PREDICTIVE MAPPING OF HABITAT SUITABILITY FOR COYOTE (*Canis latrans*) IN DELAWARE

by

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A thesis submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the Degree of Bachelor of Science in Wildlife Ecology and Conservation with Distinction

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ABSTRACT

Little is known about the abundance and distribution of *Canis latrans* (coyote) in the northeastern United States because of their relatively recent range expansion. Most states document presence but at low populations, including Delaware. In this study, I used observed habitat preference trends in previous studies throughout the northeast in order to create a predictive coyote habitat suitability map of Delaware. Important habitat matrices were identified as landcover, especially agriculture and forest edge, deer densities, biomass and proximity to roads. I then created a spatial database of corresponding spatial data to use and manipulate in ArcGIS. Using this habitat data, I created habitat suitability index (HSI) scores, based off of gamma distributions that corresponded with the habitat preference trends seen in the literature, for points in a 100 m grid across Delaware, thus creating a habitat suitability map for coyotes in Delaware. To assess the predictive capabilities of this map, I used coyote harvest and sighting reports obtained from the Delaware Division of Fish and Wildlife from 2014 until present. Of the nine coyote observation points, four were in areas of low suitability and five were in areas of medium to high suitability. While the small sample size limits my ability to test this map, it does show areas of potential high suitability for coyotes throughout the state. The presence of coyotes here can have

both positive and negative ecological effects so these high suitability areas may be helpful for land managers to direct efforts of management and public education.

Chapter 1

INTRODUCTION

Coyotes (*Canis latrans*) were historically restricted to the Great Plains of the United States, but because of their generalist nature, and human control of competitors, e.g., grey wolves (*C. lupus*) and red wolves (*C. rufus*), they have significantly expanded their range (Gompper 2002*a*). Their high adaptability to varied landscapes and the vacant niche of extirpated wolves has resulted in 16 subspecies of coyote occurring throughout North America. Populations are small in most eastern states but have been confirmed in every state of the continental U.S as well as in Canada, and Mexico (Tesky 1995). There is a plethora of scientific research on western coyote subspecies but research is lacking and occasionally contradictory in the Mid-Atlantic and Northeast regions, including Delaware (Gompper 2002*a*).

Colonization of coyotes has been reported in areas such as the Elizabeth Islands and Cape Cod, suggesting their strong swimming abilities (Gompper 2002*b*). This supports range expansion into the Delmarva Peninsula, despite it being an isolated area. The Fish and Wildlife Service estimates that coyotes have been in Delaware for 20 years and there are about 100 individuals. In 2014, a hunting and trapping season was established for coyotes throughout the state. During that season, only two individuals were reported harvested (Wilson 2015). Besides the harvested individuals, occasional road kill, and unsubstantiated sightings, little is known about the abundance and distribution of coyotes in the area.

This information is important because of the uncertainty concerning present and future coyote populations in Delaware. The newly established hunting season was intended to help provide population data, but state biologists are unsure whether the small harvest is indicative of a small population size or under reporting due to unclear harvest reporting requirements. Currently, landowners are allowed to harvest coyote year-round in the case of threatened human, livestock, or pet safety as per a Secretary's Order (Wilson 2015). A habitat suitability map can help land managers and state officials identify areas where coyote density is likely to increase and prepare specific conflict mitigation plans and control efforts. Landowner education on harvest regulations and reporting requirements can also be directed at these high suitability areas.

Targeted management provides the opportunity to enhance the benefits of coyote presence while minimizing the disadvantages. Although coyotes are non-native to the area, their natural range expansion could benefit the state by limiting the increasing deer population. This could result in increased forest understory growth, which would help songbird and small mammal populations. Because deer are tick hosts, reduced deer populations could also lower Lyme disease occurrence (Gompper 2002*b*). However, coyote are also associated with livestock loss, increased detrimental coyote-human interactions, and competition with other mesocarnivores. A management plan that limits the harvest of coyote in areas where they may be more beneficial, but has more liberal harvest in areas of high livestock concentration/human population densities could have a beneficial impact in the state.

Habitat preferences where Northeastern coyote subspecies occur may help inform potential current and future distributions in Delaware. In North Carolina, coyotes had smaller home range size as agriculture increased on the landscape, and larger home ranges in less agriculturally productive areas, meaning agricultural lands are more productive for coyotes (Elfelt 2014). In West Virginia, coyotes had a high preference for areas that had timber harvest within the past decade. These areas had more open space and early successional flora that support white-tailed deer (*Odocoileus virginianus*), a primary prey species for coyotes. Whereas, in the summer in their eastern range, coyote diets appear to be supplemented by a variety of small mammals and berries, as they become more abundant (Crimmins et al. 2012). In a study of the landscape ecology of coyotes in the Adirondacks of northern New York, there was a positive correlation between forest and higher population density. However, vegetative structures were determined better predictors and disturbed and broken canopy forests with abundant edges was most preferred. This study also highlighted lower coyote densities in areas of high human development (Kays et al. 2008).

In this paper I use observed habitat preferences to create a predictive coyote habitat suitability map for the state of Delaware. I then assess predictive capabilities using a small number of known coyote locations in the state.

STUDY AREA

I predict coyote habitat suitability throughout the state of Delaware, in the Mid-Atlantic region of the northeast United States. Delaware is divided into two physiographic regions, piedmont and coastal plain. The piedmont plateau is found at the northern tip of the state and the transition line into coastal plain occurs in New Castle, the northern most county. The piedmont is characterized by rolling hills and contains Delaware’s highest elevation point of 447 feet. The rest of the state is classified as coastal plain, which is typically flat. Forest composition is predominantly hardwood oak/hickory (*Quercus spp*., *Carya spp.*) in the north, transitioning to softwood loblolly pine/short leaf pine (*Pinus spp.*) in the south. Delaware land use consists mostly of residential and urban areas with substantial agricultural land and deciduous forest to mixed forest in the south (Aerial Information Systems 2012).

METHODS

From reviewing literature on northeastern coyote habitat, the most often mentioned descriptive metrics included: landcover, especially agriculture and forest edge, deer densities, biomass and proximity to roads (Tesky 1995, Crête et al. 2001, Gompper 2002*a*, Kays et al. 2008, Gehrt et al. 2009, Crimmins et al. 2012, Elfelt 2014, Person and Hirth 2016). For each metric I accessed the most relevant available spatial data and created a spatial database for manipulation using ArcGIS (Esri 2016). All layers were projected using the Delaware State Plane in the North American Datum 1983 (NAD83). It has also been shown that coyote home range largely depends on resource availability (Crête et al. 2001). I used two potential home range size estimates to extract data for analysis, 20 km^2 and 40 km^2, which represent gross averages for coyotes in North America (Tesky 1995, Crête et al. 2001, Gompper 2002*a*, Gehrt et al. 2009, Person and Hirth 2016).

Land Use

Land use is an important factor for wildlife presence because it affects viable habitat including food availability and cover. I used the 2012 Land Use Land Cover polygon shapefile created from aerial imagery taken by Aerial Information Systems (Aerial Information Systems 2012) to classify Delaware landcover types. I first converted the shapefile to a raster dataset with a cell size of 10x10 m using the Polygon to Rater tool. I next reclassified the 57 landcover classes into seven more basal categories: residential, urban, agricultural lands, forest, clear-cut, water, and wetlands (Table 1). I then isolated each of these reclassified landcover types into separate rasters using a conditional statement within the Raster Calculator tool. Next, I implemented a moving window neighborhood analysis using the Focal Statistics tool for each of these seven landcover rasters. This created a new raster where the output cell values are the sum of the respective landcover type cells in the circular neighborhood of 20 km^2 and 40 km^2 representing potential coyote home ranges (radii of 2.52 km and 3.57 km, respectively: Figure 1). I then divided this sum landcover cell value by the total number of cells within the 20 km^2 and 40 km^2 neighborhoods, effectively creating a percent landcover value. These rasters retained the 10x10 m cell size, with each individual cell having a value representing the percent of the landcover type within a 20 km^2 and 40 km^2 neighborhood. This process resulted in 14 final percent landcover layers, one for each of the seven landcover types, and at each the 20 km^2 and 40 km^2 neighborhood scale.

Forest Edge

I extracted forest edge data using the independent raster for forest covertype isolated from the reclassified Land Use Land Cover raster from the previous step. To define edge I first used a conditional statement within the Raster Calculator tool to calculate for each raster cell how many other cells classified as forest were adjacent. If a forest-classified cell touched zero to seven other cells of forest I categorized it as edge at levels one through eight. If eight cells of forest surrounded a forest cell I classified it as inner forest. Cells that contained no forest with zero cells of forest surrounding it had no forest categorization. Based off of these criteria, I then simplified this raster further to three different categories: no forest, forest edge, and inner forest using another conditional statement within the Raster Calculator tool. This created a final edge layer with which I again used the Focal Statistics to find the sum of forest edge cells within both the 20km^2 and 40 km^2 neighborhood.

Deer Density

Delaware Natural Resource and Environmental Commission (DNREC) provided a Delaware deer management zone polygon shapefile (Delaware Division of Fish and Wildlife 2003). Each of the polygons consisted of the amount of deer habitat, deer abundance and density pre 2005/06 hunting season, total harvest, and deer abundance and density post 2005/06 hunting season. I created a new density table to include metric measures of kilometers rather than miles and acres, and to calculate deer density per square kilometer (Table 2). Using the new table, I created a raster, again with a 10x10m cell size, with each cell having the attributes of the underlying management zone from the original shapefile. I then calculated the mean deer density within the 20 km^2 and 40 km^2 neighborhood using the Focal Statistics tool.

Biomass

Using the National Biomass and Carbon Data set (Kellndorfer et al. 2000) which contains vegetative biomass information for the nation with a 30x30 m cell size, I created a raster layer to calculate forest density. This layer was first clipped to the boundaries of Delaware then at each cell I used the Focal Statistics tool to calculate the mean value of vegetative biomass within the 20 km^2 and 40 km^2 neighborhood.

Distance from Roads

I measured Euclidean distance from a road using the Euclidean distance tool and data from the U.S Census Bureau's 2015 TIGER/Line shapefiles (U.S Census Bureau 2016), I then clipped the resultant 10x10 m raster to the boundaries of Delaware and used the Focal Statistics tool to calculate mean distance to road for both the 20 km^2 and 40 km^2 home range neighborhoods.

Data extraction

To extract data from each of the habitat layers, i.e., seven covertypes, deer density, distance to road, vegetative biomass, and forest edge rasters, I first created a grid of points, with 100 m spacing, across all of Delaware. I then used the Extract Multi-values to Point tool to assign each of these 548,881 points the attributes from each of the underlying habitat layers. Finally I exported the attribute table data into an excel spreadsheet to use in calculating a habitat suitability score.

Habitat suitability scoring

In Excel, I normalized all covariates to have a range from zero to one using the ((Value-Minimum)/(Maximum-Minimum)) formula. I then used a set of gamma-distribution curves created in R (R Core Team 2013), also normalized to have an input value range of zero-one, to assign scores for each habitat covariate, at each of the 548,881 points. I removed water and wetlands from scoring at this point because an association could not be determined from the literature. I used a gamma distribution with shape parameter $k = 1$ and scale parameter $\theta = 1$, to fit the negative association of coyotes with urban areas. I used the inverse of this distribution to fit the positive association of coyotes with of forested landcover, forest edge, recent clear-cuts, and Euclidean distance from roads (Figure 2). I used the inverse of a gamma distribution with shape parameter k = 1 and scale parameter θ = 2 to fit the positive association of coyotes with of prey availability, i.e., deer density (Figure 3). I used a gamma distribution with shape parameter k = 8 and scale parameter θ = 0.5 to fit the negative association of coyotes with canopy cover, i.e., vegetative biomass (Figure 4). Finally, I used the inverse of a gamma distribution with shape parameter k = 5 and scale parameter θ = 0.5 to fit the positive association of coyotes with agricultural land (Figure 5). For each covariate I matched the normalized value at a given point, with the normalized input value for the chosen gamma distribution. The resultant probability from that input value was then considered as the “score” for the covariate.

Finally, given that some habitat metrics seemed to be more important than others. I chose to weight certain scores. Agriculture, clear-cut, and edge were weighted by a factor of 2.0, forest and deer density were weighted by a factor of 1.5, and the remaining covariates were left as is, i.e., weighted by a factor of 1.0. These weights are estimates based upon the prevalence of correlations determined in previous studies (Tesky 1995, Crête et al. 2001, Gompper 2002*a*, Kays et al. 2008, Gehrt et al. 2009, Crimmins et al. 2012, Elfelt 2014, Person and Hirth 2016). I then took the sum of all scores, accounting for weights, to provide a Habitat Suitability Index (HSI) score for each the 20 km^2 and 40 km^2 home range scales at all 548,881 points spaced in a 100-meter in a grid across Delaware. I then created a point shapefile using the Create Feature Class tool to input the scores into ArcGIS, followed by the Points to Raster tool to create two, raster based, coyote Habitat Suitability Index maps of Delaware (Figure 7).

Assessing Accuracy

To assess the accuracy of my predictive map, I compiled coyote harvest information from the 2014/15 hunting season and sighting data from DNREC, to see if there is a relationship between where the map predicts high suitability and where coyotes have been located. Of the 11 reports, nine were specific enough to create exact or closely estimated points in Google Earth (Table 3). I then converted the GPS coordinates to decimal degrees and exported them into ArcGIS (Figure 8). Using ArcGIS, I identified the 100-meter grid point in closest proximity to each known coyote location and then extracted the raw percentage landcover data, weighted scores, and HSI scores for analysis. For each of these grid points, now considered coyote observation points, I calculated the number of standard deviations it differed from the average for each habitat scoring component to elucidate the cause for outliers.

RESULTS

Northern Delaware (New Castle County) contains two cities, Newark and Wilmington, and thus high residential and urbanization land use. This created an area of lower predicted suitability. This trend was followed south along Route 1 to Delaware's capital of Dover. In the southern portion of the state where agriculture and forestland cover types have higher proportions, patches of higher probability occurred more often. These areas typically had the highest deer densities per km^2 as well.

When comparing our predictive map to coyote observations we found four of the nine points, the northern most points in Delaware, to be in areas of lower predicted habitat suitability. For these points, biomass, residential, and urban lands did not show the expected relationship. They deviated negatively between 1-2σ from the average values. Additionally, the four points deviated positively by 1.2σ for deer density (Figure 9). The other five points did not deviate from our predicted habitat suitability.

DISCUSSION

My predictive map suggests that there are several large, contiguous blocks of potential high-quality habitat for coyotes in Delaware. This is especially true of the southwest part of the state where agriculture is prevalent over urbanization land-use, as well in and around protected lands such as Bombay Hook and Prime Hook National Wildlife Refuges on the east shore and White Clay Creek State Park in the northwest. The higher HSI scores of southern Sussex County can be attributed to the higher deer density per km^2 and large amounts of agriculture proximal to forest edge habitat, which make for productive areas for coyotes to hunt prey (Tesky 1995).

My ability to test the accuracy of the map is limited given the small sample size of known locations. However, it is promising that most points were found in areas of moderate to high-predicted suitability. High levels of biomass, residential, and urban lands likely drove the low HSI scores of areas in northern New Castle County. These habitat metrics were predicted as negatively correlated with coyote presence, but the presence of four coyote observations suggests they may be of less impact than expected based on the literature. Additionally, New Castle County has high deer density values, which could be a possible driver for coyote presence in this area despite the lack of productive agricultural lands.

This is the first effort to create a map of coyote habitat suitability in Delaware. Until more data is available about coyote populations in the state, predictive mapping exercises based on environmental factors are the best available tool to prepare for continued colonization. Coyotes are generalists native to North America and their range expansion into the northeast means their populations will likely continue to increase. As resident coyotes become more prevalent, more information on preference can be collected, which will clarify habitat associations and allow for a more refined mapping product.

This map may be useful to land managers as they prepare for both the positive and negative effects of an increased coyote population in Delaware. There is the beneficial possibility that increased coyote populations could control deer populations. This would allow the forest understory to regrow, restoring balance to an ecosystem that has been absent any large predators, and resulting in benefits such as increasing survival of ground nesting bird species. Conversely, increased coyote abundance would likely be a cause of concern for public land users, private landowners, and farmers with livestock, as increased coyote populations means increased negative coyote-human interactions. Additionally, regardless of whether or not coyotes could limit the deer population, recreational sportsmen may see them as competition for their game species. The Delaware Department of Natural Resources and Environmental Control currently has information on their website about coyote identification and safety which to limit unwanted interactions, but an expanding population will require more active management.

I recommend that research continue with updated probability scores as more information becomes available, this will allow the predictive map to be refined over time, providing a spatial resource to use in reducing the instances of negative interactions. Some enhancements could include more recent landcover and harvest data, as well as a larger sample size.

REFERENCES

Aerial Information Systems. 2012. 2012 Land Use Land Cover. FirstMap@De.

Crête, M., J.-P. Ouellet, J.-P. Tremblay, and R. Arsenault. 2001. Suitability of the forest landscape for coyotes in norteastern North America and its imlpications for coexistence with other carnivores. Ecoscience 8:311–319.

Crimmins, S. M., J. W. Edwards, and J. M. Houben. 2012. Coyote Habitat Use and Feeding Habits in Central West Virginia. Northeastern Naturalist 19:411–420.

Delaware Division of Fish and Wildlife. 2003. Deer Zones. Delaware Department of Natural Resources and Environmental Control.

Elfelt, M. 2014. Coyote Movement Ecology and Food Habits at Fort Bragg Military Installation.

Esri. 2016. ArcGIS Desktop, Release 10.4. Environmental Systems Research Institute, Redlands, CA. <www.esri.com>.

Gehrt, S. D., C. Anchor, and L. a. White. 2009. Home Range and Landscape Use of Coyotes in a Metropolitan Landscape: Conflict or Coexistence? Journal of Mammalogy 90:1045–1057.

Gompper, M. E. 2002*a*. The Ecology of Northeast Coyotes. Wildlife Conservation Society 17:1–47.

Gompper, M. E. 2002*b*. Top in the Carnivores Suburbs? Ecological by Colonization of North-eastern North America by Coyotes. BioScience 52:185–190.

Kays, R. W., M. E. Gompper, and J. C. Ray. 2008. Landscape Ecology of Eastern Coyotes Based on Large-Scale Estimates of Abundance. Ecological Applications 18:1014–1027.

Kellndorfer, J., W. Walker, K. Kirsch, T. Cormier, G. Fiske, J. Bishop, L. LaPoint, M. Hoppus, and J. Westfall. 2000. The National Biomass and Carbon Dataset 2000. The Woods Hole Research Center, Falmouth, MA.

Person, D., and D. Hirth. 2016. Home Range and Habitat Use of Coyotes in a Farm Region of Vermont. Journal of Wildlife Management 55:433–441.

R Core Team. 2016. R: A language and Environment for statistical computing. R Foundation for Statistical Computing, Vienne, Austria. <http://www.r-project.org/>.

Tesky, J. L. 1995. Canis latrans. Fire Effects Information Systems. <https://www.fs.fed.us/database/feis/animals/mammal/cala/all.html>. Accessed 6 May 2017.

U.S Census Bureau. 2016. TIGER/Line Roads.

Wilson, J. 2015. DNREC Division of Fish and Wildlife reports coyote harvest from hunting and trapping seasons. DNREC. <http://www.dnrec.delaware.gov/News/Pages/DNREC-Division-of-Fish-and-Wildlife-reports-coyote-harvest-from-hunting-and-trapping-seasons-.aspx>. Accessed 6 May 2017.

Tables

Table 1 Reclassification of 2012 Land Use Land Cover Codes and Categories

Land Cover Code	Category	New Category
110	Mixed Residential	Residential
111	Single Family Dwellings	Residential
112	Multifamily Dwellings	Residential
114	Mobile Home Parks	Residential
120, 121, 123, 125, 129	Commercial	Urban
130	Industrial	Urban
122, 140-145, 149, 150	Transportation/Communication/utilities	Urban
146	Marinas/docks	Urban
160, 170	Mixed urban/built-up	Urban
180	Institutional/governmental	Urban
190	Recreational	Urban
211-213, 215, 240, 290	Farms, pastures, croplands	Agriculture
230	Animal feeding operations	Agriculture
330, 310	Rangeland	Agriculture
320	Shrub/brush rangeland	Agriculture
220	Orchards/nurseries/horticulture	Agriculture
410	Deciduous forest	Forest
420	Evergreen forest	Forest
430	Mixed forest	Forest
440	Clear-cut	Clear-cut
530	Man-made reservoirs/impoundments	Water
510, 520, 540, 550, 560	Open water	Water
623, 673	Emergent wetlands	Wetlands
610, 660	Forest wetlands	Wetlands
622, 672	Scrub/shrub wetlands	Wetlands
720, 730, 770, 780	Sandy area and shoreline	Wetlands
750, 760	Extraction and transitional	Wetlands

Table 2 White-tailed Deer Populations in the 17 Deer Management Zones in Delaware Post 2005/2006 Hunting Season

Zone	Area (Km^2)	Perimeter	05/06 Harvest	Harvest Per Km^2	Abundance Post Harvest	Density Post Harvest
3	255.99	85912.17	395	1.54	1426	5.57
2	321.39	80380.46	417	1.30	1800	5.60
5	322.30	70967.80	760	2.36	2166	6.72
4	254.03	86781.51	349	1.37	1099	4.33
6	297.36	73438.49	863	2.90	541	1.82
8	383.68	65822.65	750	1.95	2114	5.51
9	350.06	95526.44	898	2.57	3128	8.94
7	255.94	148027.17	1043	4.08	2421	9.46
12	297.72	65809.20	861	2.89	1548	5.20
10	222.84	73603.32	597	2.68	835	3.75
11	327.87	82931.98	1060	3.23	2369	7.23
15	335.04	64026.40	544	1.62	2468	7.37
14	214.19	61141.73	631	2.95	2333	10.89
13	241.85	84862.27	524	2.17	493	2.04
17	261.49	81908.81	292	1.12	400	1.53
16	300.62	73462.59	946	3.15	3932	13.08
1 B	647.39	76389.72	898	1.39	7188	11.10
1 A	647.39	88450.41	898	1.39	7188	11.10

Table 3 2014/15 Hunting Season Coyote Harvest and Recent Sightings Reported in Delaware to DNREC

Date	Type	County	Location
1/23/14	Harvest	New Castle	Private property near Hockessin
9/26/14	Harvest	Sussex	Farm on Sugar Hill Rd
11/11/14	Harvest	Sussex	Sugar Hill Rd, E Rt 1
10/12/15	Harvest	Sussex	No specifics
10/14/15	Harvest	Sussex	Waples Pond, N Rt 30
10/15/15	Harvest	Sussex	No specifics
12/14/16	Sighting	New Castle	Middle Run Valley Natural Area
12/15/16	Road kill	New Castle	Rt 52: GPS Coordinates
12/17/16	Harvest	New Castle	.5 miles from Bob Carpenter Center
"Most Recent"	Harvest	New Castle	Summit Airport
2/1/17	Sighting	Sussex	GPS Coordinates

Figures

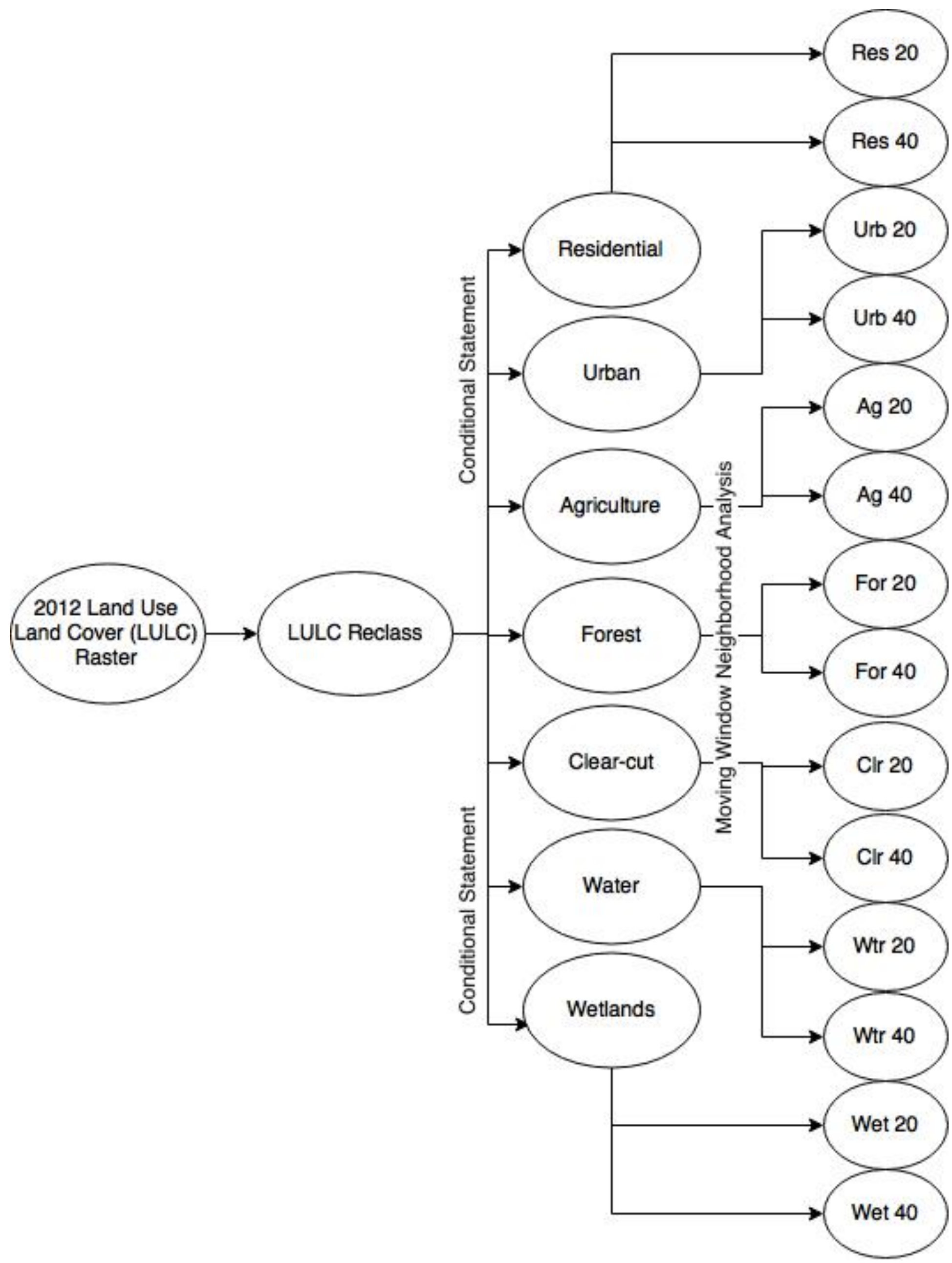


Figure 1 Model showing process from original 2012 Land Use Land Cover raster into the 14 individual layers for all seven landcover types at both 20 km^2 and 40 km^2 neighborhood measurements used in habitat suitability study for coyote in Delaware.

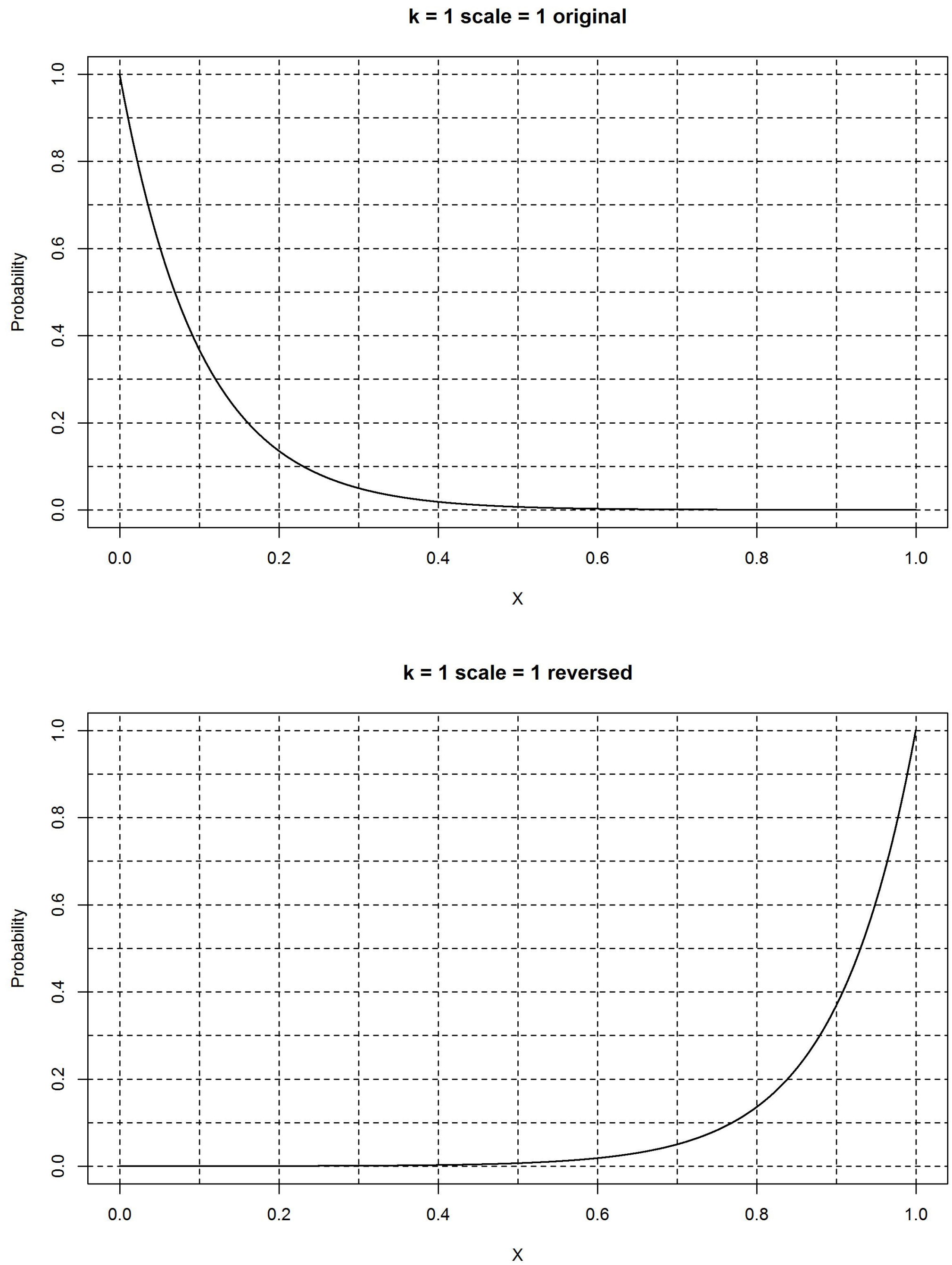


Figure 2 Gamma distribution with shape parameter k =1 and scale parameter θ = 1 used to describe the negative association of coyotes to urban areas. The inverse was used to fit the positive association of coyotes with forest, forest edge, clear-cuts, and Euclidean distance from roads in a habitat suitability study of coyotes in Delaware.

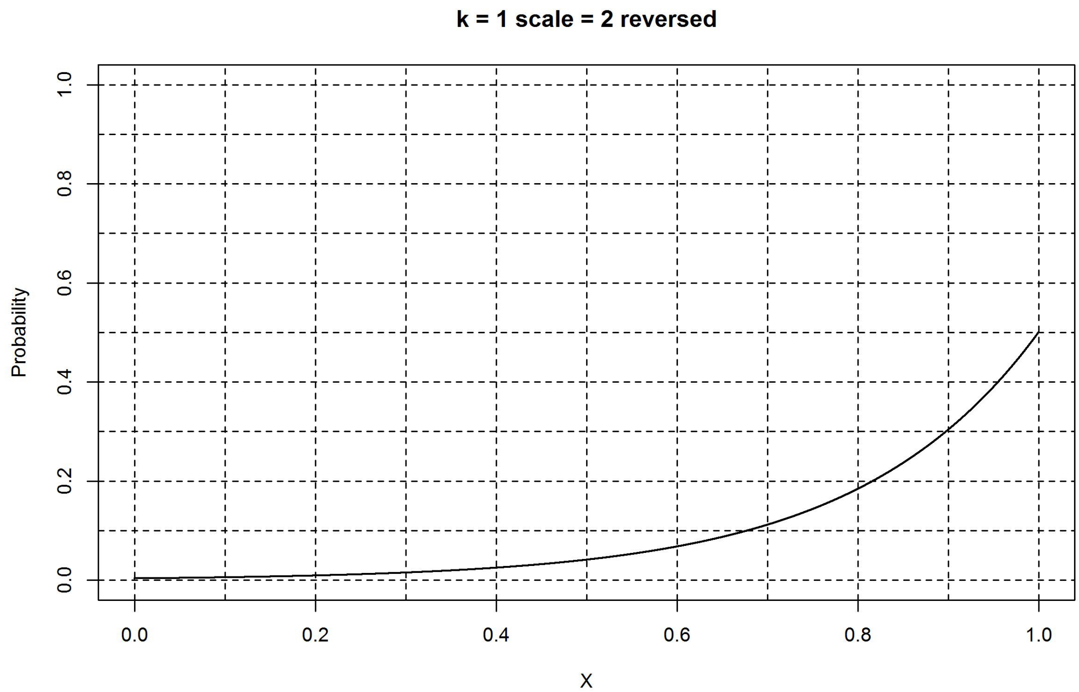


Figure 3 Inverse of the gamma distribution with shape parameter k = 1 and scale parameter θ = 2 used to fit the positive association of coyotes with prey availability (i.e deer density) in a habitat suitability study of coyotes in Delaware.

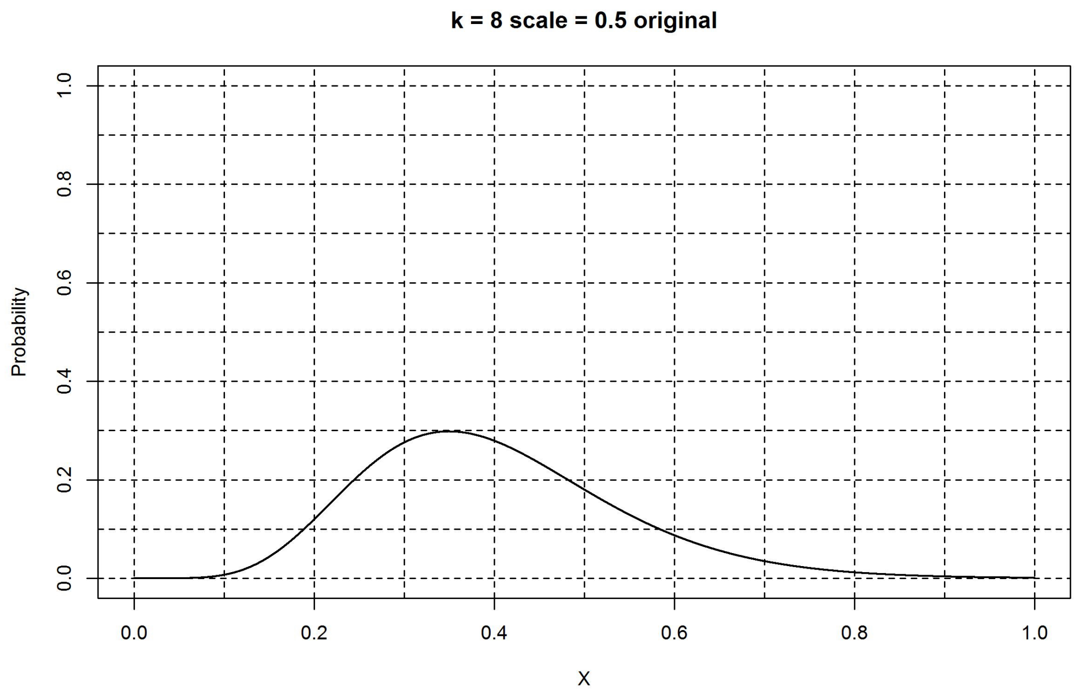


Figure 4 Gamma distribution with shape parameter k = 8 and scale parameter θ = 0.5 used to fit the negative association of coyotes with canopy cover (i.e vegetative biomass) in a habitat suitability study of coyotes in Delaware.

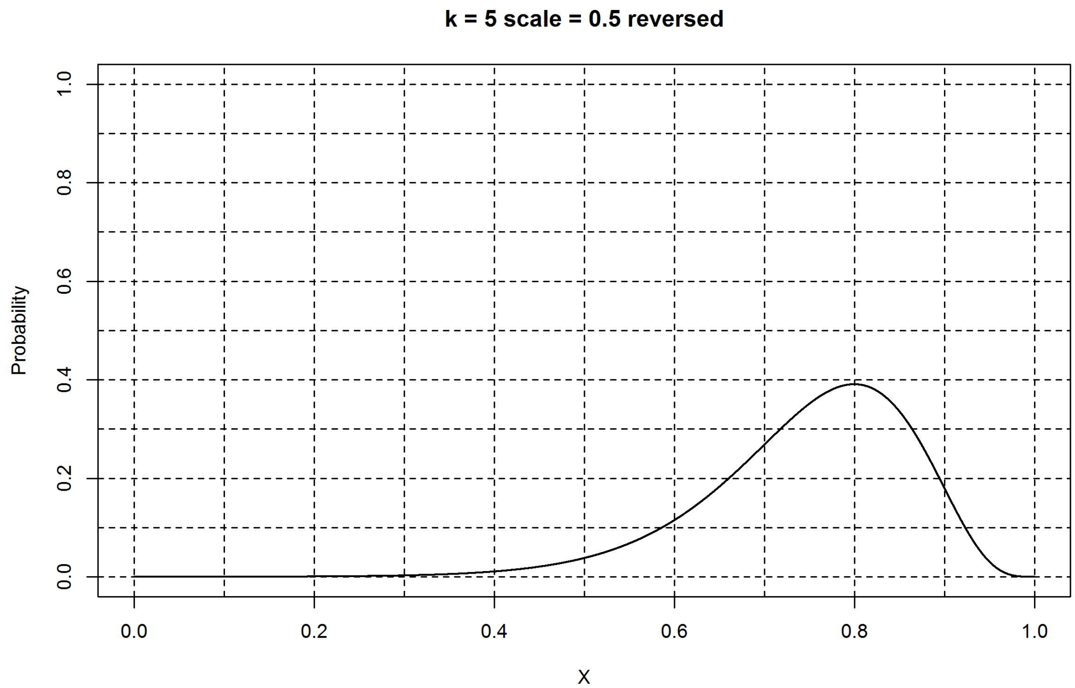


Figure 5 Inverse of the gamma distribution with shape parameter k = 5 and scale parameter θ = 0.5 used to fit the positive association of coyotes with agricultural land in a habitat suitability study of coyotes in Delaware.

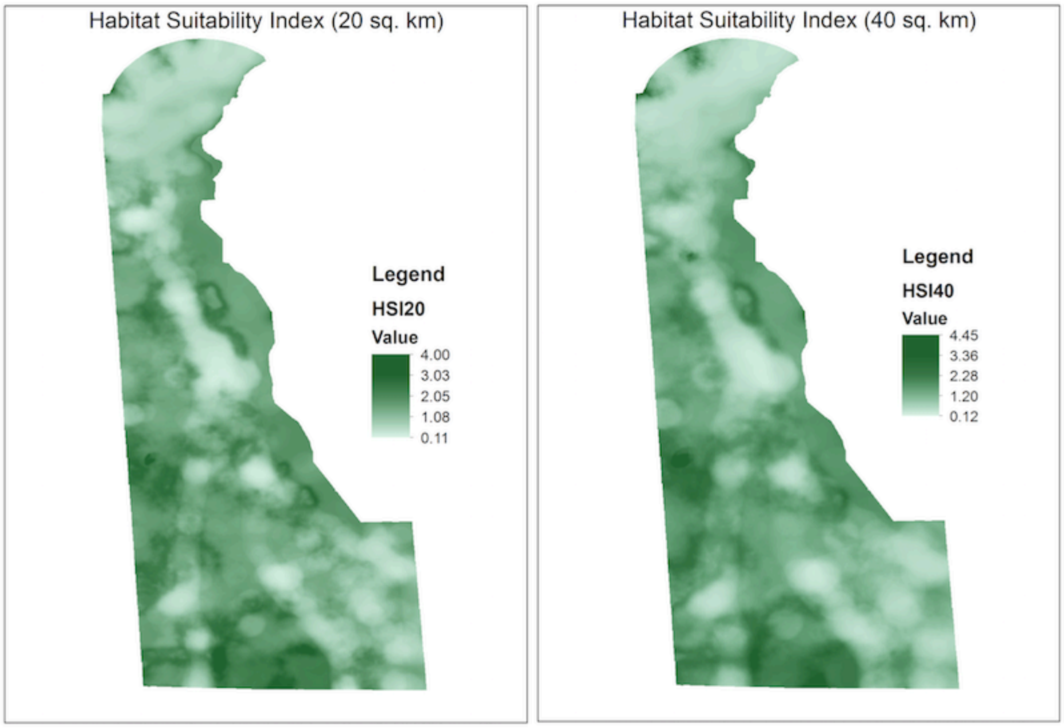


Figure 6 Map of habitat suitability for coyotes in Delaware at both 20 km^2 and 40 km^2 neighborhood measurements based on HSI scores calculated from previously observed habitat preferences and their importance.

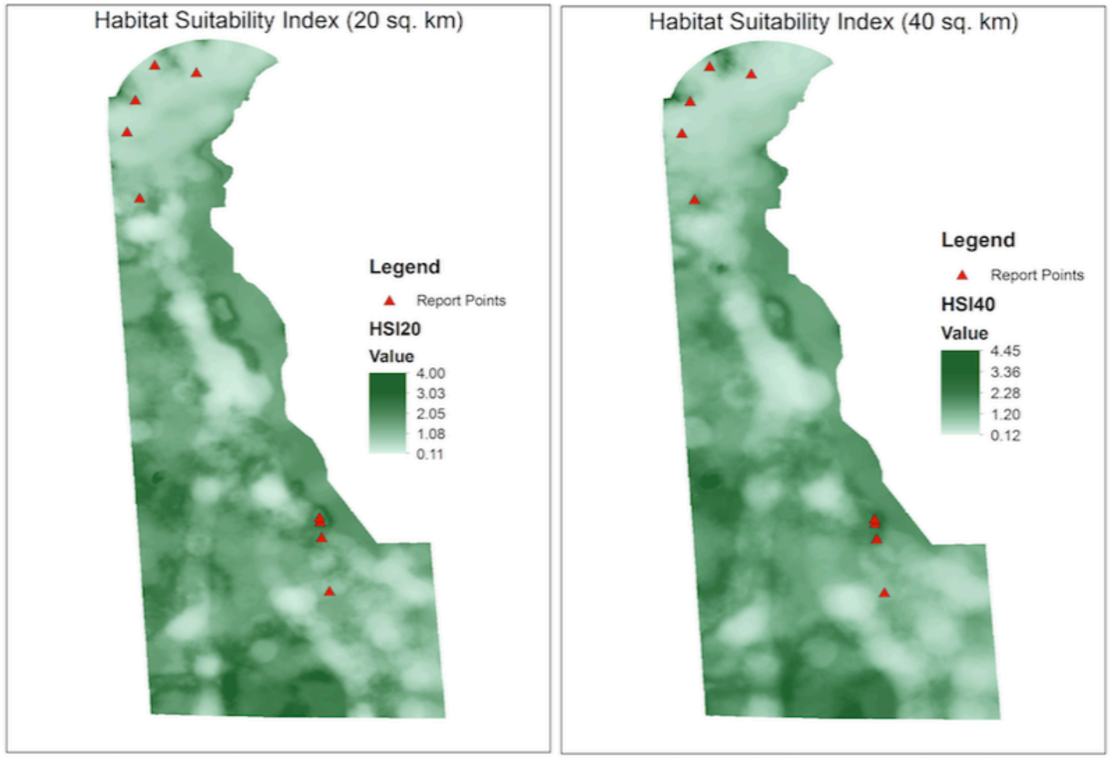
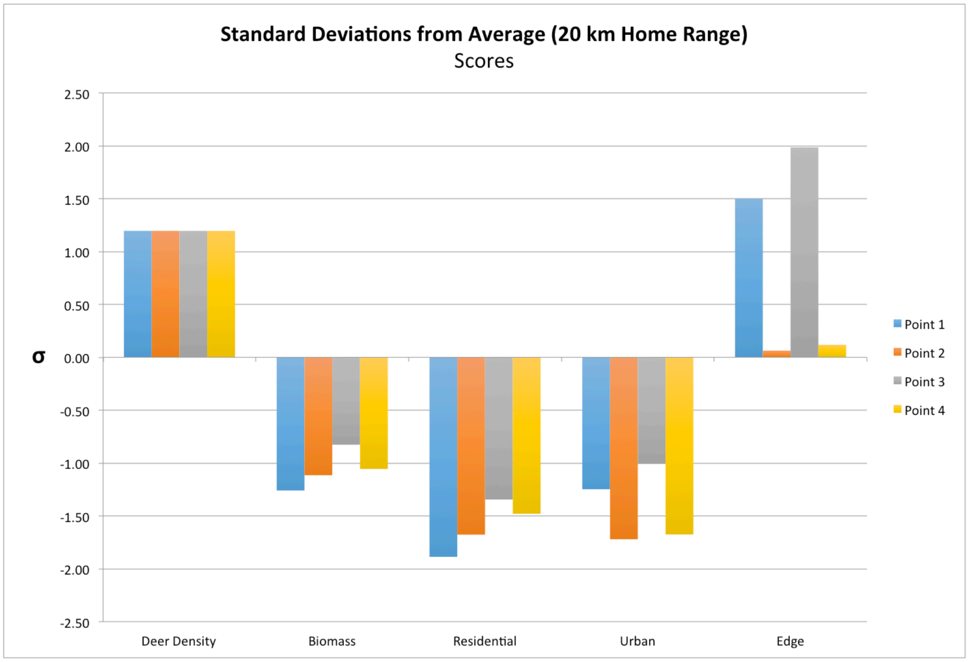


Figure 7 Report points of coyote harvest in 2014/15 hunting season, road kill, and sightings until present day obtained from Delaware Division of Fish and Wildlife in comparison to habitat suitability map for coyotes in Delaware.



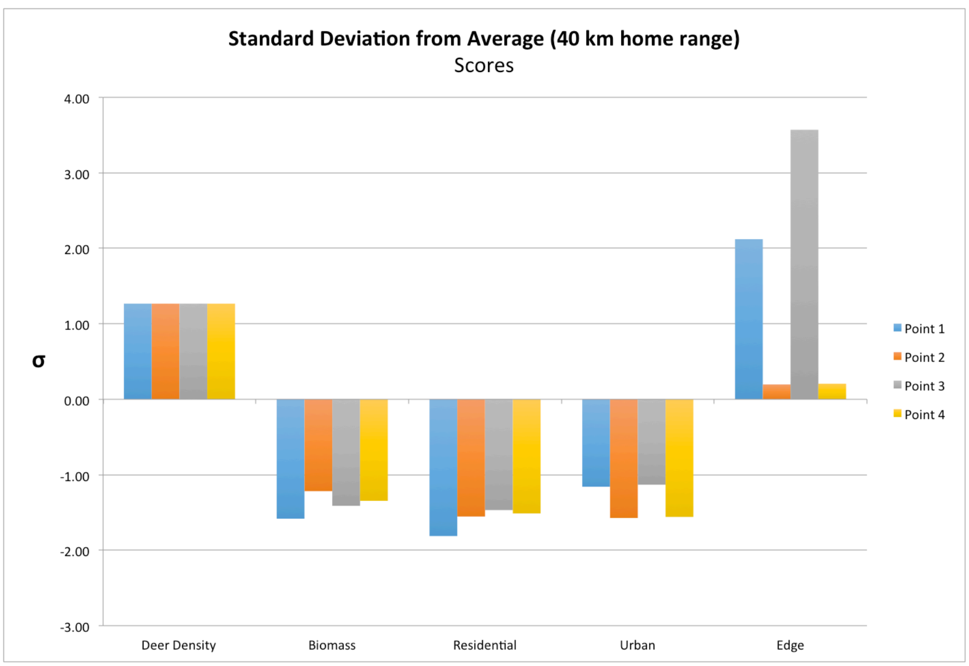


Figure 8 Standard deviations of four coyote report points found in areas of low habitat suitability for deer density, biomass, and residential, urban and edge landcover types at both 20 km^2 and 40 km^2 neighborhood measurements.