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Modeling cougar habitat in the Northeastern United States

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ABSTRACT

While the U.S. Fish and Wildlife Service has declared the Eastern cougar (*Puma concolor couguar*) extinct, proposing to remove the subspecies from the Endangered Species List, in the Northeastern United States there are over 2300 eyewitness reports and nearly a dozen confirmed accounts of cougars. This discrepancy between what has been documented by management agencies and what has been perceived by regional residents raises questions about the current and future presence of cougars in the region, yet little work has been done to examine the Northeast's capacity to support this species. I used spatially-explicit Habitat Suitability Indices to model cougar habitat in the six New England states and that portion of New York East of the Hudson River. I present one original model and five models in which I replicated methods originally established by other authors outside of the study region. For each model I identified contiguous habitat parcels capable of supporting viable breeding populations of cougars according to two estimates of population range size. I evaluated model results by comparing the percent forested land cover within viable habitat patches to that associated with historic cougar kills. I also assessed model agreement by generating two ensemble models – one comprised of each individual model output, and one comprised of viable contiguous habitat that was coincident across all models. I found that all individual models and one ensemble model identified viable habitat according to both population range estimates, while the second ensemble model identified viable habitat according to the liberal range estimate only. Individual models identified between 20,457 and 160,971 km^2 of top ranking habitat, enough area to theoretically support between 322 and 2535 cougars. Collectively these models provide a set of heuristic tools that shed light on a species that could influence future trophic interactions in the region. In light of my findings and the active expansion of cougar territory into the Midwest, I recommend that regional management begin to educate local residents about the nature of human–cougar interactions, and to consider preliminary management strategies for dispersing Midwestern cougars as resources allow. I recommend also that future modeling efforts integrate human input from regional biologists, and that these models be used to help evaluate cougar sighting reliability.

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1. Introduction

Prior to colonial settlement, the geographic range of mountain lions, or cougars (*Puma concolor* L.), stretched nearly coast to coast from the Yukon province in Canada to Southern Chile (Young and Goldman, 1946; Anderson, 1983; Culver et al., 2000). Today they are common across much of Western North America, but their presence in Eastern North America is limited, as it has been for nearly a century (Dearborn, 1927; Wright, 1959; Bolgiano, 1995; McCollough, 2011). Beginning with early colonial encounters, cougars were extirpated from most of the Eastern United States (Seton, 1929; Young and Goldman, 1946; Downing, 1982). In the Northeast specifically, the last confirmed accounts of cougars vary from as early as 1853 to 1865 in New Hampshire (Dearborn, 1927; Seton, 1929), to as recently as 1938 in Maine (Wright, 1948, see also Spargo, 1950; Stoner, 1950; Wright, 1953; Reilly, 1964).

Currently, cougars are considered extirpated in the Eastern United States by many regional biologists (T. French, Massachusetts Department of Fish and Game [MADFG], M. McCollough, Maine Department of Inland Fisheries and Wildlife [MDIFW], P. Rego, Connecticut Department of Energy and Environmental Protection [CTDEEP], C. Bernier, Vermont Department of Fish and Wildlife [VTFW], C. Brown, Rhode Island Department of Environmental Management [RIDEM], S. Van Arsedale, New York State Department of Environmental Conservation [NYSDEC], personal communication), yet eyewitness accounts of animals thought to be cougars have increased in number over the twentieth and twenty-first

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centuries (Wright, 1948; Doutt, 1969; Downing, 1982; Clark et al., 2002; McCollough, 2011, and unpublished files from the CTDEEP, MADFG, MDIFW, New Hampshire Fish and Game Department [NHFGD], NYSDEC, RIDEM, and VTDFW). By 1973, when the federal Endangered Species Act (ESA) was established (U.S.C., 1973), sightings of supposed cougars were so numerous that the Eastern cougar subspecies (*P. concolor couguar*) was listed as endangered (Federal, 1973). Listing occurred even though it was unclear whether or not people were actually seeing cougars, and whether or not viable populations could exist (USFWS, 2011). Many have maintained that cougars are a lost remnant of the Eastern landscape (Young and Goldman, 1946; De Vos, 1964; Downing, 1982; McBride et al., 1993; Scott, 1998; Sunquist and Sunquist, 2002; McCollough, 2011), and a recent U.S. Fish and Wildlife Service (USFWS) five-year review (McCollough, 2011) found no evidence to support assertions that the Eastern cougar still exists. The USFWS has proposed to delist *P. concolor couguar* based on extinction.

Despite this proposal, over the last 40 years there have been as many as 10,000 eyewitness reports of cougars in the East (McCollough, 2011:38), including more than 2300 eyewitness reports and 11 confirmed accounts from the Northeast in the last 20 years alone (unpublished files from MDIFW, NHFGD, VTDFW, MADFG, CTDEEP, RIDEM, and NYSDEC; The Cougar Network, 2007, see also Bolgiano et al., 2003). Cougar sighting data is largely unreliable and impossible to verify, while confirmed accounts provide tangible evidence of cougar presence – released captives, transient males, or otherwise. The Florida panther population aside, the Northeast represents the greatest source of validated cougar evidence East of Illinois (The Cougar Network, 2007), yet little effort has been put into assessing the current landscape in light of cougar ecology. This absence has put the rigorous evaluation of potential cougar habitat high on the list of recommendations for the immediate future (Laundré and Spatz, 2011).

The critical issue in conservation of cougars in New England landscapes is whether or not there are indeed locations that provide the habitat conditions needed to support viable, breeding populations. One way to assess this potential is through the use of habitat distribution modeling. Predictive habitat models are common in ecology, and have existed in various forms for decades (Guisan and Zimmermann, 2000). Modeling relies on working hypotheses about how the physical environment, trophic dynamics, and physiological nature of a species limit its spatial distribution. Here, my focus is on spatially-explicit Habitat Suitability Indices (HSIs) in the form of "predicted occurrence" models (Guisan and Zimmermann, 2000: 169), which often fall at the nexus of empirical, mechanistic, and analytical modeling strategies. They rely on ecologically-significant variables to predict the spatial distribution of a species, often sacrificing precision for generality. Though some cougar habitat models are based on probabilistic metrics derived from measured presence–absence data (i.e. Thatcher et al., 2006), many, including most of those presented here, rely on indirect measures and ecological analogy to identify locations where the species *may* live. The product of an HSI model is a relative index of habitat suitability reaching across the landscape under study, restricted by the local-level geographic extent of the measurement unit (i.e. pixel size).

While models for *P. concolor* populations and habitat have taken many forms over the years, the majority of studies are focused on Western source populations. Outside of Florida and its immediate vicinity, modeling for cougars in the East is limited. Of the spatially-explicit habitat models focused on the East and near Midwest, they follow similar conceptual approaches (see Appendix A for an Overview of Modeling Approaches and a Summary of Replicated Model Structures). Taverna et al. (1999), Moye (2007), and Anco (2011) each present HSI models with relatively straightforward structures. Taverna et al. (1999) offer a model for the Central Appalachian Mountains. Relative to other HSIs, unique features include a measure of prey density, and relatively coarse-grained analysis. Moye (2007) presents an HSI model for the Southern Cumberland Plateau that uses, among other predictors, two measures of landscape fragmentation. Her model does not include data on either human population density or prey abundance. Anco (2011) presents a basic univariate model based on forested land cover, but does not include predictor variables that generally hold across different bioregions (e.g. anthropogenic disturbance).

LaRue and Nielsen (2011, originally in LaRue, 2007) and Thatcher et al. (2003, 2006) present models with more complex structures than those noted above. The former used Analytic Hierarchy Process (Saaty, 1980) to quantify expert opinions for model parameterization in the Midwest. Their model does not include any measure of prey abundance. Thatcher et al. (2003, 2006) present a multi-pronged analysis for the Southeast based off empirical data from Florida panthers. Their landscape-scale empirical model is applicable to other regions, while their local-scale statistical model, metapopulation model, and expert assisted models are specific to their landscape-scale model results and their study region. The authors felt that given South Florida's unique ecological conditions (i.e. more feral hogs than deer), some of the important habitat predictors, such as prey density, should not be incorporated into their empirical model.

Laundré (2013) provides the only cougar habitat model for the Northeast specifically – a Population Viability Analysis (PVA) for cougars in New York's Adirondack Park. The approach is essentially a dual-component analysis looking at prey availability and forested land cover. Because of limited understanding in how cougars might use the Northeastern landscape, the use of complex models that rely on fine-scale habitat predictors was avoided (J. Laundré, SUNY Oswego, personal communication). Instead, Laundré evaluated habitat availability after removing buffered roads, buffered human settlement, and aquatic features from the landscape. In the Adirondack region, this leaves primarily forested land cover.

I sought to expand on previous modeling endeavors to understand (1) where in the Northeast cougars would potentially occur, and (2) whether there is enough habitat in the region to support a viable cougar population. My research addressed these questions by developing a series of spatially-explicit, predictive HSI models for the broader New England region.

2. Methods

2.1. Study area

I evaluated cougar habitat suitability in the six New England states, in addition to that portion of New York that lies East of the Hudson River and its longitudinal projection Northward (Fig. 1) – hereafter referred to as New England or the Northeast. This area represents a diverse bioregion with four distinct seasons and temperature extremes akin to regions further to the North and South (Alden and Cassie, 2005). The Northeast is famous for its acidic, granite-laden soils, and supports a wide-range of forest structures. Boreal forest is common in the Northern reaches, gradating to mixed hardwood and coniferous forests in the South (Kricher and Morrison, 1998). Coastal sites, major river valleys (e.g. the Hudson and Connecticut), and mountain ridges provide additional floristic variation. The elevation ranges from sea level at the coast to 1916 m at the top of Mount Washington, the highest point in region. Average annual precipitation is generally between 80 and 125 cm of rain, and 60 and 300 cm of snow (Alden and Cassie, 2005). The region supports a wide variety of fauna, of which moose (*Alces alces*) are notable in the Northern reaches, and white-tailed deer

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