCCUPATION- Outdoor	2.065	1.204	0.048#
OCCUPATION- Agriculture	-1.4375	0.4821	0.048#
VISIT- Infrequent	-0.2378	0.5886	0.23
VISIT- Occasion	0.5896	0.6057	0.23
ACTIVITY- Recreation	0.00605	0.622	0.99
ACTIVITY- Work	-0.07298	1.19	0.99
Intercept	-0.0503		

* $p < 0.05$

** $p < 0.01$

***$p < 0.001$

If Wald's test $p < 0.05$, Bonferroni adjustment applied to logistic regression where $p < 0.02$ is significant

Table 2.7: Estimated coefficients and standard errors of a model predicting respondent agreement to the statement "humans and carnivores can coexist" (n = 984) from surveys distributed through Missouri, Arkansas, and Kentucky, USA (Oct. 2016-Oct. 2017). The resulting p-value of a Wald's test is applied for variables analyzed with three categories ($p < 0.05$ is significant). All three categories are examined if $p < 0.05$. Consult Methods for variable descriptions.

Variable	Estimate	SE	Wald's
GENDER	-0.065	0.309	-
EDUCATION	0.289	0.471	-
AGE- Young	0.009	0.36	0.058
AGE- Middle	1.078	0.508	0.058
OCCUPATION- Other	0.437	0.663	0.75
OCCUPATION- Outdoor	0.64	0.883	0.75
VISIT- Infrequent	-0.919	0.519	0.11
VISIT- Occasion	-0.403	0.514	0.11
ACTIVITY- Recreation	-0.494	0.557	0.55
ACTIVITY- Work	0.243	1.147	0.55
Intercept	2.778		

* $p < 0.05$

** $p < 0.01$

***$p < 0.001$

[#] If Wald's test $p < 0.05$, Bonferroni adjustment applied to logistic regression where $p < 0.02$ is significant

Table 2.8: Estimated coefficients and standard errors of a model predicting respondent agreement to the statement "I am concerned about carnivores near me" (n = 973) from surveys distributed through Missouri, Arkansas, and Kentucky, USA (Oct. 2016-Oct. 2017). The resulting p-value of a Wald's test is applied for variables analyzed with three categories ($p < 0.05$ is significant). All three categories are examined if $p < 0.05$. Consult Methods for variable descriptions.

Variable	Coeff.	SE	Wald's
GENDER	-0.341*	0.178	-
EDUCATION	-0.464	0.274	-
AGE- Young	-0.628	0.212	0.012#
AGE- Middle	-0.331	0.231	0.012#
AGE- Older	0.628**	0.212	0.012#
OCCUPATION- Other	-0.875	0.372	0.02#
OCCUPATION- Outdoor	-1.28	0.466	0.02#
OCCUPATION- Agriculture	0.875**	0.372	0.02#
VISIT- Infrequent	0.24	0.265	0.62
VISIT- Occasion	0.225	0.247	0.62
ACTIVITY- Recreation	0.304	0.281	0.38
ACTIVITY- Work	0.607	0.478	0.38
Intercept	0.307		

* $p < 0.05$

** $p < 0.01$

***$p < 0.001$

If Wald's test $p < 0.05$, Bonferroni adjustment applied to logistic regression where $p < 0.02$ is significant

Table 2.9: Response to individual survey question "Which method of return do you most support for each species?" Columns with a percentage also contain number of respondents with parentheses.

Species	When a population has returned on their own	When a population is placed as part of an organized program	Both	Neither	Total Response
Black Bear	52.0% (505)	23.0% (224)	17.7% (172)	7.1% (69)	970
Mountain Lion	53.8% (520)	19.1% (185)	14.9% (144)	12.1% (117)	966
Coyote	54.3% (520)	15.8% (152)	14.5% (139)	15.1% (145)	956
Red Fox	50.8% (490)	25.6% (247)	18.2% (176)	5.1% (50)	963
Red Wolf	42.2% (405)	29.1% (279)	17.1% (164)	11.4% (110)	958

Table 2.10: Estimated coefficients and standard errors of a model predicting respondent agreement to red wolves on the landscape (n = 958) from surveys distributed through Missouri, Arkansas, and Kentucky, USA (Oct. 2016-Oct. 2017). The resulting p-value of a Wald's test is applied for variables analyzed with three categories ($p < 0.05$ is significant). All three categories are examined if $p < 0.05$. Consult Methods for variable descriptions

Variable	Coeff.	SE	Wald's
GENDER	-0.599*	0.285	-
EDUCATION	1.203***	0.331	-
AGE- Young	0.449	0.322	0.32
AGE- Middle	0.091	0.325	0.32
OCCUPATION- Other	1.421***	0.431	0.0043#
OCCUPATION- Outdoor	1.093	0.548	0.0043#
OCCUPATION- Agriculture	-1.421	0.431	0.0043#
VISIT- Infrequent	-1.04*	0.424	0.024#
VISIT- Occasion	-0.449	0.403	0.024#
VISIT- Frequent	0.449	0.403	0.024#
ACTIVITY- Recreation	0.783*	0.324	0.054#
ACTIVITY- Work	16.421	625.93	0.054#
Intercept	-0.088		

* $p < 0.05$

** $p < 0.01$

***$p < 0.001$

If Wald's test $p < 0.05$, Bonferroni adjustment applied to logistic regression where $p < 0.02$ is significant

Table 2.11: Response to educational outreach survey question "Which method of return do you most support for each species?" Red wolves are used as the focal species. Responses are in percentage of total people who chose that statement. Numbers in parenthesis indicate how many people chose that statement. Total response varies per survey-type.

Survey	When a population has returned to your state on their own	When a population is placed in your state as part of an organized program	Both	Neither	Total Responses
Pre-	29.9% (137)	40.0% (183)	26.0% (119)	3.9% (18)	457
Post-	23.0% (104)	45% (203)	29.9% (135)	1.9% (9)	451
One-	15.6% (8)	37.2% (19)	47.0% (24)	0% (0)	51
Three-	18.1% (6)	51.5% (17)	30.3% (10)	0% (0)	33
Five-	20% (9)	46.6% (21)	33.3% (15%)	0% (0)	45

Appendix 1. Source references for red wolf habitat suitability analysis.

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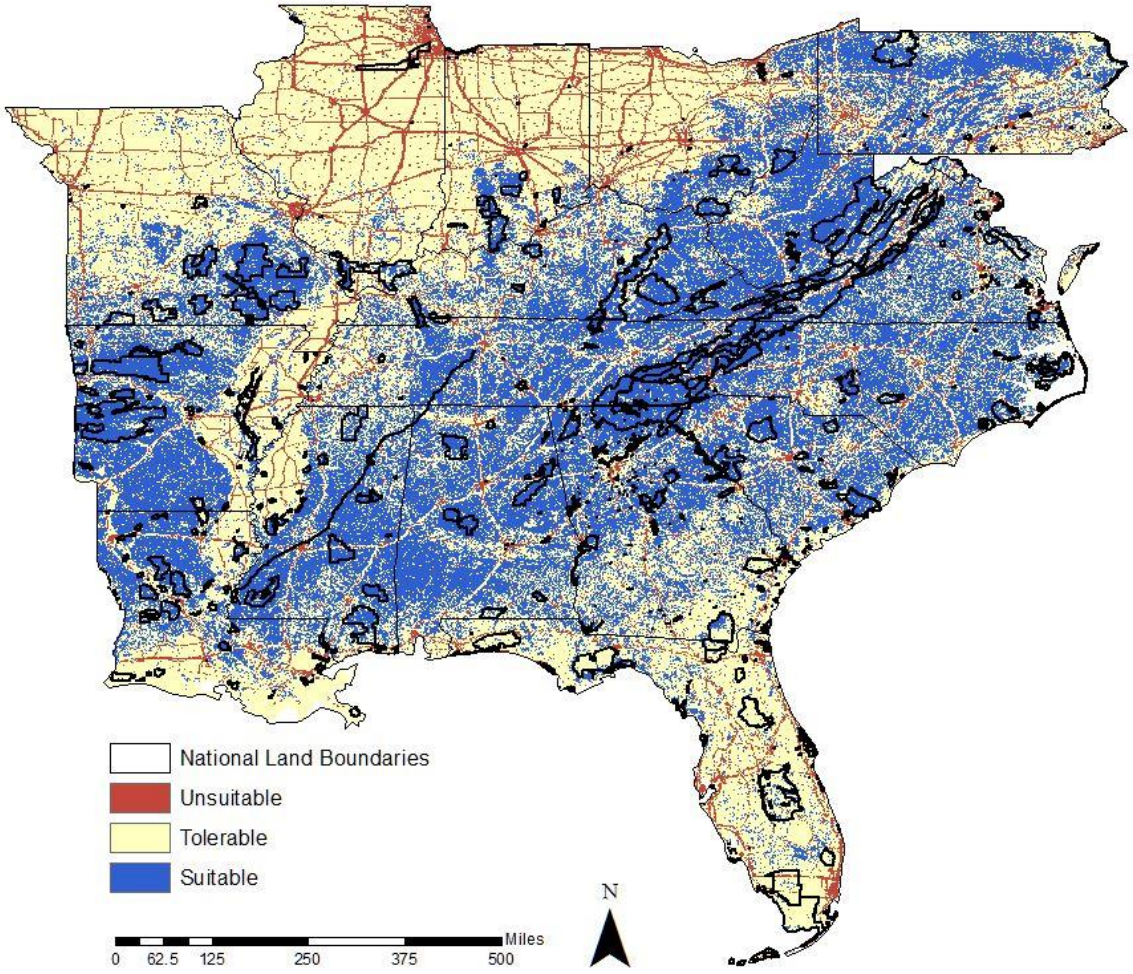
Appendix 2. Resultant maps of habitat suitability model #s1-4 and 6-10. Included is the entirety of the study area along with boundary marks that indicate the location of publicly-owned landscapes. Blue is suitable habitat, tan is moderate habitat, red is unsuitable habitat.

Model 1:



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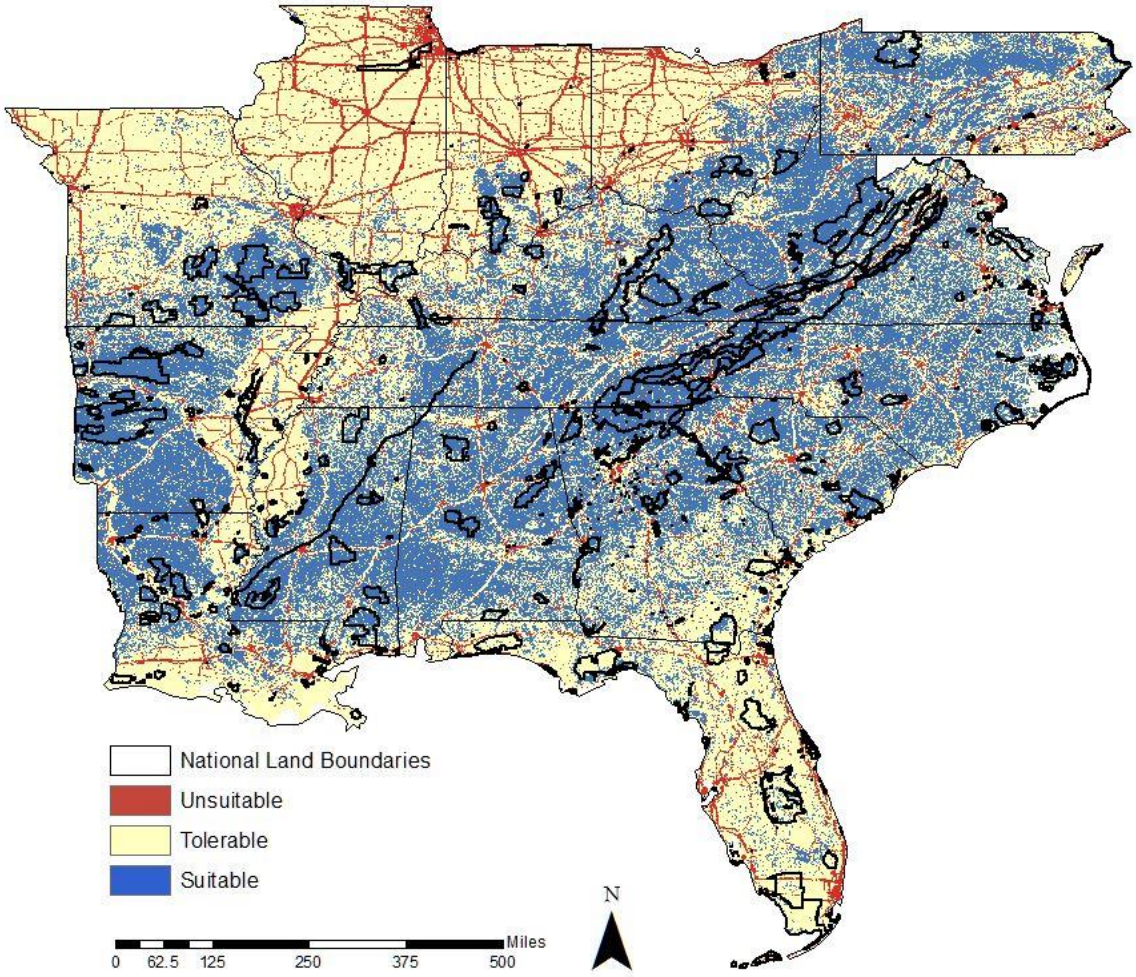
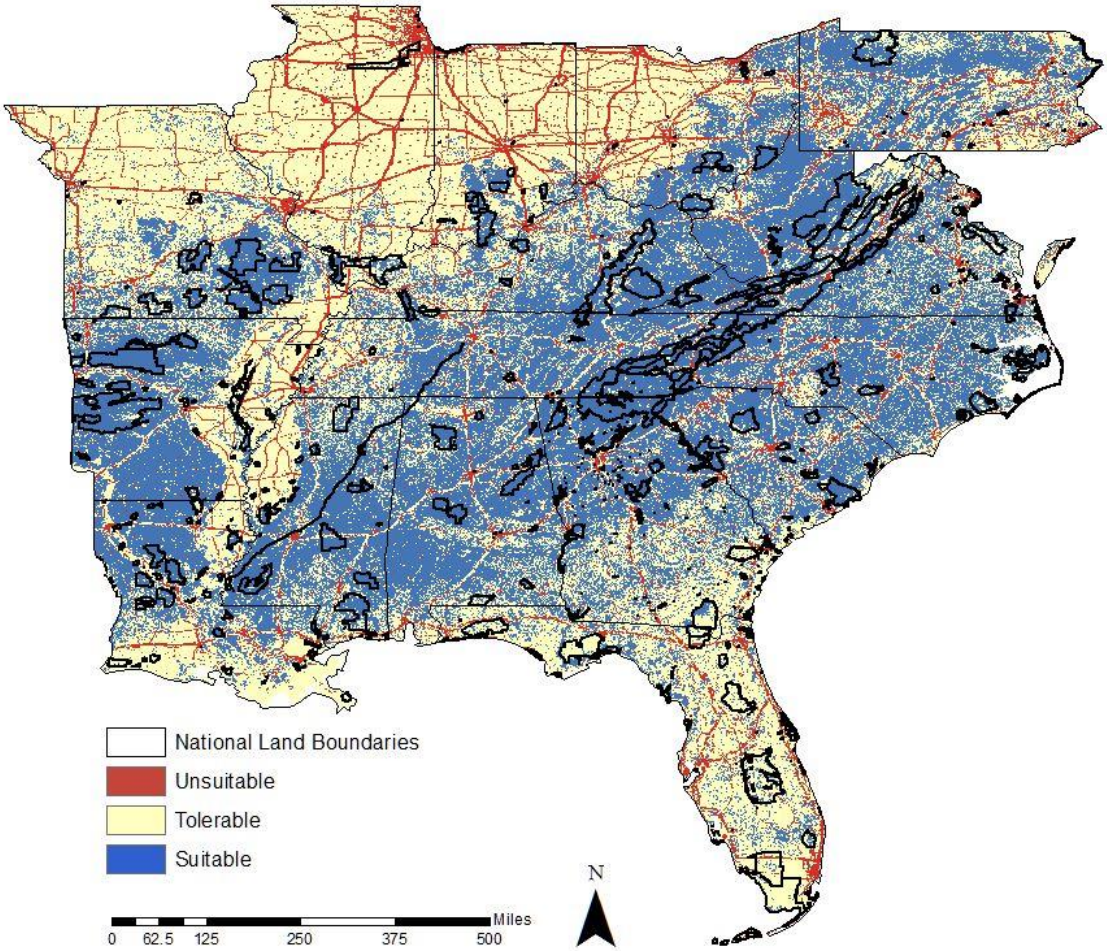

National Land Boundaries
Unsuitable
Tolerable
Suitable
N
Miles
0 62.5 125 250 375 500

Model 3: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Tolerable
Suitable
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Miles
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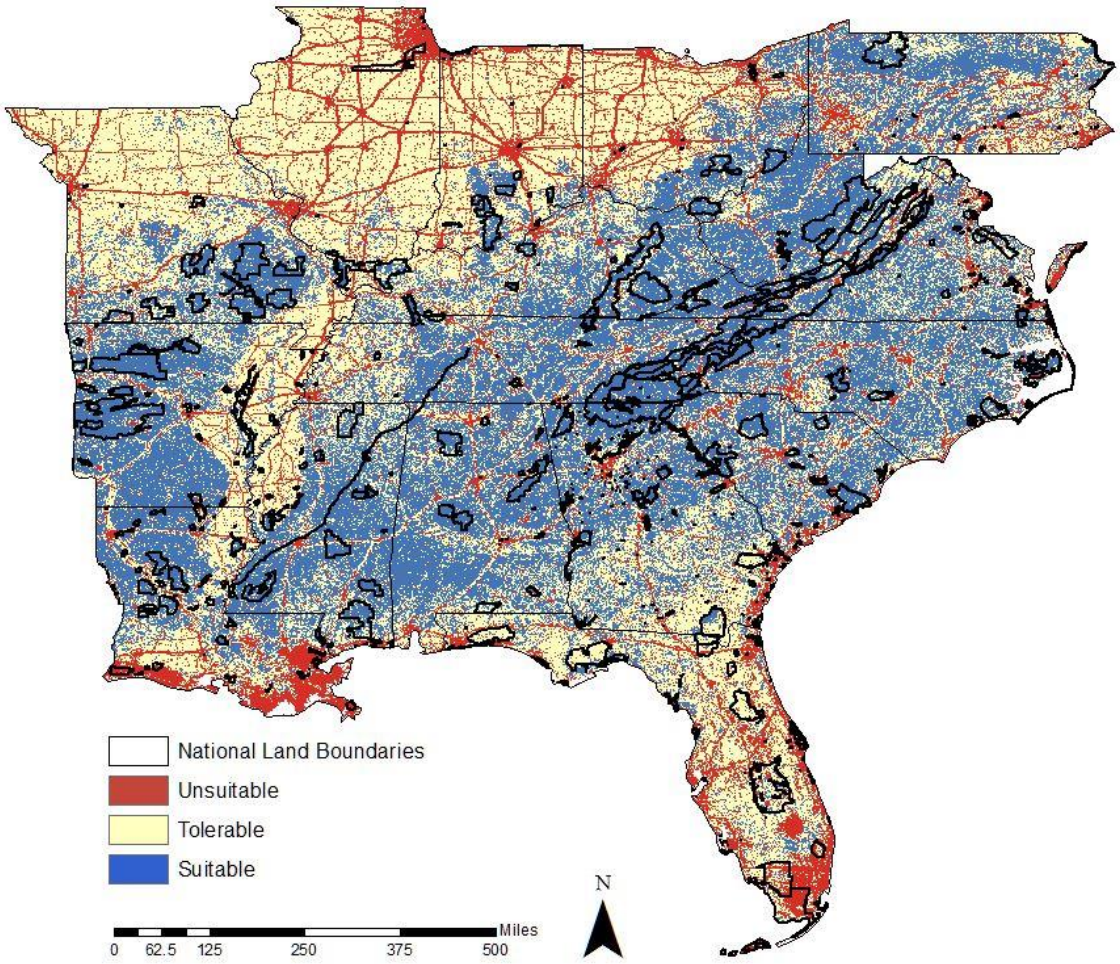
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Unsuitable
Tolerable
Suitable
N
Miles
0 62.5 125 250 375 500

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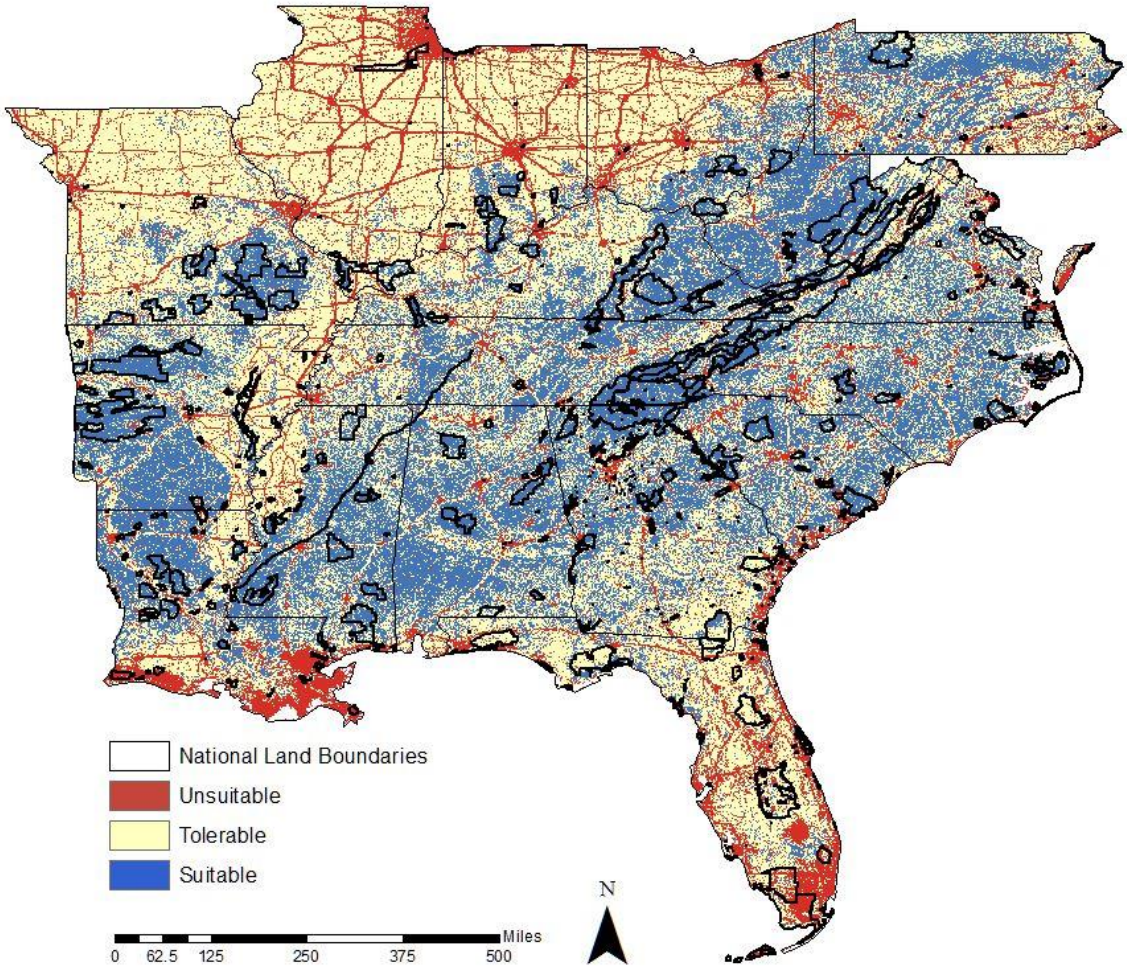
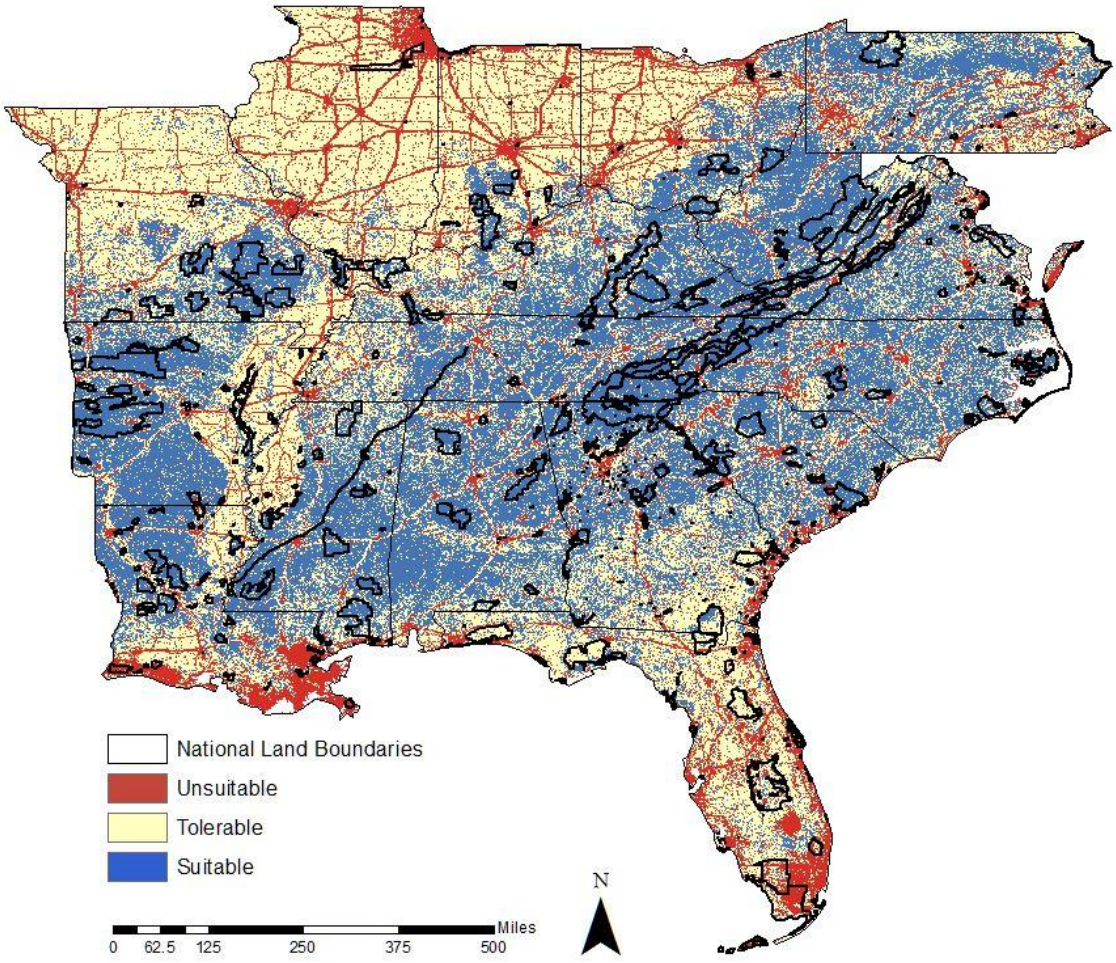
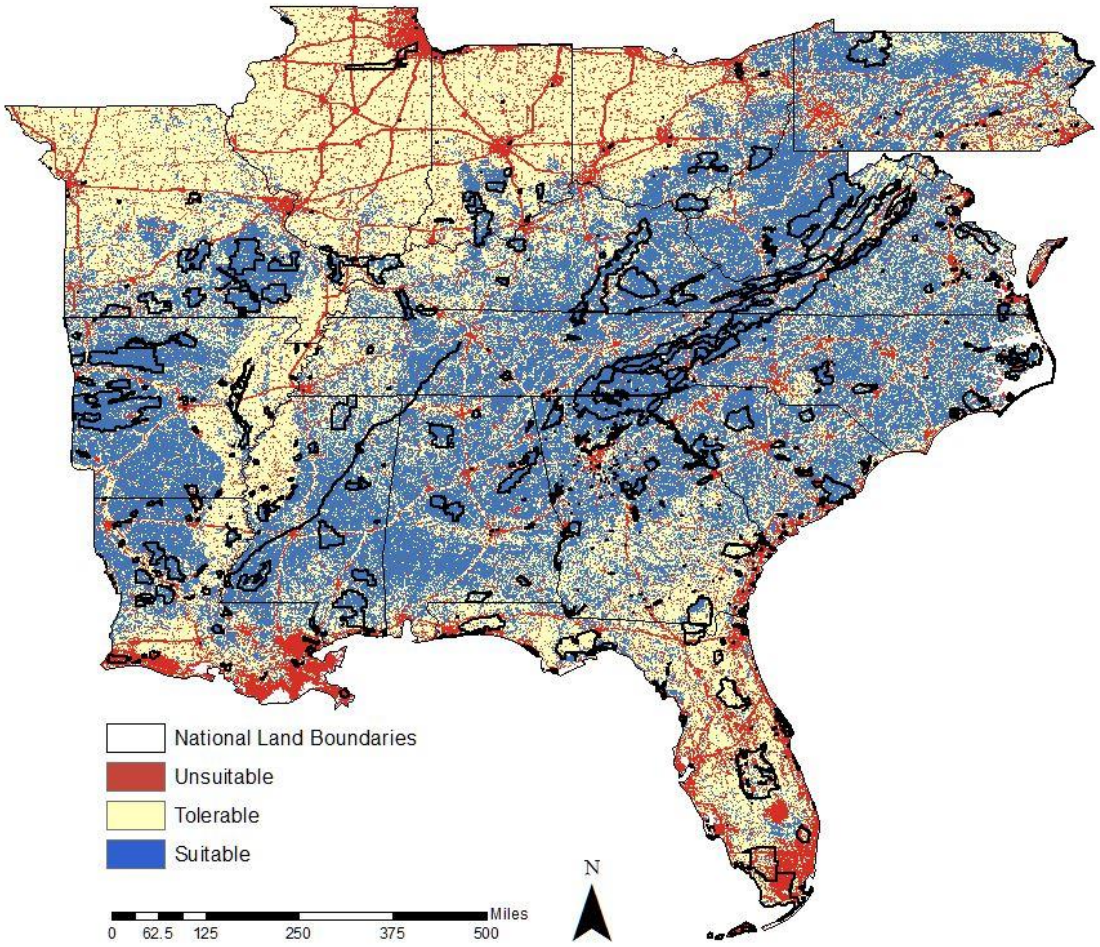

National Land Boundaries
Unsuitable
Tolerable
Suitable
N
Miles
0 62.5 125 250 375 500

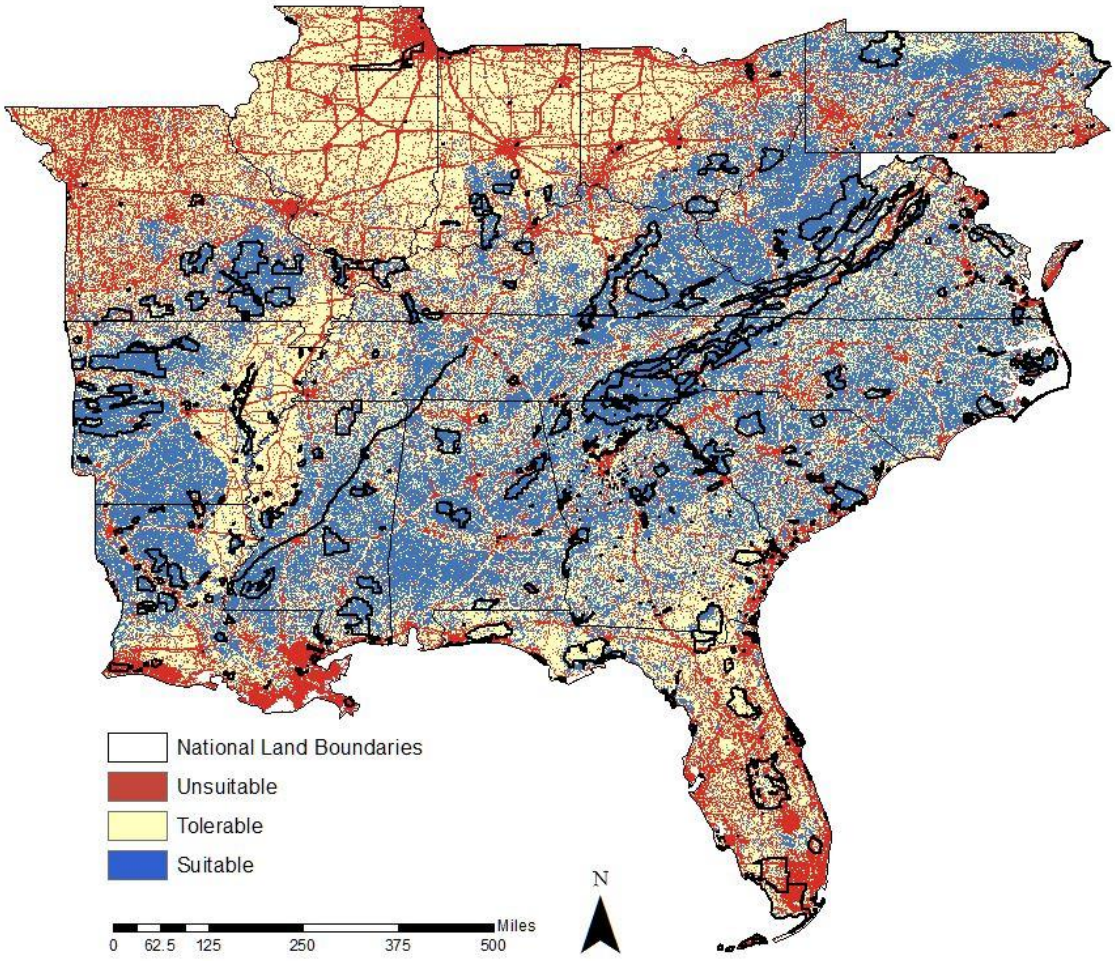
Model 8:


National Land Boundaries
Unsuitable
Tolerable
Suitable
N
Miles
0 62.5 125 250 375 500

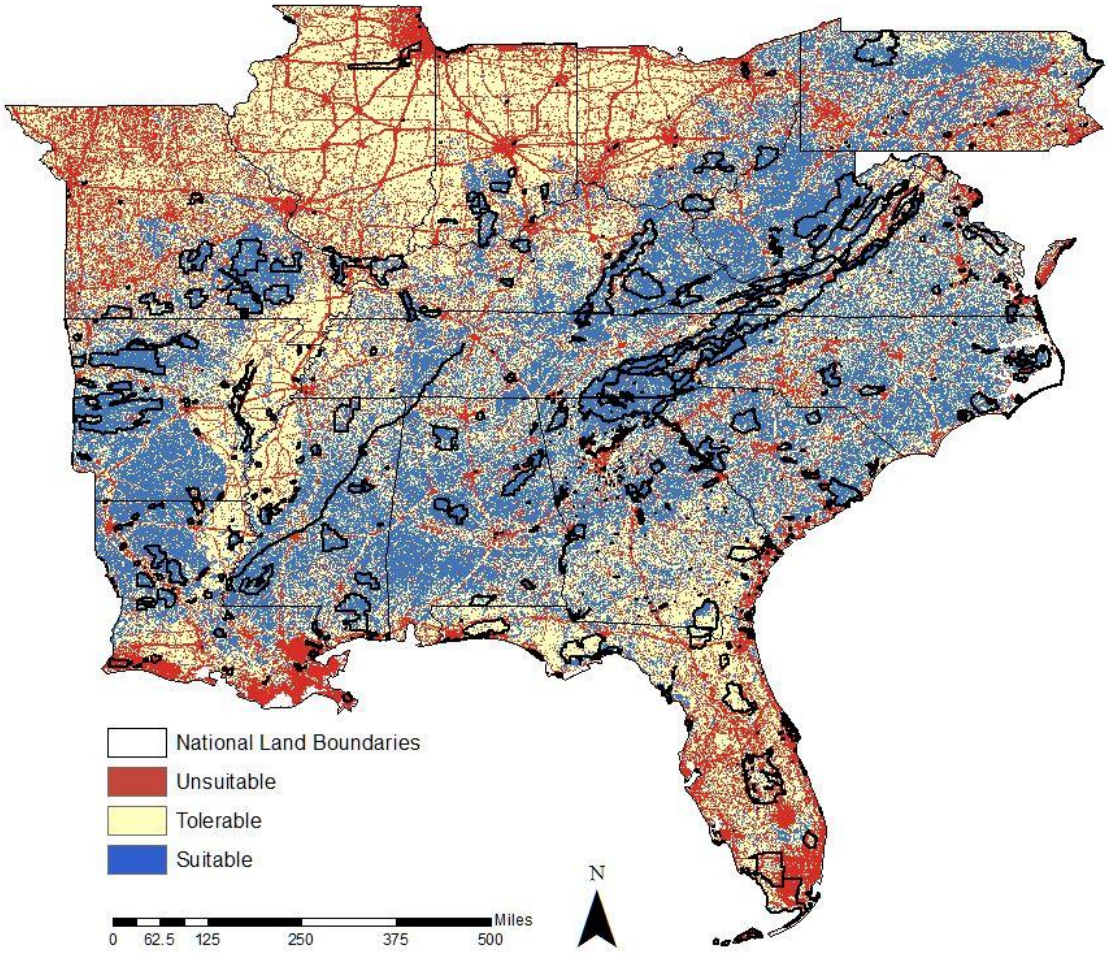
Model 9:


National Land Boundaries
Unsuitable
Tolerable
Suitable
N
Miles
0 62.5 125 250 375 500

Model 10:


National Land Boundaries
Unsuitable
Tolerable
Suitable
N
Miles
0 62.5 125 250 375 500

Model 11:


National Land Boundaries
Unsuitable
Tolerable
Suitable
N
Miles
0 62.5 125 250 375 500

Appendix 3. Questions utilized for carnivore perception individual response survey and pre-educational outreach program survey.

1.) What word(s) come to mind when you think of carnivores?

2.) Have you had any personal interaction with a carnivore? Yes No

If you answered yes, please tell us about your story.
What emotion(s) come to mind when you tell this story?

3.) The following is a list of species that used to or currently live in your state. For this survey, we are going to imagine that none of these species currently reside in your state, but have the potential to come back into your state via a method of return. Please tell which method(s) of return you would support for each species. *(Place a check under the method(s) you most support for each species, or select neither)*:

	When a population has returned to our state on their own	**When a population is placed in our state as part of an organized program**	**Neither**
Black Bear			
Coyote			
Mountain Lion			
Red Fox			
Red Wolf			

4.) Please tell us the extent to which you agree or disagree with the following statements *(Place a check in each column that best describes your choice)*:

	Strongly Agree	**Somewhat Agree**	**Neutral**	**Somewhat Disagree**	**Strongly Disagree**
Carnivores are a necessary part of the ecosystem.					
Humans and carnivores can coexist.					
I am concerned about carnivores living near me.					

If you are concerned about carnivores living near you, please share why:

In order for us to more fully understand your responses to the previous questions, we need to know a few things about your background. Remember that your responses are *completely confidential*.

5.) What town/city and state do you live in?

6.) What is your occupation?

7.) What is your gender? (*circle one*): Male Female Other

8.) What year were you born?

9.) What is your highest completed level of education? (*circle one*):

High School Some college Bachelors Masters PhD Other

10.) How often do you visit state parks, conservation areas, and/or national forests?

(*circle one*): Once a week Once a month Once a year Other

11.) What activities do you like to do in these areas?

Thank you for completing this survey. Please communicate any additional comments you may have in the space below:

Appendix 4. Questions utilized for post-educational outreach program survey.

1.) What word(s) come to mind when you think of carnivores?

2.) If you have had any personal interaction with a carnivore, do you feel differently about that interaction after this program? Yes No

3.) What are your thoughts about this program?:

4.) The following is a list of species that used to or currently live in your state. For this survey, we are going to imagine that none of these species currently reside in your state, but have the potential to come back into your state via a method of return. Please tell which method(s) of return you would support for each species. *(Place a check under the method(s) you most support for each species, or select neither)*:

	When a population has returned to our state on their own	**When a population is placed in our state as part of an organized program**	**Neither**
Black Bear			
Coyote			
Mountain Lion			
Red Fox			
Red Wolf			

5.) Please tell us the extent to which you agree or disagree with the following statements *(Place a check in each column that best describes your choice)*:

	Strongly Agree	**Somewhat Agree**	**Neutral**	**Somewhat Disagree**	**Strongly Disagree**
Carnivores are a necessary part of the ecosystem.					
Humans and carnivores can coexist.					
I am concerned about carnivores living near me.					

If you are concerned about carnivores living near you, please share why: