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Abstract: Exurban development is non-metropolitan, residential development characterized by a human population density and average property size intermediate between suburban and rural areas. Although growth in exurban areas is outpacing that of urban, suburban, or rural landscapes, studies of deer ecology in exurban areas are non-existent. During 2003–2005, we studied space use (i.e., seasonal home range and core area size and habitat use relative to human dwellings) and survival of 43 does in an exurban setting near Carbondale, Illinois. Deer had larger home ranges than most suburban deer populations and generally smaller home ranges than

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rural deer populations. When we analytically controlled for habitat use, deer exhibited a subtle avoidance of human dwellings, especially during the fawning season. The annual survival rate was among the highest reported in the literature at 0.872 (SE = 0.048). Only 5 deer (cause-specific mortality rate = 0.091) were harvested by hunters, indicating major obstacles for wildlife managers when attempting to manage deer in exurban areas using traditional hunter harvest.

***Key words*:** deer-human conflict, deer management, exurban development, habitat, human dwellings, Illinois, *Odocoileus virginianus*, space use, survival, white-tailed deer.

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Exurbia is residential land-use outside of city limits that is situated among working farms or undeveloped land, with a human population density and average property size intermediate between the suburbs and rural areas (Nelson 1992). From an ecological perspective, the important distinction between exurban and suburban landscapes is that human dwellings in exurbia are generally interspersed throughout wildlife habitat rather than habitat existing in patches (e.g., municipal parks) within suburban non-habitat (Odell and Knight 2001). Due to its more dispersed pattern, residential development in exurbia has a greater impact on the landscape on a per-unit basis than suburban and urban growth patterns (Theobald et al. 1997).

An estimated 10 million people were added to exurbia in the U.S. during the 1990s, more than were added to urban, suburban, or rural landscapes (Nelson and Sanchez 2005). Because exurbia is expanding at a greater rate than other types of human development, its potential impact on the ecology and management of white-tailed deer (*Odocoileus virginianus*) is likely considerable and deserves research attention. Although deer ecology and management have been studied considerably in urban and suburban landscapes (Cornicelli et al. 1996, Kilpatrick and Spohr 2000, Etter et al. 2002, Grund and Woolf 2002, Grund et al. 2002, Porter et al. 2004), deer space-use and survival in exurbia has not been explicitly studied.

The landscape changes resulting from exurban development and the presence of a relatively high human population result in a high potential for conflict between humans and deer. Studies of suburban deer have indicated that deer easily habituate to human development and readily use residential areas if sufficient cover is available (Swihart et al. 1995, Kilpatrick and Spohr 2000, Grund et al. 2002). Deer appear to avoid human development to some extent when possible (Swihart et al. 1995, Kilpatrick and Spohr 2000, Grund et al. 2002). However, in some cases, deer may have little choice but to exploit heavily developed areas, and have clearly done so successfully (Swihart et al. 1995, Kilpatrick and Spohr 2000, Grund et al. 2002). The dispersed, low density development in exurbia may allow deer some degree of “choice” in the intensity of space-use near human dwellings. Although deer should be able to avoid dwellings if they are disturbed by them, or if habitat near homes is of low suitability, no studies have directly tested these hypotheses. Furthermore, knowledge of deer space-use relative to human dwellings is necessary to determine how deer respond to development, and should help predict the extent to which deer-human conflicts will occur in exurban landscapes.

Survival of suburban deer is typically high due to the lack of hunting and natural predators (Etter et al. 2002). For instance, deer in the forest preserves of the Chicago metropolitan area suburbs had an annual survival rate of 82%; the dominant form of mortality was deer vehicle collisions (DVCs) (Etter et al. 2002). Hunting is generally legal in exurbia, although relatively few properties may actually be hunted (Storm 2005). Further, county-level harvest efficiency can be inversely related to non-metropolitan development (Harden et al. 2005). Therefore, it is important to determine the extent to which the reduced proportion of hunted properties affects deer survival in exurbia because it directly affects the ability of deer biologists to manage deer through hunter harvest.

We studied deer in an exurban setting near Carbondale, Illinois, to address the aforementioned paucities in the literature. Our objectives were to quantify; 1) seasonal home range and core area sizes, 2) density of human dwellings within seasonal home ranges and core areas, 3) habitat use relative to human dwellings, and 4) annual survival rate and cause-specific mortality. Our goal was to provide wildlife biologists with information useful for understanding deer ecology and the potential challenges to deer management in exurbia.

Study Area

We studied deer in an exurban setting southeast of Carbondale, Illinois, in Jackson and Williamson Counties. Summers in the region were hot and humid (31^{o} C mean July high temperature, 116.5 cm annual precipitation); winters were mild (-6.2^{o} C mean January low temperature) (Midwestern Regional Climate Center 2005). Study area boundaries were delineated using a minimum convex polygon (Mohr 1947) of all recorded deer locations and buffered by 200 m. We used the database of rural structures compiled by Harden (2002) to map human dwellings on the study area and updated the database with a hand-held GPS unit as needed. The study area encompassed nearly 18 km^2 and contained 357 dwellings (20 dwellings/km^2) arranged in a clumped distribution. Three major roads with speed limits >64 km/hr ran through the study area; road density was 1.5 km/km^2 (Illinois Department of Natural Resources 1996)

We created a land cover map for the study area by manually digitizing landcover polygons onto Digital Orthophoto Quarter-quadrangles (DOQQs) in Arc View 3.2 (Environmental Systems Research Institute 2000). We used DOQQs and ground-truthing to delineate cover types. Six cover types (forest, grassland, cropland, oldfield, wetland, and urban) comprised 59%, 25%, 11%, 3%, 1%, and 1% of the study area, respectively. The primary landscape change that accompanied exurban development on the study area was fragmentation of forest patches. We classified cover types as:

1. Forest: any land with an overstory of trees was classified as forest. Understory vegetation ranged from nonexistent to very dense. *Quercus spp*. and *Carya spp*. dominate southern Illinois woodlands (Neely and Heister 1987).
2. Grassland: hayfields, lawns, and idle grass fields with little or no encroachment by woody plants. Fescue (*Festuca spp*.) was a dominant grass on the study area.
3. Cropland: any row-crop agriculture fields were considered cropland. Crops grown on the study area consisted entirely of soybeans during the study.
4. Oldfield: areas with no overstory, but with a dense understory of herbaceous vegetation and woody plants were classified as oldfield. Autumn olive (*Eleaganus umbellata*), blackberry (*Rubus spp*.), honeysuckle (*Lonicera japonica*), goldenrod (*Solidago spp*.), multiflora rose (*Rosa multiflora*), and sweet clover (*Melitotus spp*.) were common plant species in oldfields.
5. Wetland: any non-flowing water body holding water most of the year was classified as a wetland. The majority of wetlands in the study area were man-made ponds.
6. Urban: areas of concentrated buildings and/or large parking lots.

Methods

Deer Capture and Radiotelemetry

We captured deer during October 2002-March 2003, September 2003-March 2004, and October 2004-January 2005. Deer were baited to capture sites with corn and apples and captured via tranquilizer darting (Pneu-dart Inc., Williamsport, PA, USA), drop nets (Ramsey 1968), and rocket nets (Hawkins et al. 1968). We immobilized darted deer with an intramuscular injection (3 mL) of a 2:1 mix of Telazol (Tiletamine HCl, 2mg/kg; and Zolazepam HCl, 4 mg/kg) and Rompun (Xylazine HCl, 2 mg/kg). Deer captured in nets were immobilized intramuscularly with a hand injection of Ketaset (Ketamine HCl, 10mg/kg). Either VHF radiocollars (Advanced Telemetry Systems, Inc., Isanti, MN, USA) weighing 500 g each or global positioning system (GPS) collars (Telonics, Inc., Mesa, AZ, USA) weighing 700 g each were fitted on does only. We programmed GPS collars to obtain locations at either 1- or 2-hour intervals and to detach from deer after a period of 5-6 months for collars obtaining hourly locations or 10-12 months for collars obtaining bihourly locations. Deer were captured and handled in accordance with methods approved by the Institutional Animal Care and Use Committee at Southern Illinois University Carbondale (protocol #03-003).

We located VHF-collared deer using standard, ground-based radiotelemetry (White and Garrott 1990). Triangulations were obtained from ≥3 bearings taken from fixed stations using 4-element yagi or H-Adcock antennas. Time taken to obtain ≥3 bearings for locations averaged 15.5 ± 0.3 (SE) min. We estimated locations and associated error polygons using LOCATEII (Nams 1990). Mean error ellipse size averaged 4.0± 0.4 (SE) ha. Radiotelemetry was conducted during 0500 to 2100 hrs. We did not conduct night radiotelemetry to avoid disturbing study area residents.

Space Use Analysis

Human dwellings were used as a surrogate to human influence on deer because human activity and disturbance are generally greatest near dwellings. We assessed deer space-use relative to dwellings using 2 separate analyses: 1) density of dwellings (dwellings/ha) in home ranges versus core areas, and 2) habitat selection relative to dwellings at the home range and core area levels.

Home range and core area estimation. During 2003-2005, we estimated home ranges and core areas for the fawning season (15 May-31 Jul) and winter season (15 Dec-15 Mar). These periods were chosen because they represent extremes in both plant phenology and deer behavior. For each deer, we attempted to obtain ≥50 locations/season (Seaman et al. 1999). Each GPS collar obtained >2,000 locations per 5-6 month period (Schauber et al., in press), thus a random subsample of 50 locations was used for analysis for GPS collared deer. We used the Animal Movements extension in Arcview 3.2 to calculate least-squares cross validated, fixed-kernel home ranges and core areas (95% and 50% contours, respectively; Worton 1989).

We pooled home range and core area data across years, and used the mean home range and core area size when the same individual had home ranges and core areas in consecutive years. Home range and core area sizes were not normally distributed ($W = 0.769$, $P < 0.001$; and $W = 0.782$, $P < 0.001$; respectively). Therefore, we attempted several data transformations to improve normality. A Log^{10} transformation was deemed best for both home range and core area size ($W = 0.968$, $P = 0.203$; and $W = 0.988$, $P = 0.915$; respectively). Paired t-tests ($\alpha = 0.05$ throughout) were used to compare home range and core area size between the fawning and winter seasons.

Dwellings in home ranges and core areas. We calculated density of dwellings (dwellings/ha) within seasonal home ranges and core areas. We used dwelling density rather than the number of dwellings/home range or core area to correct for individual and seasonal differences in home range and core area size. For example, a home range with a larger area may be more likely to contain more dwellings than a smaller home range. Dwelling density data were nonnormal ($W = 0.764$, $P < 0.001$), but square-root transformation improved normality ($W = 0.912$, $P < 0.001$). We used ANOVA to test for differences in mean transformed dwellings/ha between fawning and winter season home ranges and core areas. To reduce the effect of between-deer variation in dwelling density, we restricted the ANOVA to deer for which we had data during both seasons. We also included individual deer as a fixed-factor to better account for individual differences. The ANOVA was performed with interactions, which were removed if they lacked statistical significance.

Habitat selection relative to dwellings. In ArcView 3.3, we placed a 100-m circular buffer around study area dwellings. These buffers were deemed "zones of high human influence". We classified cover types within and outside the zone of human influence separately. For instance, forest cover outside the zone of influence was treated as a separate cover type from forest cover within the zones. Twenty-eight percent of the study area fell within the zone of high human influence.

We calculated the percent composition of cover types for the study area, home ranges, and core areas. We used the MACOMP.SAS code (Ott and Hovey 1997) in SAS (SAS Institute 1999) to perform compositional analysis of habitat selection (Aebischer et al. 1993). Compositional analysis compares the logratio-transformed proportions of cover types used with the logratio transformed proportions of cover types available. We assigned unused but available cover types an insignificant non-zero value (0.0001) because the number 0 cannot be log transformed. We tested for seasonal habitat selection between the study area and home ranges [second-order selection (Johnson 1980)] and between home ranges and core areas [third-order selection (Johnson 1980)] for both winter and fawning seasons because deer response to dwellings and associated activity may differ between seasons. When habitat use was nonrandom, habitats were ranked in order of preference (Aebischer et al. 1993).

Bingham and Brennan (2004) found that the substitution of arbitrarily small, non-zero values for 0% habitat use-values led to unacceptably high Type I error rates in compositional analysis. We took steps to eliminate or reduce the proportion of 0% use values by restricting the compositional analysis to 4 cover types that comprised 84% of the study area: forest and grassland cover outside the zone of influence and those 2 cover types within the zone of influence. This eliminated cover types with low availability which were more likely to be unused (Bingham and Brennan 2004) and allowed us to determine space-use relative to dwellings while partially controlling for habitat selection. For example, if deer are disturbed by houses, then the habitats outside the zones of influence should be ranked higher than the same type of habitats within the zones.

Survival Analysis

During 23 October 2002-15 March 2006, we monitored deer for survival $\geq$2 times/week. Number of transmitter-days (Trent and Rongstad 1974, Heisey and Fuller 1985*a*) was used to estimate the annual survival rate and rates of cause-specific mortality in program MICROMORT (Heisey and Fuller 1985*b*). Data were pooled across years for analysis. We investigated mortalities immediately following detection. Mortalities were classified as DVC or hunter-harvest; deer that died from capture myopathy (n = 2) were not included in the analysis. The exact date of death was known for all mortalities. We censored GPS-collared individuals from the analysis when their collars dropped off. No radiocollars failed during the study.

Results

We radiocollared 43 does (28 GPS, 15 VHF) during the study period. Averages of 48.9 ± 0.5 (SE) and 50.5 ± 1.9 locations per VHF collared deer were obtained during the fawning and winter seasons, respectively.

Space Use Analysis

Home range and core area estimation. During the fawning season, mean home range size was 53.0 ± 5.2 ha (*n* = 26, range = 25.2 - 145.0 ha) and mean core area size was 8.7 ± 1.8 ha (*n* = 26, range = 2.6 - 48.9 ha). In winter, home range size averaged 90.6 ± 9.7 ha (*n* = 34, range = 23.3 - 275.0) and core area size averaged 12.4 ± 1.3 ha (*n* = 34, range = 1.1 - 32.5). Home ranges were larger in winter than during the fawning season (t_{24} = 3.42, *P* = 0.002). Core areas were also apparently larger during the winter, with the difference approaching statistical significance (t_{24} = 2.06, *P* = 0.051).

Dwellings in home ranges and core areas. Dwelling density in home ranges and core areas during the fawning season averaged 0.13 ± 0.03 dwellings/ha (*n* = 26, median = 0.11, range = 0.00 - 0.65) and 0.14 ± 0.05 dwellings/ha (*n* = 26, median = 0.00, range = 0.00 - 1.21), respectively. Dwelling density of home ranges in winter averaged 0.18 ± 0.02 dwellings/ha (*n* = 34, median = 0.15, range = 0.00 - 0.64) and dwelling density in winter core areas was 0.16 ± 0.03 dwellings/ha (*n* = 34, median = 0.12, range = 0.00 - 0.63). Dwelling densities differed among seasons and home range and core area ($F_{72,23}$= 4.598, *P* = 0.033). Deer used areas of higher dwelling density in the winter than during the fawning season (*P* = 0.029) and dwelling density was higher in home ranges than core areas (*P* = 0.010).

Habitat selection relative to dwellings. Compositional analysis provided evidence of nonrandom habitat use during the fawning season at both the second (λ = 0.728, *P* = 0.059) and third levels of selection (λ = 0.716, *P* = 0.078). During the fawning season, within home ranges, grassland outside the zone of human influence was preferred over both grassland and forest within the zone of human influence (Table 1). At the core area level, forest outside the zone was preferred over both grassland cover types (Table 1).

Winter habitat use was nonrandom at both the second ($\lambda = 0.739$, $P = 0.023$) and third levels of selection ($\lambda = 0.641$, $P = 0.003$). At the home range level, grassland outside the zone of human influence was preferred over grassland within the zone of influence (Table 2). There were no detectable differences in habitat selection between other cover types. Within core areas, forest outside the zone of influence was preferred over all other cover types. Forest cover within the zone of influence was preferred over both grassland cover types (Table 2).

Survival Analysis

Forty-three does were monitored for survival during 18,655 transmitter-days. The annual survival rate was 0.872 (SE = 0.048). Seven deer died during the study: 3 harvested by shotgun hunters, 2 killed by archery hunters, 1 poached and 1 killed in a DVC. Cause-specific mortality rates were 0.091 (SE = 0.038) for hunter harvest and 0.018 (SE = 0.057) for both DVCs and poaching.

Discussion

Space-Use Analysis

Home range and core area size. Deer in our exurban study area had larger home ranges than most suburban deer and generally smaller home ranges than rural deer (Table 3). These results can be partially explained by how deer habitat composition and configuration differ across the rural-urban gradient. Development influences deer home range size by altering habitat composition and productivity and, in suburban areas, by introducing impediments to movement (e.g., highways, railroads, and commercial and residential expanses) (Grund and Woolf 2002).

The barriers to deer movement that exist in suburban areas are much less prevalent in the exurban landscape. However, forest fragmentation resulting from exurban development increases edge and adds food sources such as lawns, gardens, and ornamental plantings. This increase in foraging habitat could facilitate smaller home ranges in exurbia relative to rural areas as deer could decrease movements while still meeting metabolic demands. Home range size has been demonstrated to be inversely related to density of food in the home ranges of roe deer (*Capreolus capreolus*) (Tufto et al. 1996) and to habitat heterogeneity in mule deer (*Odocoileus hemonious*) (Kie et al. 2002), and roe deer (Saïd and Servanty 2005).

Deer in nearby suburban Carbondale, Illinois (Cornicelli et al. 1996) had much smaller home ranges than deer on our exurban area, even though the 2 study sites were only 5 km apart. That 2 deer populations so close together could have such differences in home range size further reinforces the notion that deer in the most human-dominated landscapes have smaller home ranges than their counterparts in relatively less developed areas. Home ranges for deer on our study area were nearly twice as large in winter as in the fawning season. As plants desiccate in winter and food becomes scarcer, deer must increase movements to attain the daily forage intake needed to meet metabolic demands. Does also reduce home range size in summer to attend fawns who spend much of their time hiding when they are very young (Ozoga et al. 1982). Increased winter home range size is common throughout much of the geographic range of white-tailed deer (Nixon et al. 1991, Campbell et al. 2004), except in northern forested regions (Tierson et al. 1985, Van Deelen et al. 1998) where the opposite is true. In these areas, heavy snowfall makes locomotion energetically expensive, and deer must conserve energy by decreasing activity, thereby reducing metabolic rate and body fat depletion (Moen 1976).

Space-use relative to dwellings. Deer generally avoided dwellings on our study area, similar to suburban deer (Vogel 1989, Cornicelli et al. 1996, Kilpatrick and Spohr 2000, Grund et al. 2002). This conclusion is based on 2 analyses: (1) dwellings within home ranges and core areas and (2) habitat use relative to dwellings. These analyses were generally concordant and complementary and provide insight into deer ecology in exurban areas.

Fawning season compositional analysis did not achieve statistical significance, which may be explained by the smaller sample size of deer during the fawning season (n = 26 in fawning season vs. 34 in winter season). Also, the home ranges of 3 of 26 deer considered for fawning season analysis contained no habitats within 100 m of a dwelling. This likely biased the third order selection in a way that would underestimate avoidance of dwellings. Although the fawning season compositional analysis did not quite achieve statistical significance, considering the ranks obtained from the compositional analysis together with the dwelling density results suggests biological significance. Thus, we will discuss fawning season results based on the notion that deer were exhibiting biologically meaningful habitat selection.

Deer during the fawning season had a lower dwelling density in their core areas than in home ranges, implying that deer on the study area avoided houses to a degree during this time. That the dwelling density was lower in fawning season home ranges than both winter home ranges and core areas suggests a stronger avoidance during the fawning season. Deer in suburban Groton, Connecticut, showed no seasonal differences in the number of dwellings per home range, however, there were more houses in winter core areas than in other seasons (Kilpatrick and Spohr 2000). The relatively high level of development in the suburbs probably diminished the ability of deer to exhibit seasonal differences in the number of dwellings per home range, through either home range contraction or shift.

Deer on our study area exhibited a second-order preference, during the fawning season, for grassland away from dwellings over habitats nearer to dwellings. Most of the grassland >100 m from dwellings was either fescue fields or idle lands containing thick ground cover. Such grassland is important habitat in southern Illinois in the summer since fawns are typically hidden along the grassland/forest edge (Rohm et al. in press) and as adults may use the tall grass for cover as well. Much of the grassland on our study area <100 m from a dwelling was lawn, which does not provide any cover, thereby resulting in deer avoidance. Does may also prefer to give birth in relatively quiet areas, away from the noise and disturbances associated with homes (Grund et al. 2002). These reasons also explain why there were fewer dwellings in core areas of deer during the fawning season.

In this study, the third-order preference during fawning season for forest outside the zone of influence over both grassland cover types is a reflection of the importance of forest as cover habitat for deer and further indication that deer prefer to keep fawns away from dwellings. Rohm et al. (in press) reported that interspersion of forest cover close to grassy edge areas is important for fawn survival in southern Illinois by reducing risk of predation by coyotes (*Canis latrans*). Hence, adult females likely choose core areas during the fawning season that maximized fawn survival.

Suburban deer in Connecticut and Minnesota increased use of residential areas during winter (Kilpatrick and Spohr 2000, Grund et al. 2002). Swihart et al. (1995) reported that suburban deer in Connecticut browsed more heavily near houses than away, and that deer regularly visited houses when foraging in winter. The shift towards dwellings in winter was explained by the anthropogenic food sources found there and (Swihart et al. 1995), in the case of Grund et al. (2002), the radiant heat and reduced wind speeds provided by homes.

In second-order selection during the winter season, deer preferred grassland away from dwellings to grassland close to houses, which may indicate that anthropogenic food sources associated with dwellings are not so important in exurbia, especially given that winters are generally mild in southern Illinois. The third-order, winter season preference of forest cover types was again indicative of the importance of forest as cover. That forest cover <100 m of dwellings was preferred over grassland >100 m from dwellings probably means that deer are less apt to avoid dwellings in the winter than during the fawning season.

Survival

Annual survival of deer in our exurban study area (87%) was higher than survival rates reported in both rural areas (57%-76%) and suburban areas (62%-82%) (Table 4). DVCs are generally the principal cause of mortality in suburban areas (Etter et al. 2002, Nielsen et al. 2003, Porter et al. 2004), although lethal control methods such as sharpshooting are important where they occur. Hunting is typically the primary cause of death for deer in rural areas (Nixon et al. 1991, Brinkman et al. 2004). On our study area, hunter harvest was low because only 19% of landowners allowed deer hunting on their property (Storm 2005). On 30% of hunted properties, 1 bow hunter constituted all of the hunting that took place. DVCs were few because only 3 major roads crossed the study area. Road density (1.5 km/km^2) on our study area was intermediate between typical rural areas and suburban areas; however, most roads on our study area were driveways, which experienced light traffic at low speed.

Management and Research Implications

This needs to shortened to 1-3 paragraphs. I cut out verbage that was repetious. What is the take home message?

State agencies rely on recreational hunting to control deer population growth. Our study indicates that hunting alone is not likely effective for managing deer in exurbia. Exurban development has been demonstrated to reduce efficiency of county-level deer harvest in Illinois (Harden et al. 2005), and this is clearly true on our study area. To manage exurban deer populations, managers may have to face the daunting task of increasing hunter access across exurbia. Even if this is possible, efforts may be futile as hunter numbers are declining in many areas (Enck et al. 1997), and there may be a lack of demand for hunting properties in some locations. Given the limits of traditional hunter harvest as a tool for deer management in exurbia, agencies must identify alternative policies and regulations to manage deer. Citizen task forces and community-based comanagement have been used to manage overabundant urban/suburban deer populations (Curtis and Hauber 1997, Schusler et al. 2000). We believe such management tools would have limited applicability in exurbia because deer-human conflict will occur almost exclusively on private land, thus no citizen task force (or similar entity) would have the authority to impose management. Any solutions that may exist will have to be implemented in the context of increasing human and deer populations and decreasing hunter numbers.

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Table 1. Ranking matrices for fawning season habitat selection of female white-tailed deer relative to dwellings at the second (A) and third (B) levels of selection (Johnson 1980) in an exurban setting near Carbondale, Illinois, USA. Log-ratio difference values between pairs of habitat types are replaced by their signs in the matrix. A positive sign indicates the habitat type in the row is preferred over the habitat type in the intersecting column. Signs are tripled when log-ratio differences are significantly different from 0 ($\alpha = 0.05$). The rank is equal to the sum of the positive values in that row. Larger rank indicates the habitat type in that row is more preferred.

	FO[a]	GO[b]	FI[c]	GI[d]	Rank
(A) Home range vs. study area habitat selection					
FO	.	-	+	+	2
GO	+	.	+++	+++	3
FI	-	---	.	-	1
GI	-	---	-	.	0
(B) Core area vs. home range habitat selection					
FO	.	+++	+	+++	3
GO	---	.	+	+	2
FI	-	-	.	+	1
GI	---	-	-	.	0

[a] FO = Forest cover outside the zone of human influence.

[b] GO = Grassland cover outside the zone of human influence.

[c] FI = Forest cover within the zone of human influence.

[d] GI = Grassland cover within the zone of human influence.

Table 2. Ranking matrices for winter season habitat selection of female white-tailed deer relative to dwellings at the second (A) and third (B) levels of selection (Johnson 1980) in an exurban setting near Carbondale, Illinois, USA. Log-ratio difference values between pairs of habitat types are replaced by their signs in the matrix. A positive sign indicates the habitat type in the row is preferred over the habitat type in the intersecting column. Signs are tripled when log-ratio differences are significantly different from 0 (α = 0.05). The rank is equal to the sum of the positive values in that row. Larger rank indicates the habitat type in that row is more preferred.

(A) Home range vs. study area habitat selection

	FO[a]	GO[b]	FI[c]	GI[d]	Rank
FO	.	-	+	+	2
GO	+	.	+	+++	3
FI	-	-	.	-	0
GI	-	---	+	.	1

(B) Core area vs. home range habitat selection

	FO[a]	GO[b]	FI[c]	GI[d]	Rank
FO	.	+++	+++	+++	3
GO	---	.	---	-	0
FI	---	+++	.	+++	2
GI	---	+	---	.	1

[a] FO = Forest cover outside the zone of human influence.

[b] GO = Grassland cover outside the zone of human influence.

[c] FI = Forest cover within the zone of human influence.

[d] GI = Grassland cover within the zone of human influence.

Table 3. Selected home range sizes of female white-tailed deer with reference to human development intensity in the United States.

				Home range size (ha)	
Study	State	Home range estimator	Development level	Summer / Fawning	Winter
Tierson et al. (1985)	NY	Hand drawn	Rural	221	132
Nixon et al. (1991)	IL	Minimum convex polygon	Rural	55	177
Cornicelli et al. (1996)	IL	Minimum convex polygon	Suburban	17	37
Filipiak (1998)	MN	Adaptive kernel	Rural	191	436
Kilpatrick and Spohr (2000)	CT	Adaptive kernel	Suburban	33	36
Grund et al. (2002)	MN	Adaptive kernel	Suburban	50	85
Campbell et al. (2004)	WV	Fixed kernel	Rural	79	92
Porter et al. (2004)	NY	Minimum convex polygon	Suburban	21	22
This study	IL	Fixed kernel	Exurban	53	91

Table 4. Annual survival rates of adult female white-tailed deer in the Midwestern and Northeastern United States, with respect to intensity of development.

Study	State	Development level	Annual survival rate (%)
Fuller (1990)	MN	Rural	69
Nixon et al. (1991)	IL	Rural	71
Swihart et al. (1995)	CT	Suburban	82
Deperno et al. (2000)	SD	Rural	57
Beringer et al. (2002)	MO	Suburban	69
Etter et al. (2002)	IL	Suburban	82
Brinkman et al. (2004)	MN	Rural	76
Porter et al. (2004)	NY	Suburban	62
This study	IL	Exurban	87