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Selection of Parturition Sites by Migrating and Dispersing Female White-tailed Deer in Illinois

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ABSTRACT

Emigration behavior by female white-tailed deer (*Odocoileus virginianus*) is an important attribute of population dynamics in Illinois. The factors influencing the process of selecting a new home range are largely unknown, yet may affect hunting success, other interactions with human activities, and deer social behaviors. Twenty-five radio-marked dispersing (N = 14) and migrating (N = 11) female white-tailed deer (4 adults, 7 yearlings, 14 fawns when marked) were followed from 3 sites (2 in central and 1 in northern Illinois) to the home ranges selected for parturition and fawn rearing. Dispersing deer (*i.e.,* those making one-way movements to a new home range) moved an average of 44.9 ± SE 6.4 km whereas migrators (*i.e.*, those moving to a new range) moved 14.0 ± SE 7.2 km from their natal ranges. Females moved rapidly in nearly a straight line to their new home range readily crossing roads, rivers, and under high tension power lines on their journey. Females marked in east-central and northern Illinois where forest cover totaled <5% of the landscape, selected sites with greater forest cover, grasslands, forest patch size and density, and total patch richness than were available in random locations. Habitats selected by females in west-central Illinois where more forest cover was available did not differ from random sites. Parturition ranges (used May 15–July 15) at all 3 sites contained fewer houses and roads and more forest patches compared with the natal ranges and the larger new range (used May 15–October 1). Migrating females survived longer than dispersing females, but female life span and fawn survival were not significantly affected by the habitat composition of the new home ranges.

INTRODUCTION

Emigration behavior is an important attribute of white-tailed deer of both sexes within the fragmented landscapes that characterize much of the Great Plains and the glaciated portions of Illinois (VerCauteren and Hygnstrom, 1994; Brinkman *et al*., 2005; Nixon *et al*., 2007). Emigration movements usually occur when deer are 10–13 mo old and may involve travel up to 200 km or more from their natal ranges (Sparrowe and Springer, 1970; Gladfelter, 1978; Dusek *et al*., 1989; Nixon *et al*., 1991). Emigration by female deer in Illinois has been triggered by mother and sibling movements, orphaning, social position, birth sequence with later born fawns in a social group more likely to emigrate, and, with many fawns breeding, a search for a suitable parturition site (Etter *et al*., 1995; Nixon *et al*., 2007; Nixon *et al*., 2008; Nixon *et al*., 2010).

Less attention has been devoted to examining the characteristics of home ranges selected by female immigrants or why they stop an emigration and settle on a new range. Possible internal incentives to stop include hunger, fatigue from travel, and changes in reproductive hormone levels associated with impending parturition (Plotka *et al*., 1977; Ozoga *et al*., 1982; Stamps, 2001; Wiems, 2001; Andreassen *et al*., 2002). External factors may also affect final selection of a new home range including an immigrant's attraction to a parturition site if >1 yr old, an attraction to or avoidance of conspecifics, a search for a landscape similar to that of the natal range, and avoidance of large rivers, interstate highways, and urban centers (Nelson and Mech, 1992; Danchin *et al.,* 2001; Stamps, 2001; Klaver *et al.,* 2008; Long *et al*., 2010). In Illinois, it is likely the sounds, scents, and sights of human activity in and around various sites that are otherwise adequate in terms of nutrition and cover, may also influence the decision on where to stop an emigration movement.

We hypothesized that selection of a stopping point for an emigration movement was a random event, based on the effect of various external and internal stimuli. Selection of a home range is a second order scale of habitat selection, when emigrating females select a landscape mosaic of forest, grasslands, and crop fields supportive of their immediate needs (Orians and Wittenberger, 1991; Morrison *et al*., 2006; Godvik *et al*., 2009; Grovenburg *et al*., 2010). Such a selection affects future survival, reproductive success, and overall fitness. We examine some of the factors that may influence immigrating Illinois breeding females in their selection of a new home range in late spring just before the critical period of parturition and fawn rearing.

METHODS

We used 3 study areas (1 in northern Illinois and 2 in central Illinois) to investigate the demographic characteristics, seasonal movements, social behavior, habitat selection, and the importance of refugia for deer in landscapes shaped by human activities (Nixon *et al*., 1991). Each area included a wooded public park surrounded by privately owned agricultural fields. The 2,953-ha east-central (EC) study area lies within Piatt County. In 1985, this region was only 2.4% forested, with forests restricted to areas too rough or wet to farm (Iverson *et al*., 1989). The Sangamon River bisected the study area from NE to SW and provided a forested emigration route for deer. The 5,942-ha west-central area (WC), located in Brown and Adams counties, was more rugged with forests covering about 22%

of the landscape (Iverson *et al*., 1989) and where farms generally included a livestock component. The 1,648-ha northern (NO) area in DeKalb County lies within a region also intensively row cropped with forests occupying about 1.3% of the landscape. Urban sprawl was evident in this region which includes Chicago and Rockford, the largest cities in Illinois. There was no major river corridor associated with either the WC or NO study area.

The 25 female white-tailed deer reported in this paper were part of a larger comprehensive study that included 286 deer captured during 1980–85 (EC) and 352 captured during 1990–1993 (WC and NO). These deer were captured using rocket-propelled or drop nets (Hawkins *et al*., 1968) (Table 1). Deer were manually restrained and marked with ear tags and radio transmitters (Wildlife Materials, Carbondale, IL; Telonics, Inc., Mesa, AZ; or Advanced Telemetry Systems, Inc., Isanti, MN). Our capture and marking methods were approved by the University of Illinois Institutional Animal Care and Use Committee.

Table 1. Life history of emigrating female white-tailed deer radio-tracked to parturition sites away from the natal range in Illinois during 1980–1985 and 1990–1993. Contact months represents the period from capture to last contact or death (NO = northern, EC = east-central, WC = west-central study areas).

Tag	Year marked	Age when marked	Type of movement	Radio fixes (N)	Distance moved (km)	Contact (mo)	Life span (mo)	Cause of death
NO Area								
155	1991	Fawn	Dispersal	28	58.5	33		Alive[1]
159	1991	Fawn	Migration	60	22.0	36	67	Auto
212	1992	Fawn	Dispersal	13	51.4	8	28	Auto
178	1992	2 yr	Migration	75	6.4	26		Alive[1]
196	1992	3 yr	Migration	69	8.5	25	77	Train
EC Area								
262	1980	Fawn	Migration	167	6.9	45	53	Bow cripple
276	1980	Fawn	Dispersal	11	57.3	9	17	Gun
218	1983	Fawn	Dispersal	30	25.5	8	17	Gun
507	1983	Fawn	Dispersal	48	65.0	25	29	Gun
577	1984	Fawn	Dispersal	23	36.8	8	17	Gun cripple
636	1985	Fawn	Dispersal	34	13.7	8	17	Gun
286	1980	Yearling	Dispersal	286	20.2	9	30	Gun
325	1981	Yearling	Dispersal	67	52.9	36	54	Auto
338	1981	Yearling	Dispersal	271	12.6	10	30	Gun
542	1984	Yearling	Dispersal	38	31.3	18	41	Unknown
619	1985	Yearling	Dispersal	19	22.8	8	28	Bow
266	1980	Yearling	Migration	157	7.3	44	65	Gun
558	1984	2 yr	Migration	111	3.2	33	65	Gun
238	1980	3 yr	Migration	113	20.8	10	54	Gun cripple
WC Area								
55	1991	Fawn	Dispersal	9	128.0	13		Alive[1]
117	1991	Fawn	Dispersal	7	60.3	10	17	Gun
138	1991	Fawn	Migration	36	5.0	8	17	Gun cripple
109	1991	Fawn	Migration	102	26.7	35	42	Gun
194	1992	Fawn	Migration	28	17.6	21	66	Gun
115	1991	Yearling	Migration	102	26.7	37	65	Gun

[1] Alive at end of study. Cause of death unknown.

Deer were aged using tooth replacement and wear from incisors and premolars observed on live deer as either fawn (<12 mo), yearling (12–23 mo), 2 yr old (24–35 mo), or adult (≥36 mo) (Severinghaus, 1949). Pregnancy was determined for fawn captures using blood progesterone levels (Wood *et al*., 1986) or from direct observation of all 25 females on the new range. We captured deer in the order they were lured to bait sites with no random capture selection attempted. Radios were allocated according to their availability each year with a priority given to radio-marking family groups *(e.g*., females with associated fawns and/or yearlings).

Females were radio tracked using 2 truck-mounted, 8-element yagi antennas aligned in a null configuration. Radio locations were validated using an unpublished program for the Apple II computer (L. P. Hansen, Illinois Natural History Survey) for the EC females and the software program LOCATE II (Nams, 1990) for the WC and NO females. Home range boundaries for each female was calculated for each natal range and for the new range selected by each immigrant using all radio fixes and observations (Table 1) and then superimposed on topographic maps (Lesage *et al*., 2002).

We defined dispersal as the one-way emigration to a new home range at least 12 km from the natal range. Migration was defined as a movement by females at least 3 km away from the natal range to a new home range where parturition took place. These females then returned to their natal range each winter. Migrating females ≥2 yr old when first captured were considered to have already located their summer ranges as fawns or yearlings. We base this assumption on 2 known characteristics of white-tailed deer in Illinois: first, known female emigrations from our study areas have always begun following their ejection from their mother's parturition site in late spring at 10–13 mo old or, for various reasons (such as reproductive state, social status, loss of kin) delayed until 21–24 mo old (Nixon *et al*., 1991); second, most mother's strong attraction each year to a site of parturition once a successful birth has occurred (Ozoga *et al*., 1982; Tierson *et al*., 1985; Dusek *et al*., 1989; Nixon *et al*., 1992; Etter *et al*., 1995) and verified by the behavior of our marked females followed for longer than a single season (14 of 25 deer).

The new home range settled by female deer was occupied from late February until October 1, the date when fawns were considered finally weaned (Clutton-Brock *et al*., 1982). The part of the new home range that was occupied May 15–July 15 was considered the parturition range, and the habitats within this range were analyzed separately from the total new home range. Generally, only migrating females moved as early as late February, whereas dispersing deer typically started moving in May. Each delineated home range was cover mapped as upland or bottomland forest <40 or ≥40 yr old, permanent grasslands (CRP lands, pastures active or abandoned, roadsides, cultivated hay fields, mowed grasses of cemeteries, lawns, and proposed housing developments), row crops of corn (*Zea maize*) or soybeans (*Glycine max*), and permanent water bodies. Forest overstories at all sites were similar to the natal sites when forest age and flooding frequency was also similar. Upland forest ≥40 yr old were dominated by various oaks (*Quercus sp*.) and hickories (*Carya sp*.). Those upland forests <40 yr old were mixtures of oaks, hickories, elms (*Ulmus sp*.), black walnut (*Juglands niger*), honeylocust (*Gleditsia triacanthos*), osage orange (*Machura pomifera*), and shingle oak (*Quercus imbricaria*). Bottomland forest <40 or ≥40 yr old that was frequently inundated was nearly a monotype of silver maple (*Acer saccharinum*), whereas dryer sites were mixtures of silver maple, hackberry

(*Celtis occidentalis*), sycamore (*Platanus occidentalis*), black walnut, cottonwood (*Populus deltoides*), ashes (*Fraxinus sp*.), and bur oak (*Quercus macrocarpa*).

Data Analysis

Because we used both migrating (N = 11) and dispersing deer (N = 14) for this analysis, we first compared the landscape characteristics of the new home ranges selected by the 2 types of movement behaviors using the t-test. The landscape variables used to analyze landscape use (the natal range, travel corridor used by each deer, parturition range, and new home range) are listed in Table 2. We separated the parturition ranges from the new home ranges because of the importance of cover to early fawn survival (Rohn *et al*., 2007).

Table 2. Landscape attributes and human presence within the natal ranges, the new home ranges (May 15–October 1), and the parturition ranges (May 15–July 15) selected by 25 emigrating female white-tailed deer in Illinois during 1980–1985 and 1990–1993.

Landscape Variables
Travel Corridors
Roads — all state and federal highways
Rivers — all river crossings
Forest patches — all distinct forest patches encountered
Power lines — all high tension lines carrying at least 34,500 volts
Home Ranges
Vegetation stage — dormant or actively growing when emigration began
Female present — females actually seen on the new home ranges
Percent forest — percent of home range forested
Percent cropland — percent of home range in active crops
Percent grasses — percent of home range in permanent grass
Richness — sum of all distinct habitat patches
Nearest neighbor — distance between forest patches (km)
Forest patch density — number of forest patches per 10 ha
Average size — average size of forest patches (ha)
Houses — all occupied dwellings in the home range
Forest age — <40 or ≥40 years
Forest type — upland or bottomland forest

Several of these landscape variables were significantly correlated as determined by the nonparametric Spearman's Rho test (Zar, 1999), a result expected because the landscape is finite and higher amounts of 1 habitat mean lower amounts of another. For example, negative correlations included percent cropland with percent forest (Rho = –0.82, $P < 0.0001$), percent grassland (Rho = –0.61, $P = 0.001$), and forest patch size (Rho = –0.69, $P = 0.0002$), while positive correlations included forest patch size with percent forest (Rho = 0.70, $P < 0.0001$) and percent grassland (Rho = 0.40, $P = 0.047$) as well as number of forest patches with distance between forest patches (Rho = 0.63, $P = 0.0007$). We used stepwise regression (backward selection) to reduce the number of variables, allowing the analysis to sort for the appropriate (less correlated) landscape variables. Backward selection regression was chosen because it is better able to identify significant independent variables than is forward selection when there is multi-collinearity among variables (Zar, 1999).

Travel Characteristics

The deviation in travel direction from a straight line was examined by comparing radio locations along each travel route to a straight line drawn from the center of the natal range to the center of the new home range. We also tested for a deviation in the angle of dispersal for 14 deer from the EC area compared to the general direction azimuth of the river corridor. We used the Wilcoxon 2-sample test to examine for differences in the 2 measurements (Zar, 1999).

The initial direction (degrees azimuth) a female moved away from the natal range was measured and placed on USGS topographic maps (published 1971–1984 for EC, 1971–1980 for NO, 1981 for WC). We then compared this chosen direction with 6 alternative directions that were 30°, 60°, and 90° on either side of this route (and the same length as the actual route) using one-way ANOVA and recorded the number of roads (Illinois Secretary of State highway maps), rivers, forest patches, and high voltage power transmission lines (Illinois Commerce Commission 1971, 1997) encountered along these azimuths. We felt limiting this effort to 90° on either side of the actual route best provided an insight into the possible travel choices available to the marked females as they were leaving their natal range. Forest patches were located along each azimuth using topographic maps and rechecked using LANDSAT satellite imagery through the internet program Google Earth.

Recently there has developed interest in the biological effects of the electromagnetic forces associated with high voltage power lines. We were interested in the biological effects, if any, of electromagnetic forces on deer travel routes and on the selection of a new range. Both roe deer (*Capreolus capreolus*) and domestic cattle (*Bos taurus*) tend to align their resting body axis in the north-south geometric direction, and high voltage lines have been shown to disrupt this body alignment suggesting that these animals can detect and respond to such an electromagnetic force (Burda *et al.*, 2009).

Using topographic maps, we also recorded the amount of forest and cropland each deer encountered (based on radio locations) during an emigration. We then compared the percent forest and cropland present on the natal range with the same variables encountered along the travel corridor and with those within the newly settled home range using one-way ANOVA. Whether distance traveled between ranges affected final landscape selection was examined using distance traveled as a dependent variable in a stepwise regression analysis and using landscape characteristics found on the new range as independent variables (Table 2).

Home Range Characteristics

In an effort to determine the characteristics of the landscape in the 10 counties where our 25 females ultimately settled, we randomly selected 75 sections from these 10 counties using a ratio of 3 times the number of females followed from each study area (EC = 14, NO = 5, WC = 6) (Anderson *et al.*, 2005). The mean area of the new home range for our 25 females was 177.9 ± SE 41.9 ha (Table 3), and we used a circle of this size centered within each selected section on topographic maps to measure the amount of forests, croplands, and grasslands present at the time of emigration. We then compared the percentage of forest, grasslands, and croplands found in these sections with the actual habitats selected by our marked females using one-way ANOVA.

Table 3. Mean values of landscape characteristics measured within the natal ranges, new home ranges, parturition ranges, and random sites of 25 female white-tailed deer in Illinois during 1980–1985 and 1990–1993. The natal and random sites were measured as the same new home range size.

						Percent of total			Forest patches only		
Location	N	Home Range (ha)	Roads (km)	Houses (N)	Richness (all types)	Forest	Grassland	Crop	Size (ha)	Density (per 10 ha)	Nearest Neighbor (km)
Natal											
	25	179.5	1.87	2.9	4.9	39.2	26.9	31.3	52.5[a]	0.12	0.08
New home (May 15–October 1)											
	25	179.5	1.47	4.36	7.2[a]	35.7	19.7	43.4	20.7	0.29	0.13
Parturition (May 15–July 15)											
	20	28.9	0.30[a]	0.72[a]	3.1	42.2	21.3	36.3	10.4	0.65[a]	0.09
Random sites											
	75	179.5	1.22	10.6	1.1	9.4	9.8	75.5	— No Data —		

[a] Value significantly different from other ranges/sites (see text)

We also used ANOVA tests to compare forest characteristics (Table 2) present in the natal ranges with the parturition and new home ranges selected by our marked females. Using one-way ANOVA, we compared similar characteristics of ranges selected by females (N = 15) that appeared to be stopped in their travels by an obstacle such as open agricultural land (*e.g.*, a lack of forest), the presence of a large urban area, or a large river valley dominated by cultivated lands with those females (N = 10) where no obvious obstacle to further travel existed.

Costs of Emigration

Stepwise regression analysis using life span as the dependent variable was compared with 13 independent variables describing the human activities, general landscape characteristics found in the selected ranges, and possible social encounters (females present or not) (Table 2).

The possible effects of landscape selection on subsequent fawn survival was examined using one-way ANOVA to compare the landscape characteristics (total patch richness, forest patch nearest neighbor, forest patch density and average size) chosen by females that successfully raised 1 or more fawns with those that lost 1 or more fawns before fawn independence at 1 yr old.

RESULTS

Twenty-five radio marked females (4 adults, 7 yearlings, 14 fawns when marked) were tracked for an average of 20.9 mo. The usable radio fixes averaged 76.2 (range 7–286) per female (Table 1). The 14 dispersing females moved an average of 44.9 ± SE 6.4 km from their natal range, whereas the 11 migrators moved an average of 14.0 ± SE 7.2 km.

One female moved in February, 5 females moved in March, 5 in April, and 7 each in May and June. The February–April movements were made by females ≥20 mo old. The fawns (10–12 mo old) moved in May or June.

Nineteen of the 25 females were marked on the edge of the study areas where subordinate groups tended to reside (Nixon *et al.*, 2010), and 18 of these 19 females were members of social groups considered subordinate. Only 5 females were offspring of a dominant matriarch or 1 of her daughters (social status was unknown for 2 females). Sixteen females were pregnant when they emigrated (6 pregnant for the first time), 5 were barren, and the reproductive status was unknown for the remaining 4 females. Twelve females left the natal range without kin support, whereas 13 traveled with a relative (2 with mother, 4 with a sibling, 7 with offspring of the previous year).

For the new home ranges selected by dispersing and migrating deer, there were no significant differences in the composition of home ranges selected by migrating (N = 11) versus dispersing (N = 14) females in the total patch richness, nearest neighbor distance, average forest patch density or size, forest type (upland vs bottomland), the percentage of landscape in forest, grassland, or cropland, or in the roads and houses present (t = 0.04–1.65, P = 0.11–0.98). Thus, we treated the 2 groups as a single sample.

Travel Characteristics

A comparison between a straight line drawn from the center of the natal range to the center of the new range indicated that travel deviated only 8.2% from a straight line. However, the matched pair test indicated the actual path deviated by 2.33 ± SE 0.53 km and was significantly different from zero (P = 0.0003). For deer emigrating from the EC study area, with the general river corridor at 45°, the mean direction for the 14 females was 59° or eastward, a significant deviation from the direction of the river (P = 0.002).

Comparing the actual route with the simulated alternate routes (30°, 60°, or 90°), EC females crossed rivers significantly more often (F = 6.9, P = 0.009) and encountered significantly more forest patches (6.6 vs. 1.8, F = 26.8, P < 0.0001), but did not differ in the number of roads (F = 0.74–1.52, P = 0.23–0.39) or power lines crossed (F = 0.04–1.26, P = 0.39–0.85). Routes selected by females from the WC and NO areas, with no river corridor, did not differ from the simulated routes in the number of forests, rivers, roads, and high voltage power lines crossed during their travels.

A comparison between forest and cropland portions of the natal ranges, travel corridors, and new home ranges found that the travel corridor had more cropland (63% in travel corridor, 43% in new home range, 30% in natal range; F = 8.4, df = 2, 72, P = 0.0005), but all 3 locations were similar in the amount of forest cover encountered (35–42%), and all differed from random sites (P < 0.001) (Table 3).

The stepwise regression for distance traveled using 13 variables resulted in 3 significant variables (vegetative stage, movement type, and number of houses encountered) accounting for nearly all the variance (R^2 = 0.83). However, these results were biased by the longer distances moved by dispersing females and the disparity in initiation of movement between fawns (May–June) and older deer (February–April). The farther deer dispersed, the more houses were present in the selected new home range, perhaps an indication that these females were becoming less discriminating as parturition approached.

Home Range Characteristics

Females selected a new home range with significantly more forest (35.7% vs. 9.0%), more permanent grassland (19.7% vs. 2.2%), and less cropland (43.5% vs. 75.5%) than was indicated as available in our random sections from 10 counties where the 25 females selected a new home range ($F = 4.7–34.2$, $P = 0.03–< 0.001$) (Table 3). Females in EC Illinois settled on areas with more total patch richness, forest patch density, and forest patch size compared to random sites ($P = 0.007$). Northern Illinois females also selected sites featuring more forest patches of larger size ($P = 0.01$) compared to random sites. Home range size was positively associated with the percent of cropland present in new home range ($F = 10.6$, $P = 0.003$) and negatively associated with the percent of forest cover present ($F = 7.3$, $P = 0.01$). This result was biased by the large ranges occupied by the 3 females that settled on landscapes entirely devoid of forest cover. However, final home range size was not influenced by patch richness, forest patch number and size, forest type and age, or the distance between forest patches ($P > 0.05$) (Table 3).

On new home ranges, the presence or absence of conspecific females (17 present, 8 absent) did not differ as to patch richness, nearest neighbor distance, size or density of forest patches, or with random sites (Table 3). In a comparison of natal, new home, and parturition ranges, patch richness was significantly higher in the new home range ($F = 7.6$, $df = 2, 65$, $P = 0.001$) (Table 3). There were more forest patches present in the parturition ranges than in the other 2 ranges ($F = 15.7$, $df = 2, 64$, $P < 0.0001$), but the natal ranges contained larger patches ($F = 15.2$, $df = 2, 62$, $P < 0.001$). Parturition sites featured fewer houses ($P = 0.04$) and roads ($P < 0.001$) than the natal or new home ranges.

Five females stopped emigrating because their way was blocked by an obvious obstacle, 3 by an urban area, 1 by the expansive Interstate-72 highway which she never crossed, and 1 female by the 1.6 km wide cultivated Illinois River valley (Table 3). An additional 7 females traveled within a watershed that progressively lost forest cover. These females stopped at the site of the last reasonably abundant forest cover after first probing ahead and then returning along the more open watershed. Six additional females stopped in the first woodlot encountered after leaving the natal range. There was no obvious reason for stopping for 7 females (5 pregnant, 1 barren, 1 reproductive status unknown) other than, in some cases, impending parturition for 5 of 7 females. We compared the landscape composition of home ranges of females stopped by an obvious obstacle ($N = 5$) with those that were not stopped ($N = 20$) to see if females that stopped had home range characteristics different from those with a more open choice. We found no significant difference in the amount of forest, grasslands, and croplands present between the 2 groups ($P > 0.05$).

Costs of Emigration

We used life span and fawn survival to assess the costs of locating away from the natal range and the loss of kin support. Stepwise regression using life span as the dependent variable and 13 landscape and human intrusion variables occurring in each new home range, found only the type of movement (disperse or migrate) significant ($R^2 = 0.50$). We did not find any significant effect of composition in the new home range on whether or not our females lost 1 or more fawns before weaning (P > 0.20). Of 6 pregnancies (by 5 females) where fawns were lost, 4 occurred by the end of August.

DISCUSSION

Emigrating females in WC Illinois did not select habitats significantly different in composition from random sites. Apparently when forest cover is abundant (in this case about 20% of the landscape), dispersing female's selection of a parturition site depends on factors other than habitat composition such as obstacles encountered, impending birth, or avoiding human intrusions. However, the more forested landscape in WC Illinois did not reduce the distance females traveled before settling on a new home range (Table 1).

In areas of Illinois where forest covers <5% of the landscape, emigrating females must search for forest cover sufficient to protect fawns from disturbance and predation. Marked females from EC and NO Illinois selected a landscape with more forest and permanent grassland present than was available in the general landscape. Three NO females (#159, #155, #196) each selected a range with no permanent forest cover except fence lines and narrow hedgerows. Two of these were from subordinate social groups, and both of these deer were pregnant. The remaining female dispersed from a dominant social group, her immediate reproductive status unknown. Selections of forest-free areas indicate some females in Illinois appear to use agricultural lands in a similar fashion as roe deer do in Europe, including settling in areas entirely devoid of forests (Harris and Woollard, 1990).

Home range habitat characteristics selected by migrating and dispersing females differed only in the distance between forest patches, with migrating females selecting the more scattered forest cover. These migrating females did not have to winter on these ranges and could accommodate a summer-fall range with less forest cover. Migratory females live longer than dispersing females, a result of their vacating hunted summer ranges for the more protected natal range (Nixon *et al*., 2008). We do not know how or when deer determine the suitability of a site for year-round occupancy, but selection of a cover-deficient site necessitates movement away in late fall. We suspect deer do not initially determine this suitability but depend on circumstances to dictate a movement response as the seasons change. The return to the natal range is the easier choice because females are familiar with the route back to the natal range.

Both types of movement behavior used nearly a straight line during emigration, readily crossing rivers, roads, and high voltage power line rights-of-way. Travel corridors traversed significantly more cropland than was present in the selected new home range, an expected result given Illinois' agriculturally dominated landscape. Travel distance was influenced by plant phenology (farther distance after leaf out), but age was the primary cause, with fawns moving later and farther than older deer.

There is almost no literature on how emigrating deer orient themselves during a dispersal movement (Andreassen *et al*., 2002). Long *et al*. (2010) found that male immigrants were influenced in their selection of a travel route by the presence of mountain ridges on 1 study area in Pennsylvania but not from a second area. These Pennsylvania deer also tended to avoid 4-lane highways, a feature of emigration detected for only 1 of our females (#262). The presence of roads can alter behaviors by affecting home range size, escape responses, and physiology for deer exposed to them (Trombulak and Frissell, 2000), but Illinois deer are exposed to many road crossings almost from birth. The natal ranges for our study females were surrounded by roads with at least moderate traffic.

A forested travel corridor existed within the EC study area but not on the WC and NO study areas, and 10 of 14 EC females used the river corridor to exit their natal range. Four of these females then left the river corridor and traversed agricultural fields to the site of new home range selection. Three of these females selected ranges without other females present, perhaps because of resident female harassment during travel or that 3 of these females were considered subordinate in the social order on their natal range. One female (#507) was born into a dominant group, but also selected a female-free location for a parturition site.

Most of our study females moved rapidly and in nearly a straight line between the natal and final home range, considered the simplest and most efficient way to complete an emigration movement (Zollner and Lima, 1999; Wiems, 2001). Long *et al.* (2010) also observed that emigrating male white-tails moved quickly without much wandering and, because of this behavior, felt that males were not searching for specific habitats. Kilgo *et al.* (1996) found that dispersing deer also traveled rapidly in nearly a straight line while moving through unfamiliar landscapes in Florida. There appeared to be no avoidance of rivers, major roads, or high voltage power lines during female travels between ranges in Illinois. In fact, 10 of 25 females settled on ranges with a high voltage power line present and were seen bedded and feeding within the power line rights-of-way. Except during flooding episodes, rivers encountered were generally <50 m wide and presented no obstacle to continued movement.

Parturition ranges for all 25 females contained fewer houses and roads and more forest patches than either the natal ranges or the larger new home ranges. Storm *et al.* (2007) reported that breeding females avoided occupied houses during the parturition season in southern Illinois. More forest cover has been associated with increased fawn survival in Illinois (Rohn *et al.*, 2007) and a somewhat higher ratio of resident females to migrating females in the northern plains (Grovenburg *et al.*, 2011). Coyotes are less efficient hunters in forest cover, so more forest cover should improve fawn survival (Richer *et al.*, 2002; Rohn *et al.*, 2007). Rohn *et al.* (2007) found that more edge and larger forest patches improved fawn survival by reducing predator risk in southern Illinois. They also noted that smaller forest patches surrounding the larger forest blocks reduced home range size and provided more feeding opportunities (Rohn *et al.*, 2007). Our marked females also selected ranges for increased patch density and fewer human activities in the parturition range. Fawn survival appeared to be independent of landscape composition, similar to observations in Pennsylvania where patch diversity, amount of forest edge, and road density had no significant affect on fawn survival (Vreeland *et al.*, 2004).

Life span of females was affected by the amount of forest cover, with larger forests more likely to offer increased hunting opportunities and a lower life expectancy. This is the reverse situation found for deer in South Dakota where more forest cover improved life span (Klaver *et al.*, 2008). In Illinois, even the larger forest patches were generally <100 ha in size (Iverson *et al*., 1989). Harden *et al*. (2005) found that the larger blocks of forest cover attracted more deer hunters in southern Illinois.

The new home range selected by our marked females tended to be elongate in shape, considered an optimum shape for exploiting a patchy environment (Ford, 1983). Home range size was affected by the amount of cropland encountered with females encompassing a much larger home range as forest cover declined, similar to that observed in SW Minnesota (Walter *et al*., 2009). Home range size for the 3 females with no forest cover present ranged up to 1,000 ha with daily movements often 2–3 km, similar to home ranges and movements described for deer in South Dakota (Sparrowe and Springer, 1970; Grovenburg *et al*., 2009). Two of the 3 females were migrants, returning to their natal range each winter after corn harvest. The third female sheltered in unpicked corn during winter.

A first pregnancy for 6 females that delayed emigration until late May–early June meant that these females did not have a lot of time before parturition to find a new range. As noted by Orians and Wittenberger (1991), the later emigration is delayed before some important event (parturition, winter weather, etc.), the poorer the options available. Estrogen levels continue to increase from 6 wk prepartum to parturition, and the estrogen/progesterone ratio rises steeply during the final weeks of pregnancy (Plotka *et al*., 1977) which may stimulate pregnant females to disperse quickly close to parturition. Five of these females were dispersers, and 1 was a migrant. Even though forest cover was quite limited for 3 of these females, all 6 reared fawns to weaning age, and 2 of these females survived >2 yr on their new range.

Some of the marked fawns and yearlings departed the natal range without kin support (10 moved alone, 2 with unknown deer), relying on instinct and perhaps the knowledge gained by familiarity with the characteristics of the natal range (forest age and composition) to guide their selection process. Forests surrounding all sites were very similar to the natal ranges for these females in age and flooding frequencies (Nixon *et al*., 1991). Deer obviously use olfactory cues, sounds emanating from the environment, and their vision to settle on or avoid areas as they travel (Andreassen *et al*., 2002). Six females had favorable winds blowing from the site of final settlement during at least 2 days while emigrating.

Six of our 25 females were known to have stopped for 1–3 days along the journey, perhaps accessing the qualities of the site for permanent occupancy (Opdam, 1990; Stamps, 2001). Emigration then continued perhaps because of resident deer aggression (Ozoga *et al*., 1982), insufficient cover before crops are high enough for concealment before a June movement (Nixon *et al*., 2007), insufficient forage (unlikely in an agriculture-dominated landscape), excessive human disturbance (Etter, 2001), or, for 5 of the 6 females, impending parturition.

Dispersal theory states that dispersing individuals should disperse to the first vacant territory and stop because longer movements incur more risks (Murray, 1967). However, in areas where forests cover is <5% of the landscape and human disturbances are frequent, dispersing females are forced to travel long distances before settling (Sparrowe and Springer, 1970; Zagata and Haugen, 1973; Kernohan *et al*., 1994; Nixon *et al*., 2007).

Migrating females move shorter distances and can afford to be less selective as to cover because they return to their natal range in winter. Unlike males, females, because of fawn rearing requirements, must be more selective in order to protect fawns when selecting a new range. Life threatening events such as hunting are not apparent when females select new ranges in late spring-early summer, but even so, life history attributes like dispersal or migratory behaviors that evolved as protection from predation, variable climates, or habitat alterations from the Pleistocene to the present day are still effective options in today's environment in Illinois (Danchin *et al*., 2001; Stamps, 2001).

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