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13
14 **Space Use and Survival of White-Tailed Deer in an Exurban Landscape**

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23 **Abstract:** Exurban development is non-metropolitan, residential development characterized by a

24 human population density and average property size intermediate between suburban and rural

25 areas. Although growth in exurban areas is outpacing that of urban, suburban, or rural

26 landscapes, studies of deer ecology in exurban areas are non-existent. During 2003–2005, we

27 studied space use (i.e., seasonal home range and core area size and habitat use relative to human

28 dwellings) and survival of 43 does in an exurban setting near Carbondale, Illinois. Deer had

29 larger home ranges than most suburban deer populations and generally smaller home ranges than

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² Deceased.

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

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

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

46 An estimated 10 million people were added to exurbia in the U.S. during the 1990s, more
47 than were added to urban, suburban, or rural landscapes (Nelson and Sanchez 2005). Because
48 exurbia is expanding at a greater rate than other types of human development, its potential
49 impact on the ecology and management of white-tailed deer (*Odocoileus virginianus*) is likely
50 considerable and deserves research attention. Although deer ecology and management have
51 been studied considerably in urban and suburban landscapes (Cornicelli et al. 1996, Kilpatrick

52 and Spohr 2000, Etter et al. 2002, Grund and Woolf 2002, Grund et al. 2002, Porter et al. 2004),
53 deer space-use and survival in exurbia has not been explicitly studied.

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

68 Survival of suburban deer is typically high due to the lack of hunting and natural
69 predators (Etter et al. 2002). For instance, deer in the forest preserves of the Chicago
70 metropolitan area suburbs had an annual survival rate of 82%; the dominant form of mortality
71 was deer vehicle collisions (DVCs) (Etter et al. 2002). Hunting is generally legal in exurbia,
72 although relatively few properties may actually be hunted (Storm 2005). Further, county-level
73 harvest efficiency can be inversely related to non-metropolitan development (Harden et al.
74 2005). Therefore, it is important to determine the extent to which the reduced proportion of

98 delineate cover types. Six cover types (forest, grassland, cropland, oldfield, wetland, and urban)
99 comprised 59%, 25%, 11%, 3%, 1%, and 1% of the study area, respectively. The primary
100 landscape change that accompanied exurban development on the study area was fragmentation of
101 forest patches. We classified cover types as:

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

117 **Methods**

118 **Deer Capture and Radiotelemetry**

119 We captured deer during October 2002-March 2003, September 2003-March 2004, and
120 October 2004-January 2005. Deer were baited to capture sites with corn and apples and captured

121 via tranquilizer darting (Pneu-dart Inc., Williamsport, PA, USA), drop nets (Ramsey 1968), and
122 rocket nets (Hawkins et al. 1968). We immobilized darted deer with an intramuscular injection
123 (3 mL) of a 2:1 mix of Telazol (Tiletamine HCl, 2mg/kg; and Zolazepam HCl, 4 mg/kg) and
124 Rompun (Xylazine HCl, 2 mg/kg). Deer captured in nets were immobilized intramuscularly
125 with a hand injection of Ketaset (Ketamine HCl, 10mg/kg). Either VHF radiocollars (Advanced
126 Telemetry Systems, Inc., Isanti, MN, USA) weighing 500 g each or global positioning system
127 (GPS) collars (Telonics, Inc., Mesa, AZ, USA) weighing 700 g each were fitted on does only.
128 We programmed GPS collars to obtain locations at either 1- or 2-hour intervals and to detach
129 from deer after a period of 5-6 months for collars obtaining hourly locations or 10-12 months for
130 collars obtaining bihourly locations. Deer were captured and handled in accordance with
131 methods approved by the Institutional Animal Care and Use Committee at Southern Illinois
132 University Carbondale (protocol #03-003).

133 We located VHF-collared deer using standard, ground-based radiotelemetry (White and
134 Garrott 1990). Triangulations were obtained from ≥ 3 bearings taken from fixed stations using 4-
135 element yagi or H-Adcock antennas. Time taken to obtain ≥ 3 bearings for locations averaged
136 15.5 ± 0.3 (SE) min. We estimated locations and associated error polygons using LOCATEII
137 (Nams 1990). Mean error ellipse size averaged 4.0 ± 0.4 (SE) ha. Radiotelemetry was conducted
138 during 0500 to 2100 hrs. We did not conduct night radiotelemetry to avoid disturbing study area
139 residents.

140 **Space Use Analysis**

141 Human dwellings were used as a surrogate to human influence on deer because human
142 activity and disturbance are generally greatest near dwellings. We assessed deer space-use
143 relative to dwellings using 2 separate analyses: 1) density of dwellings (dwellings/ha) in home

144 ranges versus core areas, and 2) habitat selection relative to dwellings at the home range and core
145 area levels.

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

154 We pooled home range and core area data across years, and used the mean home range
155 and core area size when the same individual had home ranges and core areas in consecutive
156 years. Home range and core area sizes were not normally distributed ($W = 0.769$, $P < 0.001$; and
157 $W = 0.782$, $P < 0.001$; respectively). Therefore, we attempted several data transformations to
158 improve normality. A Log^{10} transformation was deemed best for both home range and core area
159 size ($W = 0.968$, $P = 0.203$; and $W = 0.988$, $P = 0.915$; respectively). Paired t-tests ($\alpha = 0.05$
160 throughout) were used to compare home range and core area size between the fawning and
161 winter seasons.

162 *Dwellings in home ranges and core areas.* We calculated density of dwellings
163 (dwellings/ha) within seasonal home ranges and core areas. We used dwelling density rather
164 than the number of dwellings/home range or core area to correct for individual and seasonal
165 differences in home range and core area size. For example, a home range with a larger area may
166 be more likely to contain more dwellings than a smaller home range. Dwelling density data were

167 nonnormal ($W = 0.764$, $P < 0.001$), but square-root transformation improved normality ($W =$
168 0.912 , $P < 0.001$). We used ANOVA to test for differences in mean transformed dwellings/ha
169 between fawning and winter season home ranges and core areas. To reduce the effect of
170 between-deer variation in dwelling density, we restricted the ANOVA to deer for which we had
171 data during both seasons. We also included individual deer as a fixed-factor to better account for
172 individual differences. The ANOVA was performed with interactions, which were removed if
173 they lacked statistical significance.

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

180 We calculated the percent composition of cover types for the study area, home ranges,
181 and core areas. We used the MACOMP.SAS code (Ott and Hovey 1997) in SAS (SAS Institute
182 1999) to perform compositional analysis of habitat selection (Aebischer et al. 1993).

183 Compositional analysis compares the logratio-transformed proportions of cover types used with
184 the logratio transformed proportions of cover types available. We assigned unused but available
185 cover types an insignificant non-zero value (0.0001) because the number 0 cannot be log
186 transformed. We tested for seasonal habitat selection between the study area and home ranges
187 [second-order selection (Johnson 1980)] and between home ranges and core areas [third-order
188 selection (Johnson 1980)] for both winter and fawning seasons because deer response to

189 dwellings and associated activity may differ between seasons. When habitat use was
190 nonrandom, habitats were ranked in order of preference (Aebischer et al. 1993).

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

201 **Survival Analysis**

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

210 **Results**

211 We radiocollared 43 does (28 GPS, 15 VHF) during the study period. Averages of $48.9 \pm$
212 0.5 (SE) and 50.5 ± 1.9 locations per VHF collared deer were obtained during the fawning and
213 winter seasons, respectively.

214 **Space Use Analysis**

215 *Home range and core area estimation.* During the fawning season, mean home range
216 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
217 ($n = 26$, range = 2.6 - 48.9 ha). In winter, home range size averaged 90.6 ± 9.7 ha ($n = 34$, range
218 = 23.3 - 275.0) and core area size averaged 12.4 ± 1.3 ha ($n = 34$, range = 1.1 - 32.5). Home
219 ranges were larger in winter than during the fawning season ($t_{24} = 3.42$, $P = 0.002$). Core areas
220 were also apparently larger during the winter, with the difference approaching statistical
221 significance ($t_{24} = 2.06$, $P = 0.051$).

222 *Dwellings in home ranges and core areas.* Dwelling density in home ranges and core
223 areas during the fawning season averaged 0.13 ± 0.03 dwellings/ha ($n = 26$, median = 0.11, range
224 = 0.00 - 0.65) and 0.14 ± 0.05 dwellings/ha ($n = 26$, median = 0.00, range = 0.00 - 1.21),
225 respectively. Dwelling density of home ranges in winter averaged 0.18 ± 0.02 dwellings/ha ($n =$
226 34 , median = 0.15, range = 0.00 - 0.64) and dwelling density in winter core areas was $0.16 \pm$
227 0.03 dwellings/ha ($n = 34$, median = 0.12, range = 0.00 - 0.63). Dwelling densities differed
228 among seasons and home range and core area ($F_{72,23} = 4.598$, $P = 0.033$). Deer used areas of
229 higher dwelling density in the winter than during the fawning season ($P = 0.029$) and dwelling
230 density was higher in home ranges than core areas ($P = 0.010$).

231 *Habitat selection relative to dwellings.* Compositional analysis provided evidence of
232 nonrandom habitat use during the fawning season at both the second ($\lambda = 0.728$, $P = 0.059$) and
233 third levels of selection ($\lambda = 0.716$, $P = 0.078$). During the fawning season, within home ranges,

234 grassland outside the zone of human influence was preferred over both grassland and forest
235 within the zone of human influence (Table 1). At the core area level, forest outside the zone was
236 preferred over both grassland cover types (Table 1).

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

243 **Survival Analysis**

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

249 **Discussion**

250 **Space-Use Analysis**

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

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

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

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

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

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

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

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

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

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

332 **Survival**

333 Annual survival of deer in our exurban study area (87%) was higher than survival rates
334 reported in both rural areas (57%-76%) and suburban areas (62%-82%) (Table 4). DVCs are
335 generally the principal cause of mortality in suburban areas (Etter et al. 2002, Nielsen et al. 2003,
336 Porter et al. 2004), although lethal control methods such as sharpshooting are important where
337 they occur. Hunting is typically the primary cause of death for deer in rural areas (Nixon et al.
338 1991, Brinkman et al. 2004). On our study area, hunter harvest was low because only 19% of
339 landowners allowed deer hunting on their property (Storm 2005). On 30% of hunted properties,
340 1 bow hunter constituted all of the hunting that took place. DVCs were few because only 3 major
341 roads crossed the study area. Road density (1.5 km/km²) on our study area was intermediate
342 between typical rural areas and suburban areas; however, most roads on our study area were
343 driveways, which experienced light traffic at low speed.

344 **Management and Research Implications**

345 **This needs to be shortened to 1-3 paragraphs. I cut out verbiage that was repetitious. What is**
346 **the take home message?**

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

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

505						
506						
507 (A) Home range vs. study area habitat selection						
508						
509 FO ^a GO ^b FI ^c GI ^d Rank						
510						
511						
512	FO	.	-	+	+	2
513	GO	+	.	+++	+++	3
514	FI	-	---	.	-	1
515	GI	-	---	-	.	0
516						
517 (B) Core area vs. home range habitat selection						
518						
519	FO	.	+++	+	+++	3
520	GO	---	.	+	+	2
521	FI	-	-	.	+	1
522	GI	---	-	-	.	0
523						

524 ^a FO = Forest cover outside the zone of human influence.

525 ^b GO = Grassland cover outside the zone of human influence.

526 ^c FI = Forest cover within the zone of human influence.

527 ^d GI = Grassland cover within the zone of human influence.

528

529

530

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

539

540

541 (A) Home range vs. study area habitat selection

542

543 FO^a GO^b FI^c GI^d Rank

544

545						
546	FO	.	-	+	+	2
547	GO	+	.	+	+++	3
548	FI	-	-	.	-	0
549	GI	-	---	+	.	1

550

551 (B) Core area vs. home range habitat selection

552

553	FO	.	+++	+++	+++	3
554	GO	---	.	---	-	0
555	FI	---	+++	.	+++	2
556	GI	---	+	---	.	1

557

558 ^a FO = Forest cover outside the zone of human influence.

559 ^b GO = Grassland cover outside the zone of human influence.

560 ^c FI = Forest cover within the zone of human influence.

561 ^d GI = Grassland cover within the zone of human influence.

562

563

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

565

566 Home range size (ha)

567

568 Study	State	Home range estimator	Development level	Summer / Fawning	Winter
569					
570 Tierson et al. (1985)	NY	Hand drawn	Rural	221	132
571 Nixon et al. (1991)	IL	Minimum convex polygon	Rural	55	177
572 Cornicelli et al. (1996)	IL	Minimum convex polygon	Suburban	17	37
573 Filipiak (1998)	MN	Adaptive kernel	Rural	191	436
574 Kilpatrick and Spohr (2000)	CT	Adaptive kernel	Suburban	33	36
575 Grund et al. (2002)	MN	Adaptive kernel	Suburban	50	85
576 Campbell et al. (2004)	WV	Fixed kernel	Rural	79	92
577 Porter et al. (2004)	NY	Minimum convex polygon	Suburban	21	22
578 This study	IL	Fixed kernel	Exurban	53	91

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

581

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

593

594