Home Range and Habitat Use of West Virginia Canis la (Coyote)

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Home Range and Habitat Use of West Virginia *Canis latrans* (Coyote)

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Abstract - *Canis latrans* (Coyote) has undergone a range expansion in the United States over the last century. As a highly opportunistic species, its home range and habitat use changes with ecological context. Coyotes were first reported in West Virginia in 1950 but were not commonly observed until the 1990s, and there is scant information on Coyotes in the region. We used telemetry data from 8 radiocollared Coyotes in West Virginia to estimate home-range size and third-order habitat selection. Home-range areas (95% utilization distributions; UDs) varied from 5.22 to 27.79 km^2 (mean = 12.48 ± 2.61 km^2), with highly concentrated use of smaller core areas (mean 50% UD = 1.85 ± 0.34 km^2), indicated by low flatness ratios (50% isopleths/95% isopleths varied from 0.11 to 0.20). Third-order habitat selection revealed most use was proportional to availability, although there was evidence of avoidance of disturbed /developed and riparian land cover at the 95% UD scale, and selection for softwood stands at both spatial scales when available. Our results provide preliminary space-use information for West Virginia Coyotes and suggest that although Coyotes are habitat generalists, space use in the region is not uniform, but instead concentrated in disjointed areas that are used intensively.

Introduction

Home-range movements and habitat selection can provide valuable insight into the behavior of individuals in a population including required and potentially impacted resources (Powell 2012). *Canis latrans* Say (Coyote) is a medium-sized, opportunistic, omnivorous, social carnivore, which has expanded its range and now occurs across most of North America (Bekoff and Gese 2003, Gompper 2002). The dietary and social plasticity of Coyotes and their ability to adapt to a broad range of habitats and conditions across different regions has facilitated this expansion (Crimmins et al. 2012). As a result, there is difficulty in predicting population responses to management actions and potential impacts to agricultural and natural resources in recently colonized areas of the Coyote's range.

Evaluating animal home ranges, or the area an individual requires to meet daily and seasonal resource needs, is a common method for describing space use of individuals within a population (Burt 1943). Coyotes are territorial, and the availability of undefended space can be a limiting factor in population regulation (Knowlton

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and Gese 1995). Home-range size is dependent on availability and distribution of resources (Mills and Knowlton 1991, Patterson and Messier 2001), and Coyotes tend to have larger home ranges in areas where resources are sparse and spatially dispersed (Wilson and Shivik 2011). However, home-range size is also limited by the metabolic requirements of defending a territory (McNab 1963), and ideal despotic distribution predicts greater disparity in available resources will result in more intense competition among individual Coyotes for high-value territories (Andren 1990, Morin and Kelly 2017). When individuals are unable to establish and defend a territory (i.e., behave as a resident), they may become transients, occupying expansive home-range areas, or biding areas, commonly in suboptimal habitats and in the interstitial spaces between territories (Hinton et al. 2015, Kamler and Gipson 2000).

Coyotes are commonly described as habitat generalists because they can occur in most habitat types (Chamberlain et al. 2000, Litvaitis and Harrison 1989), but there may still be differences in how individuals use habitat within their home range (third-order habitat selection; Johnson 1980). Habitat selection by Coyotes is typically attributed to prey or food availability (Boisjoly et al. 2010, Mills and Knowlton 1991), and studies in the eastern US suggest Coyotes select for open habitat types which are assumed to provide improved foraging capabilities (Cherry et al. 2016, Crête et al. 2001, Hinton et al. 2015, Richer et al. 2002, Ward et al. 2018). However, habitat selection and utilization by Coyotes can be highly variable and likely context dependent (Gosselink et al. 2003, Harrison et al. 1991, Parker and Maxwell 1989, Patterson and Messier 2001). The distribution of areas and resources selected or avoided can elucidate how Coyotes use space within their territories relative to high-value resources, threats from intraspecific competition, and risk of mortality (Monsarrat et al. 2013, Patterson and Messier 2001).

Coyotes were first reported in West Virginia in 1950 (Taylor et al. 1976, Wykle 1999), and occurrences there continued to be sporadic until the 1990s (Wykle 1999). The West Virginia Division of Natural Resources reported an increase in the number of Coyote pelts sold from 1989 to 2017, but no other demographic information on Coyote populations in the state is currently available (R. Rogers, West Virginia Division of Natural Resources, Romney, WV, 2017 per comm.). Information on eastern Coyote home ranges and habitat use in the central Appalachians is also limited (Crimmins et al. 2012, Mastro 2011, Morin and Kelly 2017). We used telemetry data from 8 radio-collared Coyotes monitored across 16 counties to obtain preliminary baseline information on Coyote home-range size and third-order habitat selection in West Virginia.

Field-site Description

We captured Coyotes on the Stonewall Jackson Wildlife Management Area in Lewis County, and on private properties in Lewis, Nicholas, Pendleton, and Randolph counties in West Virginia. Radio-collared animals were monitored in Calhoun, Barbor, Fayette, Greenbrier, Harrison, Lewis, Upshur, Mercer, Monroe,

Nicholas, Pendleton, Pocahontas, Randolph, Raleigh, Summers, and Webster counties. These counties lie within the Ridge and Valley and Appalachian Plateau physiographic provinces (Fenneman 1938). The Ridge and Valley is a long parallel series of uniform ridges interspersed with wide valleys that run northeast–southwest (Fenneman 1938). The Appalachian Plateau is a large, sloping plateau which has been dissected and eroded into various systems of mountains and valleys (Fenneman 1938). Elevations in the aforementioned counties vary from 184 m to 1400 m (USGS 1999). This wide range in elevation causes prevailing weather patterns to deposit anywhere from 152 cm of precipitation to less than half this amount per year on the region (USFS 2011). These climatic differences lead to a wide variety of ecological communities; high elevations are dominated by *Picea rubens* Sarg. (Red Spruce) forest typical of northern boreal forests, while low elevations are dominated by stands of mixed northern hardwoods and dry-site *Quercus* (oak) and *Pinus strobus* L. (Eastern White Pine) (USFS 2011).

Methods

Capture and monitoring

We captured Coyotes using padded foot-hold traps (Victor #3 Softcatch, Lititz, PA). We checked traps each morning but did not set them when overnight temperatures were forecast to fall below 0° C. Upon capture, Coyotes were physically restrained with muzzles and hobbles during processing. We recorded each animal's sex, weight, body condition, and age, which we determined by tooth wear (Gier 1968). We fitted each of the first 5 Coyotes captured with a store-on-board global positioning system (GPS) collar (Lotek, Newmarket, ON, Canada). We programmed collars to acquire locations at 3- or 4-hour intervals for 23 weeks and then drop-off. We fitted all subsequent captured Coyotes with both a GPS collar and an independent lightweight secondary very high frequency (VHF) collar (Advanced Telemetry Systems, Isanti, MN). We released Coyotes at the capture site. Capture and handling methods were reviewed and approved by the US Department of Agriculture, National Wildlife Research Center's Institutional Animal Care and Use Committee (QA-1649). We monitored collars for VHF mortality signals from the ground using a hand-held receiver (Communication Specialists, Inc., Orange, CA) and a 3-element Yagi (AF Atronics, Inc., Urbana, IL) or a whip antenna (Laird Technology, Akron, OH), and from the air using a hand-held receiver and a fixed-wing aircraft fitted with a pair of 3-element Yagi antennas. We monitored the radio-collared Coyotes until the GPS collar dropped-off, a mortality event occurred, or radio contact was lost.

Home range and habitat selection

Although the total number of Coyotes was small, there was a high frequency of relocations for individual Coyotes (every ~3 hours for 2–6 months for each individual), and we were able to estimate utilization distributions using biased-random bridges (Benhamou 2011). Biased-random bridges (BRB) are a movement-based kernel estimator that considers not only the location of recorded points, but also the

time at which they were recorded. A trajectory is estimated based on the chronological order and amount of time between points. Unlike Brownian-bridges (Horne et al. 2007), the BRB method also estimates a diffusion parameter to infer likely direction of movement between points of relocation, instead of assuming unknown movement in between relocations is random.

We visually identified and removed dispersal and pre-dispersal exploratory movements to ensure estimates appropriately reflected home range and not a transition to a transient stage or multiple home ranges over time. We estimated BRB activity utilization distributions (UD) for Coyotes for the total length of time that they were radio-collared using the 'adehabitatHR' package (Calenge 2006) in R (R Core Development Team 2015). We estimated home-range size for total (95% UD isopleths) and core (50% isopleths) home range. Because we used a kernel density estimator, 50% of the UD can be equivalent to 50% of the total area (a flat kernel distribution), or the distribution can be very peaked, or consist of multiple peaks that would cover a smaller area (the more concentrated the use, the more peaked the kernel density distributions and the smaller the estimated 50% core areas relative to the total home-range area). To quantify this relationship, we calculated a UD "flatness" ratio (core-area isopleth/total-area isopleth; Monsarrat et al. 2013) to compare degree of concentrated space use within a home range where a value of 0.53 is approaching uniform space use, and smaller values represent more concentrated use. In other words, lower flatness ratio values indicate increasingly smaller patches of core home-range use over the total home-range area. Visual inspection of plotted isopleths revealed several individuals with very patchy UDs consisting of multiple disjointed polygons distributed across a larger region (diffuse multimodal kernel density distributions). To quantify this pattern, we estimated the 95% minimum convex polygon (95% MCP) to describe the total area encompassing all observations for an individual during the time they were monitored. We did not use this metric as an estimate of home range, but as a way to compare the total area covered by an individual in the process of moving between all parts of its home range.

We used land-cover types from the National Land Cover Database GAP analysis (USGS 2017) as a proxy for habitat, collapsing them into 8 general categories (Appendix A) to estimate third-order habitat selection. To estimate habitat selection ratios (Manly et al. 2002) at the third-order of selection, we masked the land-cover types with the 95% and 50% UD vertices to quantify available habitat for each individual's home range and estimated selection ratios (w_i; defined as use/availability) using the widesIII function in the 'adehabitatHS' package in R (Calenge 2006). We compared selection ratios for the global tracked population, where a selection ratio >1 suggests greater use of a land-cover type proportional to availability, and <1 suggests less use proportional to availability.

Results

We captured and radio-collared 11 adult Coyotes (5 males, 6 females) from October 2009 to October 2011. However, we were only able to recover and

download data from GPS-collars deployed on 8 of these animals (4 males, 4 females). The GPS-collars collected data during different intervals from October 2009 to January of 2012 (Table 1). Collars provided a total of 29 months of data (2–6 months per animal; Table 1). Percent of successful GPS location attempts varied from 46.37% to 66.52% (mean = 57.54) for individual Coyotes. Four of the GPS-collars were collected after the pre-programmed drop-off unit deployed at 23 weeks, while the other 4 were returned before the 23 weeks elapsed, when the animals were shot, snared, or trapped; radio contact was lost for 3 collars which we were unable to recover.

Home range and habitat selection

There was high individual variability in 95% UD home-range size (Table 1). Mean 95% UD home range was 12.48 ± 2.61 km^2. Mean 50% UD core home range was 1.85 ± 0.33 km^2. The difference in 95% UD compared to the extent of the area covered by individuals (represented by MCPs) indicate that while Coyotes in the study area covered large swaths of land (95% MCP = 13.85–573.89 km^2), use was relatively concentrated in smaller patches within the home range (Fig. 1). Low values of the estimated flatness ratios (0.11–0.20) further demonstrate the concentrated use of small areas within the 95% UD. Based on visual inspection, 6 Coyotes behaved as residents, appearing to maintain and defend stable territories over time, while 2 individuals displayed transient-like movements including shifting areas of use resulting in larger overall area encompassed (residents: 13.85 km^2–28.73 km^2, transients: 54.54 km^2–573.89 km^2).

The proportions of available land cover were remarkably similar at both the 95% and 50% home-range level (Table 2). Mixed stands were the predominant land-cover type within Coyote home ranges (77.6%) and were used in proportion to availability at the 95% UD scale (w_i = 1.04, 95% CI = 0.9–1.12). Selection ratios

Table 1. Home-range metrics for Coyotes with GPS collars in West Virginia, October 2009–December 2011. Utilization distributions were estimated using biased-random bridges. Mean 95% utilization distribution (UD) was 12.48 km^2 (± 2.61 SE) and mean 50% UD was 1.85 km^2 (± 0.34). The UD "flatness" ratio (50% isopleth/95% isopleth; Monserrat et al. 2013) describes the degree of concentrated use. Flatness values approaching 0.53 represent uniform use of space, whereas lower values indicate more concentrated use of core areas. The 95% minimum convex polygons are not intended as a home-range estimate, but as a proxy for the total area covered by an individual during the time they were monitored.

Coyote (sex)	Time range	Relocations	95% UD (km^2)	50% UD (km^2)	UD flatness ratio	95% MCP (km^2)
c089 (M)	October 2009–March 2010	858	16.50	1.88	0.11	28.73
c120 (M)	December 2009–January 2010	255	5.22	0.85	0.16	54.54
c139 (F)	December 2009–January 2010	274	10.38	2.00	0.19	24.93
c733 (M)	May 2010–September 2010	605	7.65	1.46	0.19	13.85
c793 (F)	May 2010–August 2010	410	16.02	3.22	0.20	22.21
c300 (M)	June 2011–September 2011	585	8.74	1.27	0.15	14.61
c797 (F)	June 2011–September 2011	488	27.79	3.28	0.12	573.89
c808 (F)	November 2011–December 2011	227	7.58	0.85	0.11	17.82

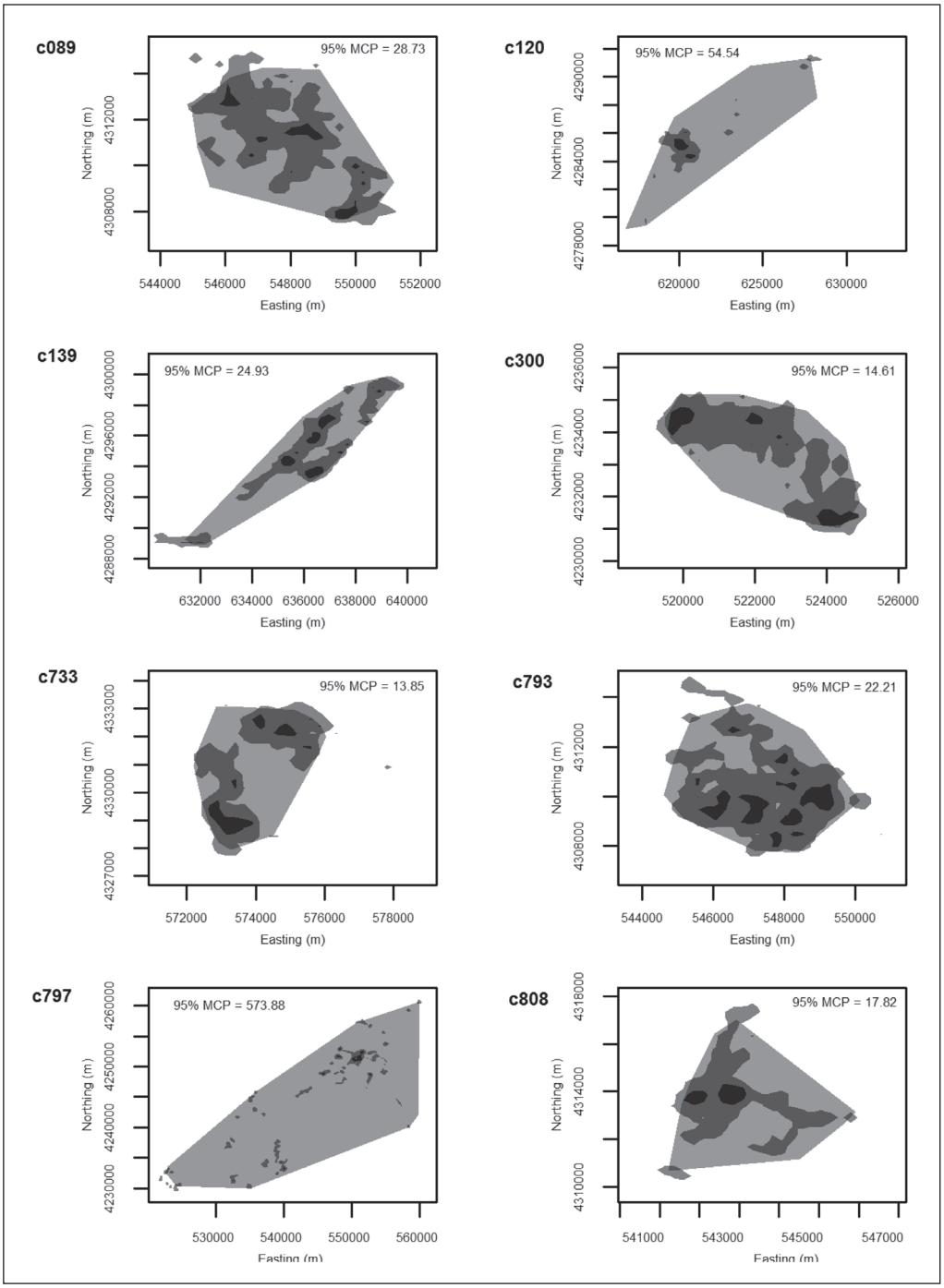

Figure 1. Plots of 50% (dark gray) and 95% (medium gray) utilization distributions for 8 Coyotes in West Virginia overlaid on 95% minimum convex polygons (MCP, light gray) showing concentrated home-range space use compared to patchy, diffuse home-range space use over much greater areas (c120 and c797). Note scale is not consistent between panels due to large differences in area.

Table 2. Proportion of available land-cover types within 50% and 95% home-range utilization distributions (UD) and third-order habitat selection ratios (w_i) for 8 Coyotes monitored in West Virginia from October 2009–December 2011, for duration of tracking.

UD area/ Metric	Pasture	Disturbed/ developed	Grass	Hardwood	Mixed stands	Riparian	Scrub	Softwood
95% UD								
Proportion of available land-cover type	0.05	0.02	<0.01	0.04	0.84	0.04	<0.01	0.01
Third-order habitat selection ratios (95% CI)	1.05 (0.49–1.61)	0.41 (0.25–0.57)	1.58 (0.00–3.42)	1.01 (0.94–1.08)	1.04 (0.97–1.11)	0.52 (0.33–0.71)	1.59 (0.00–4.76)	1.40 (1.18–1.63)
50% UD								
Proportion of available land-cover type	0.05	0.02	<0.01	0.04	0.86	0.03	<0.01	0.01
Third-order habitat selection ratios (95% CI)	1.04 (0.40–1.67)	0.47 (0.00–1.46)	1.89 (0.09–3.69)	0.80 (0.27–1.32)	1.01 (0.97–1.06)	0.74 (0.33–1.14)	1.25 (0.00–2.96)	2.16 (2.16–2.16)

showed an avoidance of disturbed/developed (w_i = 0.41, 95% CI = 0.25–0.57) and riparian (w_i = 0.52, 95% CI = 0.33–0.71), and moderate selection of softwood stands (w_i = 1.40, 95% CI = 1.18–1.63) at the 95% UD scale (Table 2). Selection ratios estimated at the 50% UD scale all overlapped 1 indicating use was proportional to availability, except for softwood stands, which were available and selected for by 1 individual at the core home-range scale (w_i = 2.16).

Discussion

We found Coyotes in West Virginia had highly variable home-range sizes, although core-area sizes were relatively consistent. This is likely due to resource dispersion influencing the home-range area of each individual (Mills and Knowlton 1991, Wilson and Shivik 2001). The flatness ratios for all individuals indicated concentrated use of disproportionally small core areas, suggesting resources were clumped and territoriality may be a limiting factor (Morin and Kelly 2017, Windberg 1995, Windberg and Knowlton 1988). While data is preliminary, the space-use patterns observed are consistent with patterns reported previously in low-density Eastern Coyote populations in rural areas (Crête et al. 2001, Morin et al. 2016, Richer et al. 2002).

Eastern Coyote home-range size can vary widely (Crête et al. 2001, Holzman et al. 1992, Person and Hirth 1991). Previous home-range estimates of eastern Coyotes have varied from 1.8 km^2 (Crossett 1990) to 122.9 km^2 (Crawford 1992) depending on region, habitat type, social structure, group size and hierarchical position, age, sex, season, and prey availability (Harrison and Gilbert 1985, Hinton et al. 2015, Parker and Maxwell 1989). The home ranges of Coyotes in the eastern United States are 100–200% larger than that of their western counterparts (Patterson and Messier 2001). However, generalizations about home range are difficult to make, not only due to the breadth of influencing factors, but also because methods of obtaining data and estimating home range differs between studies (Voigt and Berg 1987). Coyote home-range sizes are often negatively correlated with availability of resources (Hidalgo-Mihart et al. 2004, Mills and Knowlton 1991). Home-range size has repeatedly been found to decrease in areas of increasing human use and human-associated habitat, with small home ranges in urban, suburban, or agriculturally fragmented landscapes, and larger home ranges in forested landscapes (Atwood et al. 2004, Crête et al. 2001, Gehrt 2007). Overall home-range sizes of Coyotes in our study were large compared to estimates from other regions, suggesting relatively low resource availability, but were consistent with the intermediate range of reported estimates for Coyotes in rural areas (Atwood et al. 2004).

Despite relatively large home-range size and support for the effects of resource dispersion, there is some evidence to suggest competition for resources and territoriality influenced home-range use and movements in the region as it would in an established population. Six Coyotes behaved as residents, they regularly covered the entirety of their 95% MCP, and appeared to utilize the periphery of these areas more than the centers (Fig. 1). The consistently low

flatness ratios demonstrated intensive use of core areas relative to total home range, suggesting much of the land cover within maintained home range (predominantly mixed forest) was suboptimal.

Although there may be some bias in habitat selection ratios due to our fix acquisition rate (Frair et al. 2010), and additional research is needed, our findings were similar to other prior work. With the except of softwood stands, which appeared to be favored, Coyotes in our study selected for forested land-cover types proportional to availability, suggesting hardwood and mixed forests provide minimal resource value for Coyotes (Chamberlain et al. 2000, Crête et al. 2001, Crimmins et al. 2012, Morin 2015). Also similar to prior work, Coyotes avoided disturbed/developed areas at the 95% UD scale, indicating that Coyotes may be avoiding human activity at the third-order of selection (Atwood et al. 2004, Gehrt et al. 2009, Mitchell et al. 2015). Coyotes in our study avoided riparian land-cover types at the 95% UD scale similar to the findings of Hinton et al. (2015) but in contrast with those of other studies (Gosselink et al. 2003, Morin 2015, Sumner et al. 1984). We suspect that Coyotes may have avoided riparian areas in our study area because these areas represented increased association with humans (37.5% of Coyote home ranges were located in Stonewall Jackson Wildlife Management Area which includes a 1052-ha [2600-acre] lake and is adjacent to a State Park popular with outdoor recreationalists).

While we can glean much from home range and habitat use of individual Coyotes, there are still many gaps in our knowledge of the West Virginia Coyote population. We can make assumptions about territory densities and spatially limiting factors, but we do not know overall population density, which can be largely influenced by prey, social structure, and rates of mortality (Messier and Barrette 1982, Morin et al. 2016). In addition, we do not know the local population response to mortality, including capacity for compensatory immigration, that would be critical for predicting the effect of management strategies (Kierepka et al. 2017, Morin and Kelly 2017). Overall, although our study suggests Coyote space use in West Virginia adheres to previously identified trends for Coyotes across their range, there are still many questions about local dynamics that would improve our ability to make informed management decisions.

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Appendix A. Collapsed land-cover types and National Land Cover Database (NLCD) GAP habitat classifications.

Collapsed land-cover types	NLCD GAP classifications
Pasture	Cultivated Cropland
	Pasture/Hay
Disturbed/developed	Developed, High Intensity
	Developed, Low Intensity
	Developed, Medium Intensity
	Developed, Open Space
	Disturbed, Non-specific
Grass	Harvested Forest – Grass/Forb Regeneration
	Introduced Upland Vegetation – Annual Grassland
	Southern Appalachian Grass and Shrub Bald
Hardwood stands	Central and Southern Appalachian Montane Oak Forest
	North-Central Interior Wet Flatwoods
	Northeastern Interior Dry-Mesic Oak Forest
	Southern Appalachian Northern Hardwood Forest
Mixed stands	Allegheny-Cumberland Dry Oak Forest and Woodland - Hardwood
	Appalachian Hemlock-Hardwood Forest
	Central Appalachian Alkaline Glade and Woodland
	Central Appalachian Oak and Pine Forest
	Central Appalachian Pine-Oak Rocky Woodland
	Introduced Upland Vegetation - Treed
	Managed Tree Plantation
	Northeastern Interior Dry Oak Forest - Mixed Modifier
	Northeastern Interior Dry Oak Forest - Virginia/Pitch Pine Modifier
	Northeastern Interior Dry Oak Forest-Hardwood Modifier
	South-Central Interior Mesophytic Forest
	Southern and Central Appalachian Cove Forest
	Southern Ridge and Valley Dry Calcareous Forest
Riparian	Central Interior and Appalachian Floodplain Systems
	Central Interior and Appalachian Riparian Systems
	Central Interior and Appalachian Swamp Systems
	Open Water (Fresh)
	Ruderal Wetland
Scrub	Appalachian Shale Barrens
	Central Interior Calcareous Cliff and Talus
	Central Interior Highlands Calcareous Glade and Barrens
Softwood stands	Central and Southern Appalachian Spruce-Fir Forest
	Southern Appalachian Montane Pine Forest and Woodland