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Author(s): Andrew N. Tri, John W. Edwards, Michael P. Strager, J. Todd Petty, Christopher W. Ryan, Colin P. Carpenter, Mark A. Ternent, and Patrick C. Carr

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Andrew N. Tri[1,6,7], John W. Edwards[1], Michael P. Strager[1], J. Todd Petty[1], Christopher W. Ryan[2], Colin P. Carpenter[3], Mark A. Ternent[4], and Patrick C. Carr[5]

[1]*Division of Forestry and Natural Resources, West Virginia University, 322 Percival Hall, P.O. Box 6125, Morgantown, WV 26506, USA*
[2]*Wildlife Resources Section, West Virginia Division of Natural Resources, 322 Percival Hall, P.O. Box 6125, Morgantown, WV 26506, USA*
[3]*Wildlife Resources Section, West Virginia Division of Natural Resources, 2006 Robert C. Byrd Drive, Beckley, WV 25801, USA*
[4]*Bureau of Wildlife Management, Pennsylvania Game Commission, 2001 Elmerton Avenue, Harrisburg, PA 17110, USA*
[5]*New Jersey Division of Fish and Wildlife, Mail Code 501-03, P.O. Box 420, Trenton, NJ 08625-0420, USA*

Abstract: Despite a large body of literature that reports habitat use in non-urban areas, we lack a fundamental understanding of how American black bears (*Ursus americanus;* hereafter, black bear) use habitats in the urban–wildland interface in the eastern United States. This lack of information is problematic for bear managers in areas where bear populations are large and adjacent to urban areas. To better understand characteristics of urban–wildland habitat occupied by black bears, we conducted a study to understand habitat use of black bears in 7 urban areas in New Jersey, Pennsylvania, and West Virginia. We fit data from 77 individual black bears with Global Positioning System–Global System for Mobile Communications collars during 2010–2012 in Johnstown, State College, and Scranton, Pennsylvania; northwestern New Jersey; and Beckley, Charleston, and Morgantown, West Virginia. We fit resource selection functions using generalized linear mixed models in R with different combinations of study area, human impact (human density and housing density), habitat (distance to roads, patch size), land cover (deciduous forest, evergreen forest, mixed forest, shrubland, grassland, pasture, barren, open-, low-, medium-, and high-intensity development, woody wetlands, and herbaceous wetlands), topographic (elevation and slope), and other variables (year, period of day [night or day], age and sex of the individual bear). Black bears used habitat similarly among study areas and between sexes. Black bears used forested slopes and riparian corridors in the urban–wildland interface. Black bears on the urban–wildland interface selected habitats similarly to wildland bears within the body of literature. Habitat selection was similar for males and females, regardless of study area, time of day, season, or year. Our results indicate that managers can employ the same suite of management tools to reduce human–bear conflicts at the urban–wildland interface that they use to deal with black bear conflicts in wildland areas.

Key words: American black bear, habitat use, New Jersey, Pennsylvania, predictive modeling, resource selection function, suburban, urban, *Ursus americanus*, West Virginia

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Despite a large body of literature documenting bear habitat use in rural areas, a paucity of research exists on space use of urban and suburban (hereafter, urban) American black bears (*Ursus americanus;* hereafter, black bear) in the United States. Some research on urban black bears has been conducted in the western United States (Beckmann and Berger 2003, Merkle et al. 2011, Baruch-Mordo et al. 2013), but there has been a dearth of research on urban black bears in

[6]Present address: Minnesota Department of Natural Resources, 1201 East Highway 2, Grand Rapids, MN 55744, USA
[7]email: andrew.tri@state.mn.us

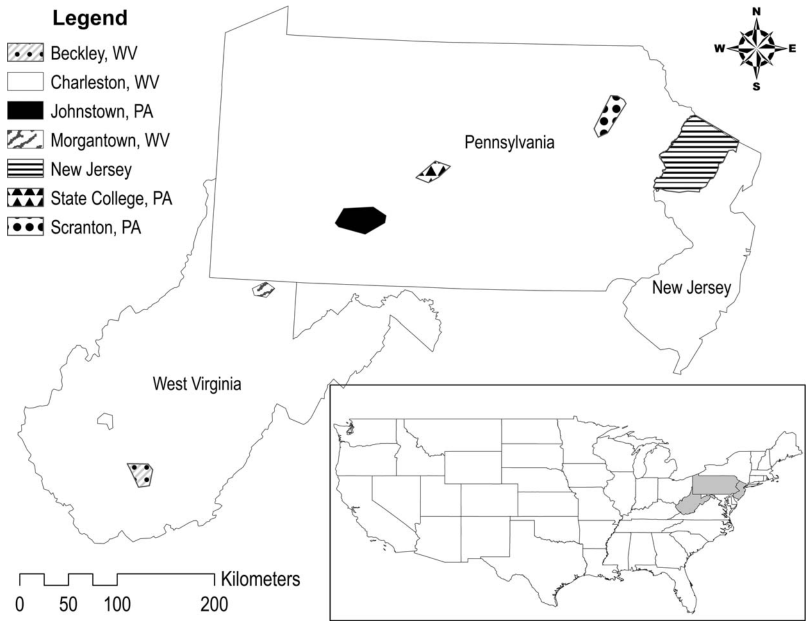

Fig. 1. Map of the study areas where we assessed American black bear (*Ursus americanus*) habitat use in the urban–wildland interface in New Jersey, Pennsylvania, and West Virginia (USA) during 2010–2012.

the eastern United States. Habitat use of rural black bears has been well-characterized (Clark et al. 1993, Costello and Sage 1994, Van Manen and Pelton 1997). Food availability (Costello and Sage 1994, Vaughan 2002, Beckmann and Berger 2003) and landscape components (i.e., topography, vegetation community structure, road density; Van Manen and Pelton 1997) influence habitat use of rural black bears. Black bears are habitat generalists, but tend to use forested slopes where resources are sufficient to meet their needs. We presume that this pattern is reflected in urban black bears, but no study has tested this empirically in the eastern United States.

Bear managers require a fundamental understanding of black bear spatial ecology in urban areas to address increased human–bear conflicts that arise from increasing bear populations. Growing bear populations have resulted in natural resource agencies expanding hunting opportunities (Poelker and Parsons 1980, Spiker and Bittner 2004, Wolgast et al. 2005, Ternent 2006, Treves et al. 2010). Some agencies have expanded hunting seasons to reduce conflicts and have had limited success (Treves et al. 2010). Certainly expanded hunting opportunities have resulted in increased harvests, but have not resulted in a direct, correlated reduction in human–bear conflicts (Ternent 2008, Obbard et al. 2014). Such limited success may be due to how little we understand about how black bears use urban habitats. Furthermore, an understanding of black bear use of urban habitat would be beneficial for non-harvest management options.

The primary objective of our study was to characterize habitat selection (the probability that a specific resource unit will be used at least once over the course of our study; Lele et al. 2013:1187) of black bears in the urban–wildland interface using resource selection functions. Black bears have been shown to be primarily diurnal and crepuscular (Lindzey and Mezlow 1977, Larivière et al. 1994, Powell et al. 1997); however, some black bears in urban areas utilize the landscape at night (Beckmann and Berger 2003, Baruch-Mordo et al. 2014). We wanted to understand how habitat selection of these bears differed among seasons, day and night periods, study areas, sexes, or years.

Study areas

We captured black bears on 7 different study areas—(1) Johnstown, Pennsylvania, (2) Scranton–Wilkes-Barre, Pennsylvania, (3) State College, Pennsylvania, (4) New Jersey, (5) Beckley, West Virginia, (6) Charleston, West Virginia, and (7) Morgantown, West Virginia—during 2010–2012 (Fig. 1). Johnstown, Pennsylvania, lies in the Appalachian mixed mesophytic forests ecoregion (World Wildlife Fund 2015, derived from Omernik 1987; https://www.worldwildlife.org/biome-categories/terrestrial-ecoregions). The State College and Scranton–Wilkes-Barre, Pennsylvania, study areas, as well as the northwestern half of the New Jersey study area, are found within Appalachian Forests ecoregion; the southeastern half of the New Jersey study area is located in the northeastern forests ecoregion (World Wildlife Fund 2015, derived from Omernik 1987; https://www.worldwildlife.org/biome-categories/terrestrial-ecoregions). All 3 West Virginia study sites were located in the Appalachian mixed mesophytic forests ecoregion. All of our study areas have relatively similar forest structure and composition. These mixed deciduous forests consist of oaks (*Quercus* spp.), hickory (*Carya* spp.), ash (*Fraxinus* spp.), tulip poplar (*Liriodendron tulipifera*), and black gum (*Nyssa sylvatica*) at low elevations. Higher elevation forests consist of yellow birch (*Betula alleghaniensis*), sugar maple (*Acer saccharum*), beech (*Fagus grandifolia*), and eastern hemlock (*Tsuga canadensis*), with dense understories of mountain laurel (*Kalmia latifolia*) and rhododendron (*Rhododendron* spp.).

Johnstown, Cambria County, Pennsylvania

This study area (N40.326790°, W78.921615°) is located in the southwestern region of Pennsylvania and is the smallest of the 3 Pennsylvania study areas. It is not situated in a mountain valley, but rather on the Allegany Plateau. It is bounded by the borough of Bolivar in the west, PA Route 30 in the south, US-220 in the east, and the Clearfield County line in the north. The area contains Johnstown and the surrounding municipalities, with public lands such as the Gallitzin State Forest and State Game Lands (SGL) 26, 42, and 79. Population density of this study area was 1,336.7 people/km^2 in 2010 (U.S. Census Bureau Fact Finder 2010; http://factfinder.census.gov).

Scranton–Wilkes-Barre, Luzerne, Lackawanna, and Wyoming counties, Pennsylvania

This study area (N41.345001°, W75.749933°) is located in the northeastern region of Pennsylvania and lies primarily within the Wyoming Valley, extending northeast from the borough of Mountain Top, north of Interstate 80, to the borough of Clark's Summit. The Scranton–Wilkes-Barre study area (hereafter, Scranton) is bounded by Ricketts Glen State Park in the west, I-80 in the south, the Wayne County line in the east, and the Susquehanna County line in the north. The urban area runs the length of the valley with public lands such as the Lackawanna State Forest and SGL 91 and 119 adjacent to the highly urbanized valley center. The study area is bisected by Interstate 81. Population density of this study area was 875.8 people/km^2 in 2010 (U.S. Census Bureau Fact Finder 2010; http://factfinder.census.gov).

State College, Centre County, Pennsylvania

This area (N40.797144°, W77.859352°) is located in the central part of Pennsylvania and primarily occurs within the Nittany Valley, extending from the borough of State College east–northeast to the community of Pleasant Gap, and includes portions of the Penns Valley between the borough of Centre Hall and community of Boalsburg. The area is bounded by PA Route 153 in the west, PA Route 305 in the south, PA Route 445 in the east, and I-80 in the north. The study area includes Moshannon and Rothrock state forests and SGL 176, 295, and 333. Population density of this study area was 3,574 people/km^2 in 2010 (U.S. Census Bureau Fact Finder 2010; http://factfinder.census.gov).

New Jersey

This study area (N41.078744°, W74.638993°) is located in the northwestern portion of New Jersey. It is bounded in the west by the state border with Pennsylvania, in the south by I-78, in the east by I-287, and in the north by the state border with New York (Fig. 1). Three municipalities were the focus of our trapping efforts (Stillwater–Branchville, Vernon Township, and West Milford, New Jersey). The urban areas are interspersed with public lands, such as Wawayanda State Park, Delaware Water Gap National Recreation Area, and Sparta Mountain Wildlife Management Area. Population density for each of the 3 major municipalities in the study areas was (1) 548.0 people/km^2 in Stillwater–Branchville, (2) 135.5 people/km^2 in Vernon Township, and (3) 132.9 people/km^2 West Milford, New Jersey in 2010 (U.S. Census Bureau Fact Finder 2010; http://factfinder.census.gov).

Beckley, West Virginia

This study area (N37.77972°, W81.18306°) includes the cities of Beckley, Mabscott, MacArthur, Sophia, Bradley, Glen Jean, Mount Hope, Pax, Eccles, Beaver, Grandview, Fairdale, and Stanaford. The study area is located in a mountain valley and is bisected by WV-16 and US 19. The study area is bounded by forested ridges and has had much commercial development over the past decade. Two major interstates (I-77 and I-64) cross the area and active coal mining is present on the study site. Population density of the area was 716.0 people/km^2 in 2010 (U.S. Census Bureau Fact Finder 2010; http://factfinder.census.gov).

Charleston, West Virginia

This study area (N37.77972°, W81.18306°) contains West Virginia's largest city and is located at the confluence of the Elk and Kanawha rivers. It contains the cities of St. Albans, Charleston, South Charleston, Kanawha City, Dupont City, and Dunbar. This study area is located 100 km to the northwest of the Beckley site. The development of the area spans 6 km north and south of the Kanawha River, which follows along I-64. Interstate 64 bisects the study area and US-119 runs through the study area from southwest to northeast. Outside the core developed area, forested ridges dominate the area. The Kanawha State Forest borders the southern boundary of the study area. Population density of the area was 629.6 people/km^2 in 2010 (U.S. Census Bureau Fact Finder 2010; http://factfinder.census.gov).

Morgantown, Monongalia County, West Virginia

This study area (N39.63361°, W79.95056°) is located in the Monongahela River valley. It contains the cities of Morgantown, Star City, Sabraton, Granville, and Westover and is wholly contained within Monongalia County. It is bounded in the south by I-68, in the west by I-79, and in the east by the Preston County Line. This area (as with all of the West Virginia study sites) is more forested and less urban than the Pennsylvania study areas. There is little agricultural production in the area. Development has increased over the past decade because of population change in the greater Morgantown area. Population density of the area was 1,126.0 people/km^2 in 2010 (U.S. Census Bureau Fact Finder 2010; http://factfinder.census.gov).

Materials and methods

Bear trapping and sample collection

Agency personnel captured black bears opportunistically within the study area in barrel-style, culvert-style, or Aldrich wrist-snare traps. Agency personnel baited and set traps on public (e.g., wildlife management areas, state forests) and private land (e.g., residences or commercial properties) within the study areas where black bears had been sighted or human–bear conflicts had occurred. Captured black bears were immobilized at the capture site with a mixture of ketamine hydrochloride (4.4 mg/kg) and xylazine hydrochloride (1.7 mg/kg) or tiletamine hydrochloride and zolazepam hydrochloride (Telazol©; Fort Dodge Animal Health, New York, New York, USA; 8 mg/kg) delivered by a syringe-mounted pole ("jab-stick") or CO_2-propelled dart. We made all attempts to release black bears near the capture site. If relocation was required to prevent injury (traffic hazards, domestic animals), the bear was relocated within a distance from the capture site approximately equal to the mean home-range diameter of black bears in the region (13 km; Alt et al. 1980). Black bears weighing >45 kg were fitted with Global Positioning System–Global System for Mobile Communications (GPS–GSM) -equipped radiotransmitting neck collars (Vectronics, Berlin, Germany; Lotek, New Market, Ontario, Canada; Northstar, King George, Virginia, USA).

The GPS–GSM collars were configured to record a location at timed intervals dependent on date. During most of the year, except for bear-hunting season (1 Sep–31 Dec), location triangulation was attempted every 3.25 hours between 0000 hours and 2359 hours, resulting in an average of 7 locations/day. During hunting season, location triangulation was attempted every 1.0 hour between 0600 hours and 1800 hours in addition to once every 3.25 hours; however, we only used points taken every 3.25 hours to reduce potential bias and maintain consistency in sampling intensity. Location data were received from GPS–GSM collars daily via cell-phone text message and maintained in a central data repository. Any bear transmitting from the same location for >1 week was investigated to assess cause-specific mortality.

Data organization and variables of interest

We censored locations from black bears that removed their collars <1 week postcapture to eliminate locations in which the bear was under possible effect of anesthesia. We also censored locations from black bears with few relocations (<500), and all locations in which the dilution of precision was >6 (D'eon and DelParte 2005). Nearly 65% of the sample black bears (66 of 102 bears) were moved outside their home range, and we censored all locations for bears that never returned (7 bears), as well as locations prior to the bear returning to its home range.

Table 1. Variables used in a predictive model of American black bear (*Ursus americanus*) habitat use in urban and suburban areas in the Mid-Atlantic Region of the United States during 2010–2012. Data sources: 2011 National Land Cover Database (NLCD), 2010 United States Census: Topologically Integrated Geographic Encoding and Referencing (TIGER), United States Geological Survey National Digital Elevation Model data set (DEM). The pixel size of all raster data was 30 m × 30 m.

Variable	Data type	Data source
Elevation (100-m units)	Continuous	National DEM data set
Slope (°)	Continuous	Derived from DEM data set
Land cover	Categorical	NLCD 2011 data set
Deciduous forest		
Evergreen forest		
Mixed deciduous forest		
Shrubland (shrub–scrub)		
Developed, open space		
Developed, low intensity		
Developed, medium intensity		
Developed, high intensity		
Barren land (rock–sand–clay)		
Grassland–herbaceous		
Pasture–hay		
Agriculture (cultivated crops)		
Woody wetlands		
Emergent herbaceous wetlands		
Distance to roads (m)	Continuous	Euclidean distance raster
Population density (people/km^2)	Continuous	U.S. Census Bureau TIGER
Housing density (houses/km^2)	Continuous	U.S. Census Bureau TIGER
Patch size (ha)	Continuous	Derived from NLCD forest layer
Period	Binary	Daytime or nighttime
Age	Binary	Juv (<3 yr old) or ad (≥3 yr)
Sex	Binary	Male or female
Study area	Categorical	City where bear lived
Year	Categorical	2010, 2011, or 2012
Season	Categorical	Spring, summer, or autumn

We also censored all locations after den entrance of each bear (mean date = 11 Dec) and before den exit (mean date = 21 Mar). Black bear habitat selection varies seasonally (Echols 2000, Lee and Vaughan 2004). We defined 3 seasons: spring (den emergence–2 Jun), summer (3 Jun–31 Aug), and autumn (1 Sep–den entry). We chose the 2 June division *sensu* Jones et al. (2015b) because the date approximates the diet shift to soft mast, as well as the mean separation date between adult females and their yearlings for the region (Lee and Vaughan 2004). We used the 1 September division *sensu* Jones et al. (2015b) to approximate the date bears shift from soft mast to hard mast as the primary food source in the Appalachian region (Powell et al. 1997).

We compiled variables that could explain habitat use by black bears (Table 1). We chose these variables based on studies of wildland black bears (Clark et al. 1993, Van Manen and Pelton 1997). We obtained land-cover data from the National Land Cover Database (Homer et al. 2015). We chose this level of resolution (30 m × 30 m) because average positional error of our GPS collars was ±14 m (Di Orio et al. 2003). We used the following cover-type categories: deciduous forest, evergreen forest, mixed deciduous forest, shrubland (scrub–shrub), barren, pasture, grassland, open space developed (<20% impervious cover, lawns, parks, golf courses, large-lot single-family housing units), low-level developed (20–49% impervious surfaces such as single-family housing), moderate-level developed (80–100% impervious surfaces such as single-family housing units), and high-level developed (80–100% impervious surfaces such as apartment complexes, row houses, commercial–industrial development), woody wetlands, emergent herbaceous wetlands, and agriculture (cultivated crops). We used ArcGIS 10.1 (ESRI, Inc., Redlands, California, USA) to calculate Euclidean distance raster layers from roads. We used U.S. Census Bureau Tiger data (U.S. Census Bureau 2015; https://www.census.gov/geo/maps-data/data/tiger.html) to estimate population and housing density for each black bear location. We calculated patch size by using the lookup tool to aggregate patches of forest and count the number of pixels per patch to arrive at patch size. To assess differences in habitat selection among daytime and nighttime, we categorized locations from dawn to dusk as daytime and points from dusk to dawn as nighttime (hereafter stated as period) using sunrise and sunset times from the U.S. Naval Observatory (http://aa.usno.navy.mil/data/docs/RS_OneDay.php). We added age, sex, period, season, and study area to the data set to determine whether habitat use differed among those parameters.

Statistical analysis

We took 2 approaches to assess habitat use by black bears in urban environments. We investigated patterns of habitat selection in the second (population) and third (home range) orders (Johnson 1980). As a result of trapping difficulties, we were unable to trap a sufficient sample of bears in Charleston, West Virginia. We eliminated data from Charleston from further analysis.

Second-order habitat selection. We generated a data set of available second-order resource units using the Geospatial Modeling Environment (Beyer 2012). We generated one random point for every bear point within the same study area to create a paired, use–availability design. We eliminated data from Charleston, West Virginia, from further analysis because of collar failure and insufficient sample size. We also censored data when a bear had <200 locations within a given season to ensure adequate seasonal habitat-use data (Seaman et al. 1999).

Third-order habitat selection. To assess habitat selection at the home-range scale, we generated seasonal home ranges for every bear. We censored all bear–season combinations when a bear had <200 locations in a given season. We used Geospatial Modeling Environment (Beyer 2012) to generate 95% fixed-kernel home ranges using a PLUGIN bandwidth (Gitzen et al. 2006). We used the PLUGIN bandwidth rather than a traditional least-squares cross-validation method because our GPS data had significant autocorrelation. Least-squares cross-validation methods often fail to converge on a bandwidth when locations are clumped or repeated fixes are in the same locations (e.g., daybeds, loafing sites, berry patches during hyperphagia); PLUGIN bandwidth estimators often converge and generate reasonable estimates when least-squares cross-validation methods fail (Girard et al. 2002, Amstrup et al. 2004, Gitzen et al. 2006). Home-range polygons generated with a PLUGIN bandwidth sometimes appear fragmented, but this was ideal for our study area, which was a matrix of urban and wildland areas. After censoring out bears with insufficient data to estimate home range size (<200 locations; Seaman et al. 1999), we used the 95% fixed-kernel home ranges to generate one paired point within a given bear's seasonal home range (available) for each (used) bear location.

Resource selection functions. We used R 3.2.2 (R Development Team 2015) to create logistic linear mixed models for our data. We did not employ parsimonious model-building procedures (e.g., AIC, BIC), but used full model designs where we could explicitly test for parameter significance (Hosmer et al. 2013). We constructed a global model with all possible 2-way interactions. We found no evidence of interactions between any variable pair, so we constructed a fully additive model: [probability of use = season + log(elevation (m)) + sqrt(slope (degrees)) + deciduous forest + evergreen forest + mixed deciduous forest + shrubland + open developed + low-intensity developed + medium-intensity developed + high-intensity developed + barren + agriculture + pasture + grassland + woody wetlands + emergent herbaceous wetlands + patch size (ha) + distance to roads (m) + log(population density (people/km^2)) + log(housing density) + study area + sex + age + period + season + (1|year) + (1|individual bear)]. In this model, (1|individual bear) and (1|year) represented variables fit as random effects. All the other variables were fit as fixed effects. The categorical reference level for (1) sex was "Female," (2) cover type was "Deciduous," and (3) study area was "State College." We tested for multicollinearity using variance inflation functions (VIF; Zuur et al. 2009). If any variable had a VIF >2, it was removed. We used a log transformation on housing density and a square-root transformation on slope to satisfy assumptions of normality. We calculated 90% confidence intervals around each regression coefficient on the log scale to determine whether habitat selection of any categorical value was different from the reference level; if the confidence interval included 0 for a categorical covariate, we determined that there was no statistical difference from the reference level.

We used backward selection from our full model using likelihood ratio tests, removing parameters one by one until likelihood ratio tests indicated that all the parameters in the model were important. We conducted a χ^2 goodness-of-fit test to determine how well the model fit the data (Agresti 2012) and used a k-fold cross-validation procedure to determine classification rates of the generalized logistic mixed models

(Boyce et al. 2002). We cross-validated 10-fold data sets 50 times to calculate a mean ± standard error classification rate.

Results

Capture and handling

We had considerable variation in sex and age ratios of our samples. We captured 120 black bears among the 3 states in the study (10 M [88% ad]:15 F [100% ad] in New Jersey, 50 M [31% ad]:26 F [56% ad] in Pennsylvania, and 18 M [66% ad]:1 F [100% ad] in West Virginia) that resulted in 163,274 locations from 2 June 2010 to 11 December 2012. Captures were skewed toward male in all study areas except New Jersey. After subsampling, we used 80,720 locations from 77 bears (7 [7 M:0 F] in Beckley, 9 [5 M:4 F] in Johnstown; 4 [3 M:1 F] in Morgantown, 16 [7 M:9 F] in New Jersey, 17 [10 M:7 F] in State College, 24 [14 M:10 F] in Scranton).

Second-order habitat selection

Human density and housing density were collinear (VIF = 3.56), so we removed human density from the full model. Our full model [probability of use = elevation + sqrt(slope) + evergreen + mixed + shrubland + open space developed + low-intensity developed + medium-intensity developed + high-intensity developed + barren + agriculture + pasture + grassland + woody wetlands + emergent herbaceous wetlands + log(housing density) + distance to roads (m) + patch size + study area + season + period + age + sex + (1|year) + (1|individual bear)] had unimportant parameters. We found no influence of study area (χ^2 = 1.893, 5 df, P = 0.863), sex (χ^2 = 0.520, 1 df, P = 0.471), season (χ^2 = 1.890, 2 df, P = 0.387), age (χ^2 = 0.890, 1 df, P = 0.346), period (χ^2 = 0.312, 1 df, P = 0.576), patch size (χ^2 = 1.711, 1 df, P = 0.191), evergreen (χ^2 = 2.160, 1 df, P = 0.142), shrubland (χ^2 = 1.146, 1 df, P = 0.284), agriculture (χ^2 = 2.019, 1 df, P = 0.155), pasture (χ^2 = 1.924, 1 df, P = 0.165), emergent herbaceous wetlands (χ^2 = 1.931, 1 df, P = 0.164), or housing density (χ^2 = 0.717, 1 df, P = 0.717). Our results suggested habitat use varied little year to year (variance = 0.002), so we dropped the parameter from the model. We used the reduced model [use = elevation (100 m) + sqrt (slope (degrees)) + mixed + open space developed + low-intensity developed + medium-intensity developed + high-intensity developed + barren + grassland + woody wetlands + distance to roads (m) + (1|individual bear)] to make further inference on this data set (Table 2). Our model fit the data well (χ^2 = 159,750.8, 161,429 df, P = 0.999) and had moderate predictive ability (mean classification rate = 70.6% ± 2.1% SE; this was 20.6% better than random).

Table 2. Beta estimates and 90% confidence limits of variables in a generalized linear mixed model of second order, American black bear (*Ursus americanus*) habitat use in urban and suburban areas in New Jersey and Pennsylvania (USA) during 2010–2012. Individual bear (variance = 0.287, SD = 0.534) was fit as a random variable. LCL and UCL = lower and upper 90% confidence limits, respectively; Reference level for cover type was "deciduous forest."

Parameter	Beta	SE	LCL	UCL
Intercept	–2.635	0.072	–2.756	–2.515
Woody wetlands	1.045	0.024	1.004	1.086
Grassland	0.545	0.056	0.451	0.639
Mixed deciduous forest	0.508	0.026	0.464	0.552
log(Distance to roads)	0.126	0.005	0.118	0.133
log(House density)	–0.185	0.017	–0.213	–0.157
Barren	–1.262	0.080	–1.395	–1.128
Moderate-intensity developed	–2.334	0.082	–2.472	–2.196
High-intensity developed	–3.306	0.201	–3.644	–2.968

There were some clear patterns of habitat selection in our results. Our results suggested that a bear is a bear on the urban–wildland interface; sex, age, and study area were all unimportant predictors of habitat use at the second-order scale. Bears primarily used forested slopes, rather than open habitats or developed areas, during all seasons and periods of day, because these parameters were unimportant predictors (Table 2). Generally, bears avoided developed areas—as development intensity increased, bear use decreased. Bears also avoided open cover types (e.g., barren, agriculture, and pasture) less than deciduous forests, but used woody wetlands and mixed forest more than deciduous forest. Bears in our study used grassland areas (Table 2). These areas are open, but can include areas of important spring and summer foods (grass, forbs, berries, and ants). Grasslands were used more than they were available, but the vast majority of bear locations consisted of forested slopes.

Third-order habitat selection

Human density and housing density were collinear (VIF = 3.56), so we removed human density from the full model. Our full model had numerous unimportant parameters at the third order of habitat selection. We dropped sex (χ^2 = 2.27, 1 df, P = 0.169), age

Table 3. Beta estimates and 90% confidence limits of variables in a generalized linear mixed model of third order, American black bear (*Ursus americanus*) habitat use in urban and suburban areas in New Jersey, Pennsylvania, and West Virginia (USA) during 2010–2012. Individual bear (variance = 0.043, SD = 0.207) was fit as a random variable. LCL and UCL = lower and upper 90% confidence limits, respectively. Reference level for cover type was "deciduous forest."

Parameter	Beta	SE	LCL	UCL
Intercept	−1.511	0.037	−1.622	−1.401
Woody wetlands	0.885	0.024	0.814	0.896
Open space developed	0.369	0.028	0.325	0.413
sqrt(Slope)	0.301	0.005	0.291	0.312
Mixed	0.222	0.028	0.213	0.231
log(House density)	−1.147	0.017	−1.191	−1.102
Grassland	−1.346	0.052	−1.479	−1.214
Moderate-intensity developed	−1.933	0.096	−2.010	−1.856
High-intensity developed	−2.709	0.219	−2.846	−2.571
Barren	−3.654	0.086	−3.993	−3.315

(χ^2 = 0.841, 1 df, P = 0.359), season (χ^2 = 3.30, 2 df, P = 0.192), period (χ^2 = 1.24, 1 df, P = 0.265), study area (χ^2 = 2.27, 1 df, P = 0.169), evergreen (χ^2 = 0.85, 1 df, P = 0.358), grassland (χ^2 = 1.77, 1 df, P = 0.184), pasture (χ^2 = 0.24, 1 df, P = 0.622), agriculture (χ^2 = 0.18, 1 df, P = 0.180), emergent herbaceous wetlands (χ^2 = 1.57, 1 df, P = 0.210), shrubland (χ^2 = 1.617, 1 df, P = 0.204), distance to roads (χ^2 = 0.19, 1 df, P = 0.663), patch size (χ^2 = 2.21, 1 df, P = 0.137), and elevation (χ^2 = 0.73, 1 df, P = 0.393), respectively. Our results suggested habitat use varied little year to year (variance = 0.001), so we dropped the parameter from the model. We found no evidence of a lack of fit (χ^2 = 145,162.2, 147,881 df, P = 0.999). Our final model [used = sqrt(slope) + mixed + open developed + low-intensity developed + medium-intensity developed + high-intensity developed + barren + grassland + woody wetland + log(housing density) + (1| individual bear)] fit the data well (χ^2 = 23,816.28, 261,979 df, P = 0.999; Table 3). Our cross-validation indicated poor predictive ability (mean classification rate = 62% ± 1.72% SE; this was 12% better than random).

Similarly to second-order selection, we found no evidence of a difference between habitat use by bears based on sex, age, period of the day, season, or study area. At this finer scale, bears used woody wetlands (typically rhododendron swamps) or mixed forest more than deciduous forest (the reference level; Table 3). Similarly to our second-order results, bears tended to avoid developed cover types; bear use decreased as development intensity increased (Table 3). Bears tended to avoid open cover types such as barren, pasture, and grassland (Table 3). Two bears (1 F in New Jersey and 1 M in Morgantown) had selection intercepts twice as high as all other bears in the study. These 2 had small home ranges (2.5 km^2 and 4 km^2, respectively) in high-quality deciduous forest patches and did not use habitats similar to those used by other bears in the urban–wildland interface. Our results indicated that third-order habitat selection of bears in the urban–wildland interface was similar among study areas, seasons, sexes, and years. In essence, bears use the urban–wildland interface similarly across our areas, regardless of factors that would typically influence habitat selection of wildland bears.

Discussion

Habitat selection analyses for black bears in the urban–wildland interface were congruent. Other studies of wildland black bears indicated similar importance of forested and riparian cover types between second- and third-order habitat selection (Lyons et al. 2003, Carter et al. 2010). Dense cover types (mixed forest, woody wetlands, and deciduous forest) were much more important than others to black bears in our study. Both final models indicated a positive association between forested slopes and bear use. This was not unexpected and has been well-documented in wildland bears (Heyden and Meslow 1999, Benson and Chamberlain 2006, Carter et al. 2010, Hiller et al. 2015, Jones et al. 2015a). Typically bears use those forested slopes and ridges to utilize hard or soft mast along ridgetops (Garner 1986, Unsworth et al. 1989, Powell and Mitchell 1998, Heyden and Meslow 1999) or to avoid humans (Powell et al. 1997). Black bears in neighboring Maryland use relatively steep slopes compared with their availability (Jones et al. 2015a).

Black bears in our study used woody wetland areas (e.g., rhododendron swamps) more than other habitat types (Tables 2 and 3). These habitats were used most in New Jersey and Pennsylvania. Our West Virginia study areas contained few woody wetlands because of the rugged topography, but bears used them whenever they were available. Riparian areas often provide more productive and diverse habitat for black bears than other cover types (Thomas et al. 1979, Hellgren et al. 1991, Lyons et al. 2003). Studies in the southeast indicated that swamps and wetlands provide permeable travel corridors (Feckse et al. 2002, Larkin et al. 2004), escape cover (Pelton 2000), foraging habitat, or denning areas (Landers et al. 1979, Hellgren et al. 1991). Mid-Atlantic black bears use mixed forest, wetlands, and areas with high stream density (Feckse et al. 2002). Black bears use riparian areas (e.g., lowland deciduous forests, rhododendron swamps; Alt et al. 1980, Ditmer 2014) in human-dominated landscapes as escape and foraging cover or for denning. Black bears in our study typically used rhododendron swamps adjacent to human development to move through the urban matrix.

Moderate to highly developed areas and open cover types (e.g., barren, pasture, agriculture) received little use. These results are similar to other black bear studies (Feckse et al. 2002, Benson and Chamberlain 2006, Carter et al. 2010) and indicate a general avoidance of these anthropogenic habitats. There was some use of developed areas, but when developed areas were used, low-intensity areas took priority over medium- or high-intensity developed areas. Further, we found no difference in habitat selection between daytime and nighttime among developed habitats. We expected that bears in our study would use moderately developed habitats more intensely at night than during the day, but we found no such pattern. Human disturbance may have been an explanation for why bears avoided developed areas and open habitats. Direct mortality through hunting is the primary regulator of black bear populations (Kasworm and Their 1994, Wooding and Hardisky 1994, Ryan 2009). Animals perceive human disturbance stimuli as predation risk (Frid and Dill 2002), and bears are likely no exception. Bears will tolerate some disturbance, but there are definite thresholds, such as groups of people or dogs, at which bears will seek safer habitats (Chi and Gilbert 1999). For example, black bears near salmon streams in Alaska remain in safer habitats during periods of increased human disturbance (e.g., high-density human fishing) and return during night hours when disturbance is reduced (Chi and Gilbert 1999). Black bears in fragmented habitats seem to have greater tolerance for disturbance and development, provided that food resources are sufficient (Ditmer 2014, Hiller et al. 2015).

Habitat selection of our bears was similar to other published studies, but with some striking differences. Based on our analysis, bears in the urban–wildland interface of the Mid-Atlantic region select habitat similarly throughout the year. In essence, a bear is a bear. We found no evidence for differences in habitat selection among seasons, study areas, years, or between sexes or ages. This finding is contrary to the body of literature. Typically, habitat selection varies seasonally because of the ephemeral nature of bear foods (Garner 1986, Young and Beecham 1986, Clark et al. 1993, Feckse et al. 2002). Wildland black bears select habitats differently among various age and sex combinations because their caloric requirements differ widely (Robbins 1992). We found no differences in juvenile or adult habitat selection, nor differences between male and female habitat selection. This was likely because of the juxtaposition of high-quality bear habitat adjacent to human settlements. Although we have no direct evidence of this, we speculate that abundance of bear foods must be sufficient on the urban periphery to sustain this resident population of black bears.

The similarity of habitats used by bears in our study to those used by wildland bears has notable bearing on management of urban black bears in the Mid-Atlantic. Managers should not be required to create different management strategies for bears on the urban–wildland interface. This information enables managers to tailor established management actions as the situation dictates. For example, managers can prioritize education efforts in neighborhoods that border a hardwood forest or riparian edge to proactively reduce potential for human–bear conflicts. In areas with low relative probability of use, managers could institute management actions that are of low cost and effort, such as flyers, notices, and promoting awareness. In areas of medium and high probability of use, managers could use more intense management methods, such as citations, ordinances, attractant removal, bear control actions (trapping, relocation and/or euthanasia), and regulated hunting. We acknowledge that a single bear in an area can cause many problems for a bear manager, but understanding how these bears use habitats in and around urban areas could help managers identify "hotspots" in which to direct management action.

Bears are habitat generalists that can thrive in the developed landscapes of the Mid-Atlantic United States. Rather than using urban areas as areas to raid for anthropogenic food or to avoid harvest pressure, bears with established home ranges that included the periphery of urban areas were reproducing (Tri 2013). Provided that food is abundant, bears tolerate being in areas one would rarely consider "traditional" bear habitat (e.g., edges of housing developments, parks, small woodlots, etc.). Managers in developed areas will have to contend with a resident, reproducing population of black bears that utilizes forest adjacent to developed areas; however, managers can treat these bears the same as they would bears in wildland populations.

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