

**HOME RANGE ATTRIBUTES AND MULTI-SCALE HABITAT SELECTION
OF RACCOONS (*PROCYON LOTOR*) IN NORTHERN INDIANA**

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For my Aunt Nancy who continues to motivate and inspired me

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ABSTRACT

Beasley, James C., M.S., Purdue University, December, 2005. Home range attributes and multi-scale habitat selection of raccoons (*Procyon lotor*) in northern Indiana. Major Professor: Olin E. Rhodes, Jr.

Numerous studies have examined home range attributes and habitat use for raccoons (*Procyon lotor*). However, information is lacking for this species regarding the effects of temporal shifts in resource availability resulting from agricultural activities, and few studies have investigated core-use areas or multi-scale habitat selection of raccoons. I examined the effects of crop availability and developmental stage on home range size, core area size, and multi-scale habitat selection of raccoons in northern Indiana. I used radio-telemetry to monitor 83 (48 male, 35 female) raccoons from May 2003 through June 2005. Telemetry data were partitioned into 3 seasons representing substantial shifts in resource availability to raccoons (non-growing period, crop-growing period, and corn-maturation period). I used fixed kernel and minimum-convex polygon methods to generate home range and core area estimates. Using compositional analysis, I assessed whether habitat selection differed from random for both sexes and ranked habitat types in order of selection seasonally across 3 spatial scales (second-order home range, second-order core area, third-order home range).

Mean fixed kernel home range (92 ± 6 ha; mean \pm SE) sizes of males were significantly larger than those for females (58 ± 7 ha), and were smaller than those reported from other fragmented agricultural landscapes. Home range sizes did not differ across seasons, despite the presence of a superabundant food source (corn) during the maturation season. Habitat selection differed across spatial scales, among seasons within spatial scales, and between sexes within seasons; however, intersexual and seasonal patterns of habitat selection were not consistent across spatial scales. When non-random

habitat utilization was observed, both sexes consistently selected forest cover over all other available habitats. Seasonal habitat selection patterns were most evident at the second-order core area scale, where raccoon selection of agricultural lands was greatest during the maturation season. Overall, my results suggested that in expansive rural landscapes raccoons can maintain small home ranges when food, water, and denning resources are readily available. However, the selection of forest cover across seasons and spatial scales indicated that raccoon distribution and abundance in fragmented landscapes is likely dependent on the availability and distribution of forested habitat.

CHAPTER 1

HOME RANGE ATTRIBUTES OF RACCOONS IN A FRAGMENTED AGRICULTURAL REGION OF NORTHERN INDIANA

ABSTRACT

For many wildlife species, agricultural landscapes undergo spatial and temporal fluctuations in the composition of food and cover annually with the planting and harvesting of crops. Raccoon (*Procyon lotor*) populations have flourished in agricultural landscapes, where crops increase foraging opportunities and efficiencies, and numerous studies have reported substantial damage to field corn (*Zea mays*) by raccoons. However, information is lacking regarding the effects of temporal shifts in food and cover resulting from agricultural activities on raccoon home ranges. I examined home range characteristics of 60 (33 male, 27 female) adult raccoons in northern Indiana from May 2003 through June 2005 to identify shifts in the size of home ranges and core-use areas among seasons defined by crop availability and crop developmental stages. Mean fixed-kernel cumulative home range (92 ± 6 ha; mean \pm SE), and core area sizes (20 ± 2 ha) of males were significantly larger than those for females (58 ± 7 ha, 13 ± 2 ha, respectively), and were smaller than those reported from other fragmented agricultural landscapes. Home range sizes varied little among seasons for either sex; however, home ranges of males were smallest during the maturation stage, whereas home ranges of females were smallest during the crop growing season. The results of my study suggest that even in expansive rural landscapes, raccoons can maintain small home ranges when food, water, and denning resources are readily available. Additionally, the lack of differences among seasonal home range sizes, despite the presence of an ephemeral

superabundant food source (i.e., corn) during the maturation season, was likely due to the proximity of foraging and denning resources across seasons.

INTRODUCTION

Vast expanses of native habitats have been cleared throughout the Midwest to facilitate crop production, resulting in landscapes characterized by complex mosaics of forested and cultivated habitats. Forest fragmentation resulting from changes in land use can have profound impacts on the distribution and persistence of many vertebrate species. For example, local densities of eastern gray squirrels (*Sciurus carolinensis*) and southern flying squirrels (*Glaucomys volans*) are negatively associated with the decreased patch size and increased isolation of forest patches that result from forest fragmentation (Nupp and Swihart 2000, Moore and Swihart 2005). Conversely, medium-sized, generalist predators often thrive in heterogeneous landscapes, where agricultural crops increase foraging opportunities and efficiencies (Litvaitis and Villafuerte 1996, Oehler and Litvaitis 1996, Heske et al. 1999). In particular, raccoons (*Procyon lotor*) have responded positively to changes in land use and increased forest fragmentation that characterize the midwestern U.S., and food resources provided through agricultural activities may artificially maintain population abundances of raccoons that are unparalleled in less disturbed landscapes.

Raccoons are highly opportunistic, which allows them to exploit ephemeral resources such as crops. In agricultural landscapes raccoon movements (Schneider et al. 1971) and den selection (Henner et al. 2004) are thought to be strongly influenced by the availability of row crops and other localized food sources (Johnson 1970). When available, corn is a primary food source for raccoons (Giles 1939, Kaufmann 1982) and the distribution of corn fields throughout agricultural landscapes can directly influence raccoon movements (Dijak and Thompson 2000). However, the degree to which corn influences raccoon movement behavior likely varies temporally with the availability and developmental stage of crops. Although raccoons likely avoid post-harvest crop fields, growing and mature crops provide a nearly continuous source of cover throughout the

landscape, presumably allowing individuals to travel among landscape elements more easily.

Raccoons utilize corn fields as a direct source of food primarily during the milk-stage of plant development, but continue to damage corn plants through harvest (Ohio DNR 2001, Humberg et al. 2005). During this brief (2-3 month) period, corn is a predictable and superabundant food source, which presumably allows raccoons to minimize energy expenditures associated with food acquisition. The concentration of corn likely allows raccoons to concentrate movements during the milk-mature stages, which should be reflected by reduced home range sizes during this period. In an agricultural region of Quebec, Rivest and Bergeron (1981) found that nearly half of the food volume consumed by raccoons consisted of corn, and during the fall, corn and apples (*Malus pumila*) constituted nearly all of their food. Soybeans (*Glycine max*) are another potential source of food for raccoons in the Midwest; however, Humberg et al. (2005) did not observe damage to soybeans by raccoons in any of 60 fields monitored for wildlife damage over a 2-year period. Although soybean fields clearly can provide raccoons with a dense source of cover, as well as access to invertebrates, corn is likely the primary agricultural resource for raccoons in the Midwest.

Data from agriculture and wildlife professionals indicate that wildlife damage to agricultural crops has increased significantly in recent years, especially crop damage by raccoons (Conover 1998, Conover 2002). Henner et al. (2004) observed shifts in habitat use and den-site selection by raccoons towards corn fields in response to corn maturation. In addition, numerous studies have documented raccoon use of corn fields at the scale of individual fields (e.g. Dorney 1954, Turkowski and Mech 1968, Sonshine and Winslow 1972), and Pedlar et al. (1997) detected a positive relationship between the amount of corn present and raccoon activity at a landscape scale. In Indiana, Lehman (1984) observed a considerable amount of raccoon activity in cornfields prior to ear development and a higher than expected use of fields by raccoons during fall. When corn is an available food source, raccoons (particularly females) utilize agricultural lands at a greater proportion than other seasons (Chapter 2) and likely concentrate movements around this predictable and superabundant resource. Female raccoons are more

physically constrained than males due to parturition and rearing; thus, females are likely more significantly influenced by variation in resource availability. Differential seasonal movement patterns of raccoons may have implications to the spread of diseases and the implementation of effective management strategies such as the distribution of bait vaccines in fragmented agricultural landscapes.

Core areas are locations of concentrated use within home ranges (Kaufmann 1962) that contain important resources such as den sites and quality foraging areas (Ewer 1968). Although core-use areas contain landscape elements biologically important to raccoons, few studies have investigated core-use areas of raccoons (Chamberlain et al. 2003). In this study I examined seasonal home range and core-use area sizes of raccoons in an agriculturally fragmented region of northern Indiana. My primary objectives were to 1) compare home range and core area size estimates between sexes, and 2) elucidate seasonal patterns of raccoon home range and core area size relative to crop availability and developmental stage. Male raccoons tend to maintain larger home ranges than females (Johnson 1970, Gehrt and Fritzell 1997, Chamberlain et al. 2003); therefore, I predicted that male raccoons would maintain larger home ranges than females during all seasons in the UWB. In addition, I predicted that raccoon home ranges would be smallest during the summer when raccoons should be concentrating movements around corn fields and largest during the period of crop absence when raccoons must travel widely to find sufficient food resources.

METHODS

Study Area

My 1,165 km² study area was located in the Upper Wabash River Basin (UWB) in northcentral Indiana, USA, encompassing portions of Grant, Huntington, Miami, and Wabash counties (Figure 1.1). The topography within the UWB was flat, with gently rolling areas near river drainages at an average elevation of 243 m above sea level. Approximately 96% of the land area within the UWB was privately owned, 71% of which was in agricultural use. The primary agricultural crops in the UWB were corn and

soybeans with small interspersed fields of hay and small grains. Only 13% of the basin was forested, compared to an average of 19% statewide. All contiguous forest tracts within the study area were confined to major drainages where frequent flooding or locally steep topography made the land unsuitable for crop production. The remaining native forests (predominantly oak-hickory-maple [*Quercus-Carya-Acer*]) in the basin were highly fragmented. Across 35 landscapes analyzed within the UWB by Moore and Swihart (2005), 75% of the forest patches were <5ha, 50% were <2ha, and only 1% of patches were >100ha.

Raccoon capture and radio telemetry

I captured 105 raccoons (62 male, 43 female) in April-May and July-August 2003-2004. Trapping was conducted in 21 forest patches located throughout the study area. Patches were selected based on their size, degree of isolation, and juxtaposition with various habitat types, to encompass as many combinations of these variables as possible. Raccoons were captured using box livetraps (Tomahawk Live Trap Co., Tomahawk, WI) baited with commercial cat food. Traps were placed systematically throughout selected forest patches (e.g., along fallen logs and streams, near latrines, at the base of den trees, etc.) to maximize capture probabilities. I immobilized captured raccoons with an injection of Ketamine HCl and Xylazine HCl at rates of 10mg/kg and 0.8 ml/kg of estimated body mass, respectively (Hodges et al. 2000). All captured raccoons were ear-tagged, weighed to the nearest 0.1 kg, and aged (tooth-wear technique; Grau et al. 1970). Only raccoons ≥ 1 yr old were fitted with radio transmitters, and I attempted to distribute radios equally among sexes within forest patches. I fitted 83 raccoons (48 male, 35 female) with neck collars containing 250 g VHF mortality-sensitive radio transmitters (est. life span 2 years; Telemetry Solutions, Ltd.). Twenty-two additional raccoons were processed and released without transmitters because they did not meet my age or desired sex-ratio requirements. All trapping and handling methods conformed to Purdue University Animal Care and Use Committee policies under protocol 01-079.

I tracked radio-collared raccoons using truck-mounted dual yagi (null/peak) antennas equipped with digital readout compasses. During the crop developmental

period (May-October) raccoons were partitioned into focal groups (4-5 raccoons) and tracked 1 night/week. I recorded 1 location/hour (maximum of 9 locations/night) for each animal during the peak hours of activity (1 hour after sunset to 1 hour before sunrise). In addition, diurnal locations were obtained biweekly for all animals throughout the growing season to incorporate resting locations within home range boundaries. During the non-growing season (November-May), 1 location/week was recorded for each individual at arbitrary time intervals, although most locations (87%) were recorded during the peak hours of activity.

Radio telemetry precision (i.e., average error arc of bearings) and accuracy (i.e., the distance from the true location of the transmitter to the triangulated location) were assessed by collecting 92 locations from 347 bearings on 6 radio collars placed at 6 georeferenced positions unknown to the observer. Accuracy tests were conducted during the summer to represent the habitat conditions present when the majority of the data collection would occur. Radio collars were distributed throughout the study area in areas utilized by radio collared raccoons. To minimize bias, test transmitters were distributed at arbitrary distances from telemetry stations, representative of distances where radio-collared raccoons were located. Precision of bearings and triangulation error were estimated to be $\bar{x} = 8.75^\circ \pm 0.4038$ and $\bar{x} = 81\text{m} \pm 4.65$, respectively (mean \pm SE).

Raccoon locations used for home range calculations were estimated by recording 2 or more bearings (usually 4) from telemetry stations along roads. The spatial coordinates of telemetry stations were defined using a handheld GPS. To minimize telemetry error, locations were triangulated from stations as close to raccoons as possible in the shortest time interval possible. Due to the extensive road network in the UWB, all locations were recorded within 1 km of the telemetry stations. Azimuths for a single radio location were recorded within a 20-min interval to reduce error associated with raccoon movement. However, most azimuths (> 90%) were recorded within a 15-min interval. I used all bearings for locations consisting of 3 or more bearings, regardless of the minimum angle difference between bearings, but defined an ad-hoc minimum angle difference of 30° for all locations consisting of only 2 bearings.

Telemetry bearings were imported into Locate III (Nams 2005) to calculate 95% maximum likelihood confidence ellipses and individual point locations. I converted all locations to Universal Transverse Mercator coordinates for further analyses. Each location was examined with Locate III to identify erroneous bearings. Bearings that did not intersect any other bearings taken for that transmitter and all bearings failing to meet my accuracy criteria were discarded.

Home-range analyses

I partitioned telemetry data into 3 seasons based on crop availability and developmental stage: non-growing (26 October - 19 May), representing the period of crop absence between crop harvest and early stages of corn development when cover is reduced to forest patches or wooded corridors; growing (20 May - 21 July), encompassing the V5-R2 stages of corn growth, when the presence of crops forms a nearly contiguous source of cover throughout the landscape; and maturation (22 July - 25 October), representing the milk-mature (R3-R6) stages of corn development when corn is a primary food source for raccoons. I selected seasons based on temporal shifts in food and cover observed in crop fields surrounding radio-collared raccoons. Specific dates for each period were delineated based on crop developmental data combined with raccoon damage data collected in a concatenate 2-year study in the same landscape (Humberg et al. 2005). Substantial damage to field corn by raccoons does not occur until the milk (R3) stage of plant development (Lehman 1984, Humberg et al. 2005). Within my study area this occurred on approximately 22 July in both 2003 and 2004, and substantial damage to field corn by raccoons was not observed until that period in the growing season.

I used the Home Range Extension (HRE) in Arc View (Rodgers and Carr 2002) to calculate fixed-kernel (FK; Worton 1989), and minimum-convex-polygon (MCP; Mohr 1947) home range estimates. I used biased cross-validation (BCV) to calculate the smoothing parameter based on 95% and 50% isopleths of the space utilization distribution (UD). The MCP method has historical prominence but is sensitive to sample size and can contain locations where the animal never goes (White and Garrott 1990,

Millsbaugh and Marzluff 2001); therefore, I report MCP estimates only to draw comparisons between my findings and those of previous studies.

Estimates of Schoener's index (Schoener 1981) and Swihart and Slade's index (Swihart and Slade 1985) calculated with the HRE indicated that my estimates included data that were moderately autocorrelated. However, the exclusive use of independent observations is unnecessary when estimating home range size with either kernel or polygon methods (Swihart and Slade 1997). Otis and White (1999) added that estimates based on sampling designs that predefine a time frame of interest and generate representative samples of an animal's movement during this time frame should not be affected by the length of the sampling interval and autocorrelation.

I calculated cumulative home ranges (95% UD) and core areas (50% UD) for all raccoons with > 30 locations that were tracked for at least 4 months. I used the term "cumulative" rather than annual because most raccoons were monitored for more than 1 year, but lacked enough locations to calculate 2 disparate annual home range estimates. Seaman et al. (1999) recommended home range estimates should include 30 or more locations, preferably at least 50 within a given time frame when using kernel estimators. To assess possible sample size bias among cumulative FK home range estimates due to the inclusion of individuals containing < 50 locations I compared home range size with the number of locations used in the home range estimate using linear regression. Seasonal FK home range (95% UD) and core areas (50% UD) were calculated for all raccoons with ≥ 25 locations in a given season. Seasonal home range contour intervals (95% UD) were overlaid onto the habitat map to determine the mean number of forest patches intersected by home range boundaries across seasons. I used Chi-square to test for differences in number of forest patches intersected across seasons. Analysis of Variance (ANOVA) was performed to determine whether mean home range and core area sizes differed between sexes, among seasons, or as a function of the interaction of these variables (proc univariate; SAS 2002). However, the residuals from this analysis were non-normally distributed and thus non-parametric tests were used for further analyses. Mann-Whitney U-tests and Kruskal-Wallis H-tests were used to examine differences in median ranks among groups. I used Mann-Whitney U-statistics to test for

differences in male and female cumulative home range and core area sizes. I used Mann-Whitney U-statistics to evaluate differences in home range and core area sizes between sexes within seasons and Kruskal-Wallis H-tests to evaluate differences in home range and core area sizes among seasons for each sex (SPSS 2003).

RESULTS

A total of 7,529 radio locations met my accuracy criteria. I estimated cumulative home ranges and core areas for 60 individuals (33 M, 27 F) monitored between May 2003 and June 2005. The number of radio locations used to estimate cumulative home range sizes ranged from 30-220 ($\bar{x} = 123 \pm 9$, $n = 33$) for males and 35-241 ($\bar{x} = 127 \pm 12$, $n = 27$) for females. I failed to detect an effect of the number of radio locations used to estimate cumulative home ranges on home range size ($F = 1$, $P = 0.322$), indicating that a minimum of 30 locations was sufficient to avoid bias in home range estimates associated with sample size. Male cumulative home range sizes ranged from 29 to 128 ha for MCP and 32 to 191 ha for FK. Cumulative home range sizes of females ranged from 12 to 146 ha for MCP and 6 to 160 ha for FK. Mean cumulative FK home range and core area sizes of males (92 ha, 20 ha) were larger than those for females (58 ha, 13 ha) at both 95% (Mann-Whitney $U = 198.0$, $P < 0.001$) and 50% ($U = 223.0$, $P = 0.001$) UD levels, respectively.

I estimated 116 seasonal home ranges for 56 raccoons (Table 1.1). I failed to detect differences in the mean number of forest patches intersected by home range boundaries across seasons ($\chi^2 = 0.001$, $P = 0.999$). The number of locations used to estimate seasonal home range sizes ranged from 25-107 ($\bar{x} = 55 \pm 2.86$, $n = 62$) for males and 25-132 ($\bar{x} = 58 \pm 3.87$, $n = 53$) for females. Mean home range and core area sizes of males were larger than those of females during the growing, ($U = 152$, $P = 0.001$; $U = 164$, $P = 0.002$), and maturation ($U = 159$, $P = 0.021$; $U = 149$, $P = 0.011$) seasons, but only marginally larger during the non-growing season ($U = 19$, $P = 0.063$; $U = 21$, $P = 0.094$). Fixed kernel home range sizes of males ranged from 21 to 144 ha during the non-growing season, 11 to 166 ha during the crop growing season, and 34 to 161 ha during the corn maturation season. For females, FK home range sizes ranged from 14 to

102 ha during the non-growing season, 5 to 90 ha during the crop growing season, and 16 to 150 ha during the maturation season. I failed to detect seasonal differences among home range or core area sizes of males ($\chi^2 = 0.58, P = 0.75$; $\chi^2 = 0.17, P = 0.92$) or females ($\chi^2 = 1.20, P = 0.37$; $\chi^2 = 1.79, P = 0.41$) at either 95% or 50% UD levels respectively.

DISCUSSION

Raccoons in the UWB exhibited small cumulative FK (male = 92 ha, female = 58 ha) and MCP (male = 70 ha, female = 52 ha) home range sizes relative to those previously reported for fragmented agricultural landscapes, but well within the reported range for this species (4-2560 ha; Gehrt 2003). Additionally, raccoons in the UWB exhibited smaller cumulative FK (male = 20 ha, female = 13 ha) and MCP (male = 16 ha, female = 11 ha) core areas than those previously reported for this species (40 ha for males, 24 ha for females; adaptive kernel; Chamberlain et al. 2003). The smaller home range sizes observed in the present study relative to other studies conducted in agricultural landscapes were likely because of the concentrated distribution of resources (i.e., den sites, water, food) within the UWB and the concentrated distribution of females within forest patches throughout the study area (Gehrt and Fritzell 1997), as well as the prevalence of human habitations throughout the landscape. Previous studies of raccoon home ranges in highly fragmented regions have primarily occurred in prairie habitat (Fritzell 1978, Kamler and Gipson 2003), although Lehman (1984) also examined home ranges of raccoons in an agricultural landscape similar to that of the current study. Agriculture (particularly corn) is typically limited or non-existent in prairie landscapes; thus, raccoons in prairie landscapes must utilize native food resources to a greater degree than in landscapes containing an abundance of corn. Native food resources typically are less abundant, unpredictable, and less concentrated than corn, likely forcing raccoons to utilize larger areas to attain metabolic requirements.

The largest home range sizes reported for raccoons (806 ha for females, 2560 ha for males; MCP) were observed in a highly fragmented prairie region of North Dakota (Fritzell 1978). The extensive home ranges observed by Fritzell (1978) relative to the

present study were likely due the limited presence of corn and the extensive distribution food, water, and den sites in his study site. In a fragmented prairie region of Kansas, Kamler and Gipson (2003) reported mean MCP home range estimates of 266 ha for males and 122 ha for females. Although Kamler and Gipson only monitored 8 individuals (4 M, 4 F), their mean home range size estimates exceeded the largest male home range size and 89% of the female home range sizes observed in the present study. Thus, despite their limited sample size, home range estimates reported by Kamler and Gipson (2003) clearly exceeded those observed in the UWB. In an agricultural region of southern Indiana, Lehman (1984) reported mean MCP home ranges of 486 ha and 264 ha for male and female raccoons, respectively. Lehman's (1984) study was conducted in a more heavily forested region of Indiana than was the present study; thus, the larger home ranges observed in his study may reflect differences in the distribution of resources (i.e., den sites, water, corn) among the 2 agricultural mosaics. Each of the afore mentioned studies utilized polygon methods and a similar number of locations to delineate home range boundaries relative to those used in the present study; thus, variation in home range estimates among studies was likely due to environmental factors and not variance in home range delineation methods.

Small home ranges are typical of raccoons inhabiting areas of high population density and abundant food resources (Hoffmann and Gottschang 1977), which typically occur in urban environments. Raccoons (especially females) in fragmented agricultural landscapes exhibit a high fidelity to forested habitat (See Chapter 2), which often is limited in such landscapes. Thus, raccoons in fragmented agricultural landscapes likely are highly concentrated in forest patches, especially those patches containing water sources. The high concentration of raccoons within forest fragments diminishes the need for males to travel in search of receptive females. The availability of water is also considered by many to be a primary factor limiting raccoon distribution and abundance (Stuewer 1943, Dorney 1954, Kaufman 1982), and raccoons often concentrate their movements along streams or other bodies of water (e.g. Sherfy and Chapman 1980). Within the UWB, free water was primarily limited to streams and vernal pools located in

forest patches. Thus, the concentration of water within forest patches likely accentuated the importance of forested habitat to raccoons in the present study.

When crops are available, forest edges juxtaposed with agricultural crops provide highly productive foraging areas proximate to den locations. Within the UWB, forest patches were typically surrounded by crop fields, and in the absence of crops, food resources were primarily restricted within forest patches. Thus, food resources within the UWB were highly concentrated around forest patches regardless of crop availability. The maintenance of small home range sizes across seasons suggested that in the absence of agricultural crops, waste grain and food sources associated with forested areas likely provided sufficient food resources for raccoons to attain their energetic requirements. This hypothesis is supported by the observation that the mean number of forest patches intersected by home ranges of raccoons did not differ among seasons.

Raccoons in the UWB exhibited considerable variance in home range estimates among individuals and between sexes. Male raccoons maintained significantly larger home ranges and core areas than females during the growing and maturation seasons, and male cumulative home ranges and core areas were nearly twice as large as those of females across seasons. The larger home range sizes exhibited by males concurs with previous studies that have examined gender-specific differences in raccoon home range. Male raccoons tend to maintain larger home ranges than females (Johnson 1970, Gehrt and Fritzell 1997, Chamberlain et al. 2003), likely because of a polygamous or promiscuous mating system (Gehrt and Fritzell 1997).

Previous research indicates that changes in raccoon home range sizes relative to season appear to be driven by harsh winter weather conditions (Schneider et al. 1971, Glueck et al. 1988), the distribution and quality of resources (Johnson 1970), and the maternal responsibilities of females (Ellis 1964). Raccoons in the UWB did not exhibit significant fluctuations in seasonal home range or core area sizes, despite the presence of a superabundant and predictable food source during the corn maturation season. However, crop depredation data collected concurrently within the same landscape as my raccoon movement data identified extensive use of cornfields by raccoons during the corn maturation season (Humberg et al. 2005). Humberg et al. (2005) reported that during the

growing seasons of 2003 and 2004, over 87% of 73,100 corn plants damaged by wildlife in 100 corn fields surveyed in the UWB were damaged by raccoons, and that over 90% of the damage caused by raccoons occurred during the milk-mature stages of plant development (Figs. 1.2, 1.3). In addition, > 85% of the damage by raccoons to corn occurs within 30 m of forested edges (Beasley, unpublished data). Therefore, the concentration of raccoon damage along forested edges may have masked seasonal variation in home range and core area size relative to corn availability. Thus, despite the lack of seasonal changes in raccoon home range size relative to the maturation season, empirical evidence provided through crop depredation surveys indicated that raccoons utilized corn fields extensively during the maturation season relative to other crop developmental stages.

Although raccoons did not exhibit significant seasonal variation in home range sizes, male FK home ranges and core areas were smallest during the maturation season, which provided evidence that male raccoons concentrated movements when corn was readily available; however, this trend was not observed for females. The concentration of movements by males during the corn maturation season corresponded with the substantive damage to field corn that was observed by Humberg et al. (2005) and the selection of agricultural lands by raccoons during the maturation period (Chapter 2). The disparate trends in home range size exhibited by females likely were due to the reproductive constraints on females, which are absent for males. Parturition typically occurs in April at northern latitudes (Sanderson 1987, Gehrt 2003), and during the rearing period females restrict movements around natal dens (Ellis 1964). Raccoon cubs are restricted to their natal dens for ~12-15 weeks following parturition (Schneider et al. 1971, Gehrt and Fritzell 1998), which corresponded with end of my non-growing period and the entire crop growing period. In the present study female home ranges were smallest during the crop growing period, lending further support to studies that have observed a reduction in home range sizes of females during the rearing period.

The lack of significant seasonal variation in home range sizes of raccoons was likely the result of the proximity of productive foraging areas, denning locations, and water sources within the agricultural mosaic of the UWB. The examination of daily

movements throughout the developmental cycle of crops may better elucidate the influence of agricultural crops on raccoon movements. However, substantial shifts in food resources within less productive landscapes may have a greater effect on raccoon movements than was observed in the UWB. The results of my study suggested that despite their mobility, raccoons can maintain small home range sizes within landscapes containing proximate sources of food, water, and shelter, even in expansive rural areas.

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Table 1.1. Home-range characteristics [mean (SE)] of male and female raccoons in the Upper Wabash River Basin, Indiana. Cumulative and seasonal home-range sizes (95%) and core areas (50%) were calculated with fixed-kernel (FK) and minimum-convex-polygon (MCP) methods based on data collected from May 2003 through June 2005. (non-growing: 26 October - 19 May; growing: 20 May - 21 July; maturation: 22 July - 25 October). Standard errors for estimates of means are given in parentheses.

Period	Sex	N	Fixed Kernel		Minimum-Convex-Polygon	
			Home Range - ha	Core Area - ha	Home Range - ha	Core Area - ha
			Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)
Non-growing	M	9	93 (15)	20 (4)	36 (6)	7 (2)
	F	9	50 (11)	11 (3)	20 (4)	8 (3)
Growing	M	29	85 (8)	19 (2)	59 (7)	13 (2)
	F	22	43 (5)	10 (1)	31 (3)	10 (2)
Maturation	M	24	80 (7)	18 (2)	49 (5)	11 (2)
	F	22	59 (7)	13 (2)	37 (6)	10 (2)
Cumulative ^a	M	33	92 (6)	20 (2)	70 (5)	16 (2)
	F	27	58 (7)	13 (2)	52 (7)	11 (2)

^a Home range estimates calculated from all collected radio locations pooled across years.

Figure 1.1. Study area (1166 km²) in northcentral Indiana, USA, encompassing the counties of Grant, Huntington, Miami, and Wabash. The land cover map illustrates the intensity of row crop agriculture, as well as the 2 principal areas of contiguous forest, which surround the Mississinewa and Salamonie reservoirs.

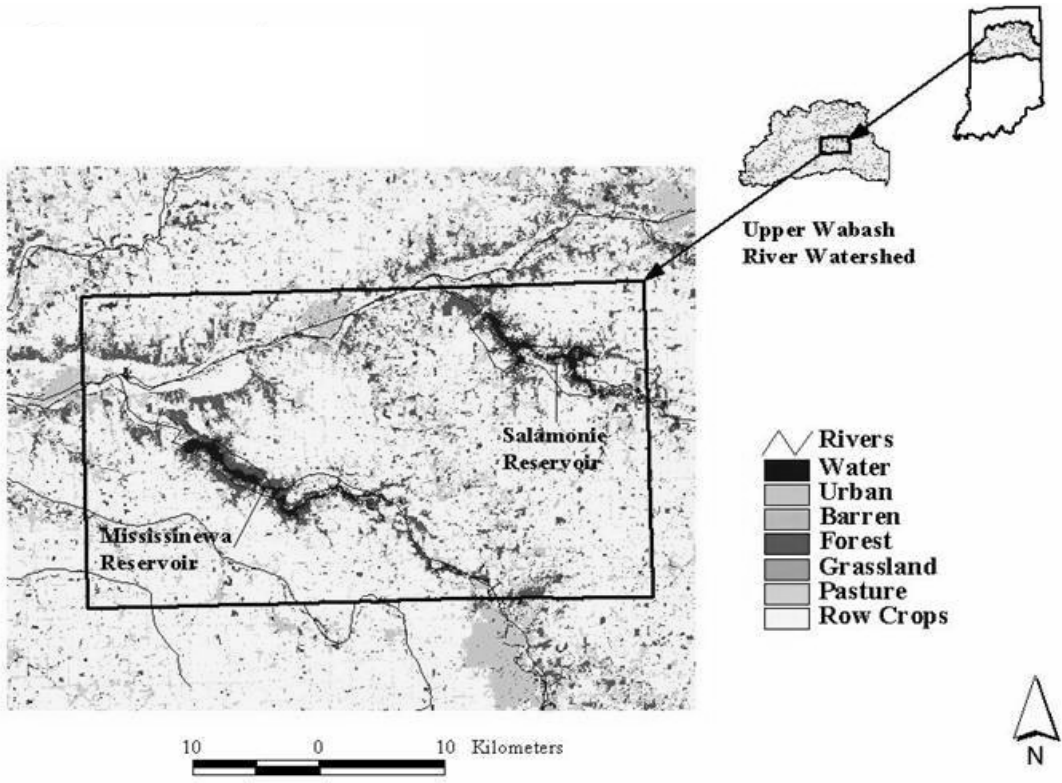


Figure 1.2. Temporal patterns of raccoon depredation to corn in 100 fields surveyed in northern Indiana during 2003 and 2004 by Humberg et al. (2005). The vegetative stage of corn growth (V_) begins with the emergence of the first collared leaf, generally in early May. The reproductive stage (R_) begins with the emergence of silk (usually early to mid-June) and continues until plant maturity (early September).

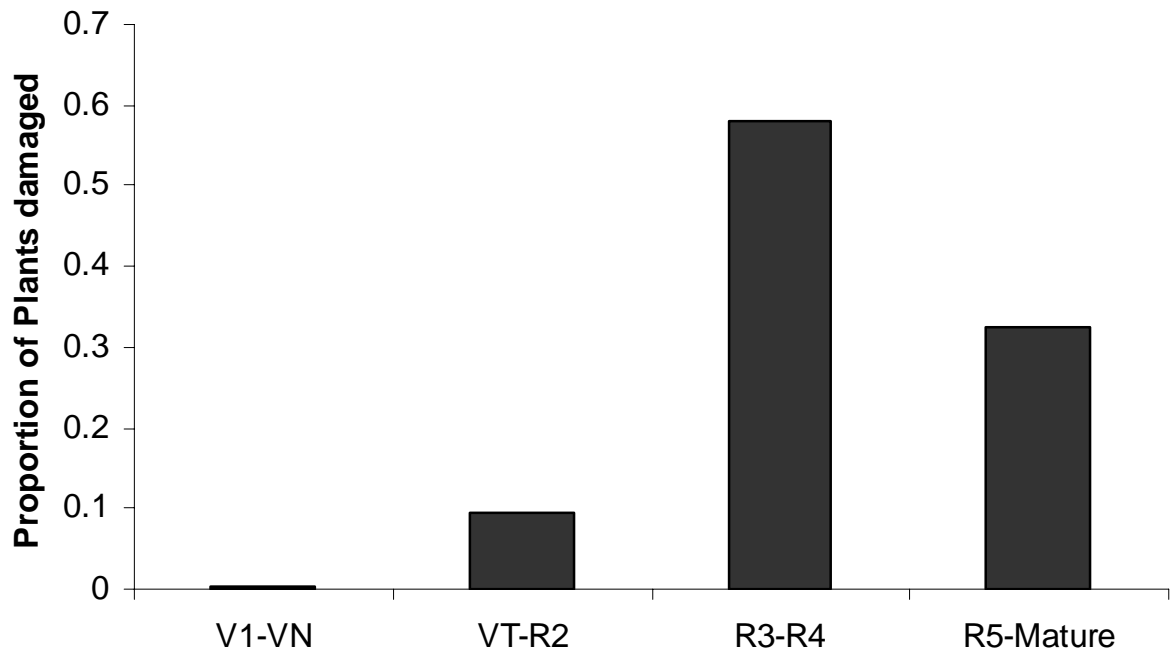
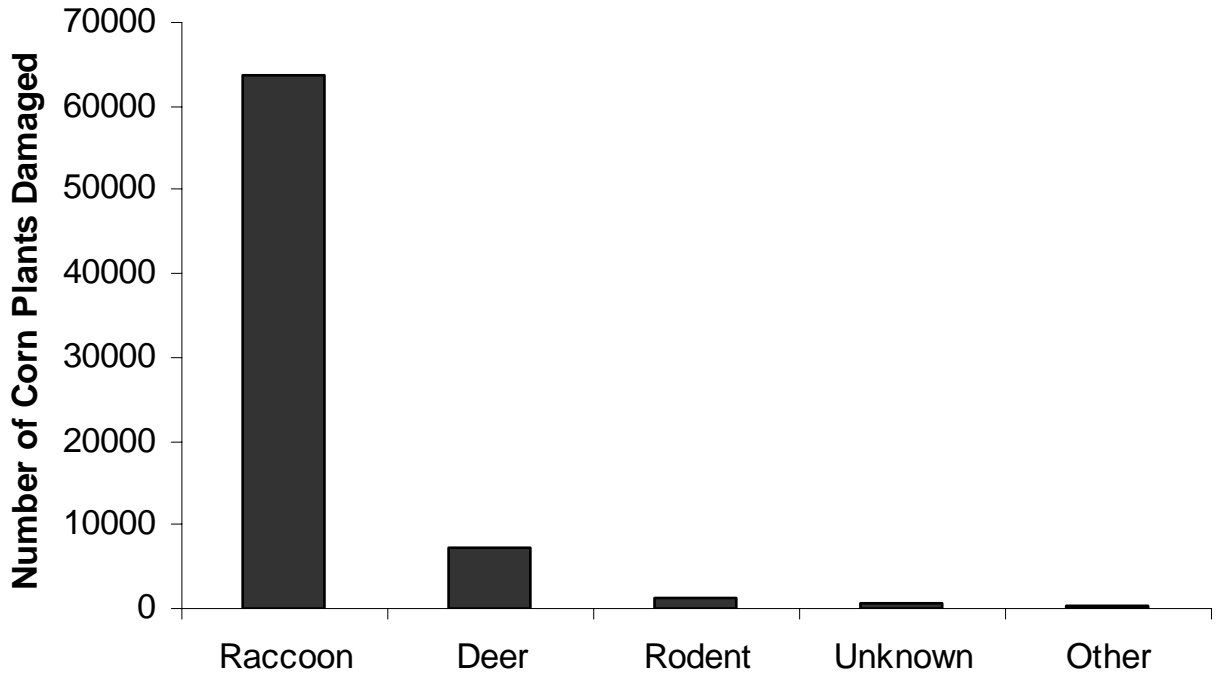


Figure 1.3. Number of corn plants damaged by wildlife species in northcentral Indiana during the 2003 and 2004 growing seasons based on data collected by Humberg et al. (2005). Fifty-three fields were surveyed in 2003 and 47 fields in 2004 at equidistant intervals throughout the entire growing season (May through October).



*Rodent=includes beaver, rabbit, groundhog, and small rodents

CHAPTER 2

EFFECTS OF CROP AVAILABILITY AND DEVELOPMENTAL STAGE ON MULTI-SCALE HABITAT SELECTION BY RACCOONS IN NORTHERN INDIANA

ABSTRACT

Although numerous studies have examined habitat use by raccoons (*Procyon lotor*), information regarding seasonal habitat selection related to resource availability in agricultural landscapes is lacking for this species. Additionally, few studies using radio-telemetry have investigated multi-scale habitat selection or core-use areas by raccoons. I examined seasonal habitat selection of 56 (31 male, 25 female) adult raccoons at 3 spatial scales (second-order home range, second-order core-use area, and third-order home range) in northern Indiana from May 2003-June 2005. Using compositional analysis, I assessed whether habitat selection differed from random and ranked habitat types in order of selection during the non-growing period, crop growing period, and corn maturation period, which represented substantial shifts in resource availability to raccoons. Habitat rankings differed across spatial scales, among seasons within spatial scales, and between sexes within seasons; however, seasonal and intersexual patterns of habitat selection were not consistent across spatial scales. When non-random utilization was detected, both sexes consistently selected forest cover over other available habitats. Seasonal differences in habitat selection were most evident at the core area scale, where raccoon selection of agricultural lands was highest during the maturation season when corn was available as a direct food source. Habitat use did not differ from availability for either sex across seasons at the third-order scale. The selection of forest cover across all

seasons and spatial scales suggested that raccoon distribution and abundance in fragmented landscapes is likely dependent on the availability and distribution of forest cover within the landscape. The lack of consistency observed in the present study in habitat selection across spatial scales further exemplifies the need to examine multiple scales in habitat selection studies.

INTRODUCTION

Throughout the Midwest, much of the formerly forested area has been cleared for production of agricultural crops. This dramatic change in land use has created a complex mosaic of forested and non-forested habitat, in which forest patches vary widely in size and degree of isolation from other forest patches (Spetich et al. 1997). Within this agricultural mosaic, resources associated with crops are transient, and the availability of these resources likely influences the seasonal movement behavior and habitat selection of wildlife species that inhabit agricultural landscapes (Rivest and Bergeron 1981, Vercauteren and Hygnstrom 1997). Although numerous investigators have examined animal responses to habitat fragmentation (e.g. Nupp and Swihart 2000, Tigas et al. 2002, Swihart et al. 2003), few studies have identified the effects of crop availability or developmental stage on seasonal habitat selection by vertebrates (e.g., Gehring and Swihart 2003).

Medium-sized, generalist predators often thrive in heterogeneous landscapes, where agricultural crops increase foraging opportunities and efficiencies (Litvaitis and Villafuerte 1996, Oehler and Litvaitis 1996, Heske et al. 1999). Raccoon populations in particular have increased throughout much of the Midwest over the past 15 years (Gehrt et al. 2002, Plowman 2003), and are likely at or near record population levels in Indiana. The substantial increase in raccoon abundance is likely due to the conversion of native forest and prairie to agriculture (Page et al. 2001), combined with concomitant decreases in pelt prices (Gehrt et al. 2002). Individuals of this species vary greatly in terms of their use of habitats and are capable of surviving in virtually any landscape containing a water source, suitable den sites, and adequate foraging opportunities (Kaufmann 1982, Gehrt

2003). The plasticity demonstrated by raccoons allows them to exploit a wide variety of ephemeral habitats and food sources as they become available. Thus, raccoons are abundant in landscapes containing a diversity of cover types (Oehler and Litvaitis 1996). In particular, raccoons have responded positively to changing land-use practices (Page et al. 2001), reaching their highest abundances in urban environments (Prange et al. 2003) and in areas that have been moderately to highly fragmented by agriculture (Pedlar 1994). Population increases in urban and agricultural landscapes are likely due to the increased foraging opportunities and efficiencies associated with these areas (Litvaitis and Villafuerte 1996, Oehler and Litvaitis 1996) and the lack of harvest pressure in urban areas.

Despite their general adaptability, raccoons are closely tied to forested habitats (Pedlar et al. 1997, Dijak and Thompson 2000, Chamberlain et al. 2003). In agriculturally fragmented landscapes, forested habitats contain the primary sources of food, cover, and shelter when crop fields are barren, and the distribution and availability of forest patches likely influences raccoon movements and abundance. For example, female raccoons preferentially select tree cavities to rear young (Endres and Smith 1993, Gehrt 2003), making forested habitats critical to raccoon reproduction. In an agriculturally fragmented landscape, Gehring and Swihart (2003) observed differential use of spatial elements across seasons by raccoons; however, raccoons selected forest patches or used them in proportion to their availability during all seasons.

When available, corn is the preferred food item of raccoons (Giles 1939, Kaufmann 1982). In agricultural landscapes corn availability is ephemeral and when available directly influences the movements and habitat selection of raccoons (Lehman 1984). Although raccoons likely avoid post-harvest crop fields, growing crops provide a nearly ubiquitous source of cover across the landscape, presumably allowing individuals to travel among landscape elements more easily. In addition, growing crops provide access to insects, which are utilized as a food source by raccoons prior to ear development in corn (Lehman 1984). Raccoons begin using corn as a direct source of food during the milk-stage, and continue to use corn through harvest (Ohio DNR 2001, Humberg et al. 2005). During the milk-stage, corn fields supply a superabundant and

dependable source of food. In an agricultural region of Quebec, Rivest and Bergeron (1981) found that nearly half of the food volume consumed by raccoons consisted of corn, and during the fall, corn and apples combined constituted nearly all of their food. Although raccoons may not decrease the size of core use areas or home ranges when corn is in a preferred foraging stage (Chapter 1), the presence of corn likely influences the daily movements and habitat selection of raccoons. As crops are harvested, other food sources may motivate raccoons to alter patterns of habitat selection to encompass these resources, which are primarily located in forested areas.

The majority of habitat selection studies have examined only the use of habitat components within an individual's home range (third-order selection; Johnson 1980) and few (particularly for raccoons) have examined higher orders of selection. Recent studies evaluating habitat selection have accentuated the need to examine multiple spatial scales in habitat selection studies (e.g., third-order, second-order selection; Aebischer et al. 1993, Pedlar et al. 1997, Gehring and Swihart 2003, Bowyer and Kie 2006). Johnson (1980) identified a hierarchical concept of habitat selection, of which, the most applicable levels in the hierarchy are second-order selection (selection of a home range within an arbitrary study area) and third-order selection (selection of habitat components within a home range). Individuals may select habitats differently at multiple spatial scales; thus, the lack of multi-scale analysis could mask important spatial aspects of habitat selection (Dickson and Beier 2002).

Although numerous studies have examined habitat use by raccoons, few have investigated multi-scale habitat use in agriculturally fragmented landscapes or the influence of crop availability and developmental stage on seasonal habitat selection. Pedlar et al. (1997) determined that at a macrohabitat scale there was a positive association between raccoon activity and agricultural edge, whereas raccoon activity at the microhabitat scale was positively related to the presence of raspberries (*Rubus spp.*) and sugar maple (*Acer saccharum*). In an agricultural region of Indiana, Lehman (1984) reported higher than expected use of farmyards, woodlots, and wetlands, and less than expected use of crop fields; however, the use of these habitats varied seasonally. Although Lehman (1984) found that raccoons selected crop fields at rates less than their

availability, based on radio locations in his 737 ha study area, his findings did not provide any inference to how raccoons selected crop fields at larger spatial scales.

In this study I examined inter-sexual and seasonal habitat selection by raccoons in a highly fragmented agricultural landscape. The objectives of this study were to quantify habitat selection by raccoons at 3 spatial scales: 1) second-order home range, 2) second-order core-use area, and 3) third-order home range, and to determine the influence of crop availability and growth stage on habitat selection at each scale. I predicted that forested and agricultural habitats would be selected by raccoons at all spatial scales, but that the ranking of agricultural lands would vary across seasons. Specifically, I also predicted that raccoons would select agricultural lands when crops were present and avoid agricultural lands in the absence of crops. The differential seasonal selection of habitats should be most evident in the selection of habitats by females because of parturition and young-rearing constraints.

METHODS

Study area

My 1,165 km² study area was located in the Upper Wabash River Basin (UWB) in northcentral Indiana, USA, encompassing portions of Grant, Huntington, Miami, and Wabash counties (Figure 2.1). The topography within the UWB was flat, with gently rolling areas near river drainages at an average elevation of 243 m above sea level. Approximately 96% of the land area within the UWB was privately owned, 71% of which was in agricultural use. The primary agricultural crops in the UWB were corn and soybeans with small interspersed fields of hay and small grains. Only 13% of the basin was forested, compared to an average of 19% statewide. All contiguous forest tracts within the study area were confined to major drainages where frequent flooding or locally steep topography made the land unsuitable for crop production. The remaining native forests (predominantly oak-hickory-maple [*Quercus-Carya-Acer*]) in the basin were highly fragmented. Across 35 landscapes within the UWB analyzed by Moore and

Swihart (2005), 75% of the forest patches were <5ha, 50% were <2ha, and only 1% of patches were >100ha.

Raccoon capture and radio telemetry

I captured 105 raccoons (62 male, 43 female) in April-May and July-August of 2003 and 2004. Trapping was conducted in 21 forest patches located throughout the study area. Patches were selected based on their size, degree of isolation, and juxtaposition with various habitat types, to encompass as many combinations of these variables as possible. Raccoons were captured using box livetraps (Tomahawk Live Trap Co., Tomahawk, WI) baited with commercial cat food. Traps were placed systematically throughout selected forest patches (along fallen logs and streams, near latrines, at the base of den trees, etc.) to maximize capture probabilities. I immobilized captured raccoons with an injection of Ketamine HCl and Xylazine HCl at rates of 10mg/kg and 0.8 ml/kg of estimated body mass, respectively (Hodges et al. 2000). All captured raccoons were ear-tagged, weighed to the nearest 0.1 kg, and aged (tooth wear technique; Grau et al. 1970). Only raccoons ≥ 1 yr old were fitted with radio transmitters, and I attempted to distribute radios equally among sexes within forest patches. I fitted 83 raccoons (48 male, 35 female) with neck collars and associated 250 g VHF mortality-sensitive radio transmitters (est. life span 2 years; Telemetry Solutions, Ltd.). Twenty-two additional raccoons were processed and released without transmitters because they did not meet my age or desired sex-ratio requirements. All trapping and handling methods conformed to Purdue University Animal Care and Use Committee policies under protocol 01-079.

I tracked radio-collared raccoons using truck-mounted dual yagi (null/peak) antennas equipped with digital readout compasses. During the crop developmental period (May-October) raccoons were partitioned into focal groups (4-5 raccoons) and tracked 1 night/week. I recorded 1 location/hour (maximum of 9 locations/night) for each animal during the peak hours of activity (1 hour after sunset to 1 hour before sunrise). In addition, throughout the growing season diurnal locations were obtained biweekly for all animals to incorporate resting locations within home range boundaries.

During the non-growing season (November-May), 1 location/week was recorded for each individual at arbitrary time intervals, although most locations (87%) were recorded during the peak hours of activity.

Radio telemetry precision (i.e., average error arc of bearings) and accuracy (i.e., the distance from the true location of the transmitter to the triangulated location) were assessed by collecting 92 locations consisting of 347 bearings on 6 radio collars placed at 6 geo-referenced positions unknown to observers. Accuracy tests were conducted during the summer to represent habitat conditions during the period when the majority of the data collection would occur. Radio collars were distributed throughout the study area in a diversity of habitat types, representing areas frequently used by raccoons. To minimize bias, test transmitters were distributed at arbitrary distances from telemetry stations (range = 150-800 m), representative of distances where radio-collared raccoons were located. Precision of bearings and triangulation error were estimated to be $\bar{x} = 8.75^\circ \pm 0.404$ and $\bar{x} = 81\text{m} \pm 4.65$, respectively (mean \pm SE).

Raccoon locations used for home range calculations were estimated by recording 2 or more bearings (usually 4) from telemetry stations along roads. Spatial coordinates of telemetry stations were defined using a handheld GPS. To minimize telemetry error, locations were triangulated from stations as close to raccoons as possible in the shortest time interval possible. Because of the extensive road network within the UWB, all locations were recorded within 1 km of the telemetry stations. Azimuths for a single radio location were recorded within a 20-min interval to reduce error associated with raccoon movement. However, most azimuths (> 90%) were recorded within a 15-min interval. I used all bearings for locations consisting of 3 or more bearings, but defined an ad-hoc minimum angle difference of 30° for all locations consisting of only 2 bearings.

Telemetry bearings were imported into Locate III (Nams 2005) to calculate 95% maximum likelihood confidence ellipses and individual point locations. I converted all locations to Universal Transverse Mercator coordinates for further analyses. Each location was examined with Locate III to identify erroneous bearings. Bearings that did not intersect any other bearings taken for that transmitter and all other bearings failing to meet my accuracy criteria were discarded. To account for error associated with radio-

telemetry, I excluded all individual locations with error ellipses larger than the mean patch size within my study area (4.5 ha).

Home-range analyses

I partitioned telemetry data into 3 seasons based on crop availability and developmental stage: non-growing (26 October - 19 May), representing the period of crop absence between crop harvest and early stages of corn development when cover is reduced to forest patches or wooded corridors; growing (20 May - 21 July), encompassing the V5-R2 stages of corn growth, when the presence of crops forms a nearly contiguous source of cover throughout the landscape; and maturation (22 July - 25 October), representing the milk-mature (R3-R6) stages of corn development when corn is a primary food source for raccoons. I selected seasons based on temporal shifts in food and cover observed in crop fields surrounding radio-collared raccoons. Specific dates for each period were delineated based on crop developmental data combined with raccoon damage data collected in a concatenate 2-year study in the same landscape (Humberg et al. 2005). Lehman (1984) observed that substantial damage to field corn by raccoons did not occur until the milk (R3) stage of plant development. Within my study area corn reached the milk-stage on approximately 22 July in both 2003 and 2004, and substantial damage to field corn by raccoons was not observed until that period in the growing season (Humberg et al. 2005).

I used the Home Range Extension (HRE) in ArcView 3.3 (Rodgers and Carr 2002) to calculate fixed-kernel (FK; Worton 1989) home range estimates. I used biased cross-validation (BCV) to calculate the smoothing parameter based on 95% and 50% isopleths of the space utilization distribution (UD). Seasonal home ranges (95% UD) and core areas (50% UD) were calculated for all raccoons with ≥ 25 locations in a given season.

Habitat use

Study area -- I used a Geographic Information System (GIS) developed from color-infrared aerial photographs and 1:24,000 U.S. Geological Survey 7.5-min quadrangles for

all habitat analyses. Habitat types were delineated at 1 m resolution as forest, agriculture, grassland, shrubland, anthropogenic (buildings, barns, etc.), water, and wooded corridor. Within the UWB free water was primarily limited to streams and vernal pools located within forest patches and wooded corridors; however, many of the water sources were ephemeral. Ground truth surveys indicated that the habitat maps used to digitize my study area lacked the resolution necessary to accurately identify many seasonal free water sources; therefore, I excluded water from habitat selection analyses. Seasonal home range (95% UD) and core (50% UD) area contour intervals were intersected with the habitat map using the HRE (Rodgers and Carr 2002). Habitat attributes associated with seasonal home ranges and core areas were exported to DBASE IV files and extracted for further analyses.

Almost all methods of habitat analysis require an arbitrary measure of habitat availability from which to compare habitat use. However, studies that use a predefined study area as a measure of habitat availability may bias habitat selection estimates if animals are monitored only in a small portion of that study area and the composition of habitat types differs between the overall study area and the region where marked animals occur (Aebischer et al. 1993). The total area used by radio-collared raccoons represented only ~20% of my overall study area. To determine whether the composition of habitats in the region containing radio-collared raccoons differed from the composition of habitats in the overall study area, I used the HRE to generate an overall 100% minimum-convex polygon (MCP) encompassing all radio locations obtained for all individuals and intersected the overall MCP with the habitat map. Habitat attributes for the MCP and the overall study area were exported to DBASE IV files and were used to obtain the proportions of each habitat type in each of the 2 regions. I used a Chi-square test to determine whether the proportions of habitat types differed between the MCP and the overall study area (SAS 2002).

Spatial scale -- I assessed seasonal habitat selection at 3 spatial scales adapted from those suggested by Johnson (1980). First-order selection (selection of a location within a species' range) was beyond the scope of my study. To evaluate second-order selection, I compared the composition of habitats within seasonal male and female raccoon home

ranges (95% UD) to the habitat composition of the overall study area (second-order study area scale). Core areas are locations of concentrated use within home ranges (Kaufmann 1962) that contain important resources such as den sites and quality foraging areas (Ewer 1968). Although core-use areas presumably contain landscape elements biologically important to raccoons, few studies have investigated habitat selection within core-use areas of raccoons (Chamberlain et al. 2003). As a second measure of second-order selection I compared the composition of habitats within seasonal core-use areas (50% UD) of male and female raccoons to the composition of habitats within the overall study area (second-order core area scale). For third-order selection I compared the proportion of seasonal telemetry locations within each habitat type with the proportion of habitat available within seasonal home ranges of individual male and female raccoons (third-order home range scale).

I used compositional analysis with multivariate analysis of variance (MANOVA; Aebischer et al. 1993) to determine whether habitat preferences differed from random ($P < 0.05$) among seasons at each spatial scale for each sex. Compositional analysis determines non-random utilization by comparing the matrices of log-ratio-transformed use and availability distributions with a log-likelihood ratio test (Aebischer et al. 1993). Aebischer et al. (1993) recommended sample sizes ≥ 10 and preferably ≥ 30 in habitat selection studies using compositional analysis. However, significant differences from non-random use can be detected if the number of individuals exceeds the number of habitat types (Aebischer et al. 1993). Thus, 7 raccoons was the minimum number of raccoons necessary to detect habitat selection for each sex within seasons. I used MANOVA to rank habitats in order of preference during each season for male and female raccoons at each spatial scale.

Compositional analysis considers the animal as the sample unit, thereby avoiding autocorrelation and pseudoreplication problems encountered when telemetry locations are used as sampling units (Aebischer et al. 1993, Otis and White 1999, Millspaugh and Marzluff 2001). However, the logarithmic transformations underpinning compositional analysis require that each animal use all available habitat types (Aebischer et al. 1993). Because of the low prevalence of several habitat types in the UWB (e.g., wooded

corridor, shrubland, grassland), most animals did not use at least one habitat, particularly at the third-order of selection. Aebischer et al. (1993) recommended substituting a small, non-zero value for all null values of habitat use; however, Bingham and Brennan (2004) identified inflated probabilities of Type 1 errors for substitution values approaching 0, suggesting that habitat selection studies using substituted values close to 0 may have produced spurious results. Bingham and Brennan (2004) suggested that a substitution value between 0.003 and 0.007 minimized the Type 1 error rate in compositional analysis; therefore, I replaced all missing habitats within sex by season categories with a value of 0.003.

RESULTS

Habitat use

Study area -- I failed to detect differences in the composition of habitat types between the 100% MCP encompassing all radio locations and the overall study area ($\chi^2 = 2.33$, $P = 0.802$). Therefore, I assumed the overall MCP to be representative of the 1166 km² study area in terms of the proportions of habitats available to raccoons and used the overall study area for all second-order habitat availability comparisons.

Spatial scale -- One-hundred sixteen seasonal home ranges (63 M, 53 F) from 56 raccoons (31 M, 25 F) had ≥ 25 locations and were used for analyses of habitat selection. At the second-order home range scale, habitat use of males differed from availability during the growing season ($F_{5, 23} = 3.71$, $P = 0.013$), and marginally during the maturation season ($F_{5, 18} = 2.55$, $P = 0.065$), but did not differ from availability during the non-growing season ($F_{5, 3} = 1.87$, $P = 0.322$; Table 2.1). Female habitat use differed from availability during the growing season ($F_{5, 15} = 5.79$, $P = 0.004$) and maturation season ($F_{5, 16} = 5.51$, $P = 0.004$), but did not differ from availability during the non-growing season ($F_{5, 3} = 3.35$, $P = 0.174$; Table 2.1). Forest cover ranked highest across all seasons for both sexes and both male and female raccoons selected forest cover relative to all other habitats during both the growing and maturation seasons. To a lesser extent, sexual differences in habitat rankings were conspicuous during the growing season, when males

selected grassland habitats, and during the maturation season when females selected agricultural habitats (Tables 2.2, 2.3). In addition, both sexes (particularly females) avoided anthropogenic habitats during the growing and maturation seasons (Table 2.2, 2.3).

At the second-order core area scale, habitat selection differed from availability ($P < 0.05$) during the growing and maturation seasons for both sexes, and marginally differed from availability during the non-growing season for males ($F_{5,3} = 8.22$, $P = 0.057$) and females ($F_{5,3} = 6.78$, $P = 0.073$; Table 2.1). Forest cover was ranked highest for both sexes and was selected over all other available habitats in all seasons (Tables 2.4, 2.5). After forest cover, the rankings of agriculture and corridors were highest and anthropogenic habitats lowest during the maturation season for both sexes (Tables 2.4, 2.5). At the third-order home range scale, habitat selection did not differ from availability for either sex during any season ($P > 0.05$; Tables 2.1, 2.6, 2.7).

DISCUSSION

Raccoons in the UWB exhibited differential selection of habitats across spatial scales, among seasons within spatial scales, and between sexes within seasons; however, seasonal and intersexual patterns of habitat selection were not consistent across spatial scales. Previous studies examining habitat use of raccoons have identified seasonal (Schneider et al. 1971, Gehring and Swihart 2003) and intersexual (Fritzell 1978, Sherfy and Chapman 1980, Endres and Smith 1993, Chamberlain et al. 2003) differences in habitat selection. However, only Chamberlain et al. (2003) used radio telemetry to explicitly examine habitat selection at multiple spatial scales, and found little variation in habitat selection across spatial scales.

At the highest order of selection (second-order home range; 95% UD) habitat use in the UWB differed among seasons within each sex. Both sexes of raccoons used habitats in proportion to their availability during the non-growing season but selected forest cover preferentially during the growing and maturation seasons. However, the strength of the selection of forest over other habitat types during the maturation season

was more strongly supported for females than for males, both in terms of the significance of the overall compositional analysis ($P = 0.004$ for females; $P = 0.065$ for males), and the degree of the support for the ranking of forest cover for each sex in this season. Nonetheless, the selection of forested habitat by both sexes supports the findings of previous studies examining habitat use by raccoons (e.g., Kuehl and Clark 2002, Chamberlain et al. 2003). In particular, mature hardwood habitats are preferentially selected by this species, likely due to the quality of foraging and denning opportunities hardwood trees provide, as well as the presence of water in these areas (Chamberlain et al. 2003). The availability of water is considered by many to be a primary factor limiting raccoon distribution and abundance (Stuewer 1943, Dorney 1954, Kaufman 1982). Within the UWB, free water was primarily limited to streams and vernal pools located within forest patches and wooded corridors. Thus, the presence of free water sources within forest patches likely contributed to the selection of forested habitat within home ranges (Stuewer 1943, Dorney 1954, Kaufman 1982) and may be the underlying factor limiting raccoon populations in the UWB.

Female raccoons preferentially select den trees to rear young (Endres and Smith 1993, Gehrt 2003) and become less active and likely restrict movement around den locations while caring for young (Schneider et al. 1971, Endres and Smith 1993, Kamler and Gipson 2003). Thus, forested habitats are particularly important for reproductively active females during the growing and maturation seasons, and the strength of the evidence for selection of forest cover by females observed during these seasons suggests that the presence of forest cover, or habitats associated with forest (i.e., water), is critical to female reproductive success in agriculturally fragmented landscapes.

Raccoons also exhibited intersexual differences in habitat selection within seasons. Specifically, during the maturation season female raccoons utilized agriculture to a greater extent than males and during the growing season males utilized grasslands to a greater extent than females. Differential habitat selection between sexes of raccoons among seasons primarily has been attributed to the maternal responsibilities of females (Fritzell 1978, Endres and Smith 1993) and the decreased movement of females during pregnancy (Schneider et al. 1971, Endres and Smith 1993). Kamler and Gipson (2003)

suggested that females exhibit greater fluctuations in energetic requirements and consequently habitat use than do males, primarily due the maternal constraints of females. Thus, intersexual differences in the selection of agriculture during the maturation season likely reflected the additional resource constraints of females due to maternal responsibilities. Intersexual differences in the selection of grassland habitats during the growing season presumably also reflected differences in reproductive constraints between sexes because of the restricted movement of females around natal dens during this time (Schneider et al. 1971, Endres and Smith 1993, Kamler and Gipson 2003).

At the second-order core-use scale (50% UD) raccoons selected habitats consistently between sexes within seasons and both sexes selected forest cover and wooded corridors over all other habitats in both the growing and maturation seasons. The lack of inter-sexual differences in habitat selection during the growing and maturation seasons suggested that during these periods male and female raccoons possessed similar habitat requirements at the core area scale. The high ranking of wooded corridors within core areas of male and female raccoons during the growing and maturation seasons suggested that corridors may play a critical role in facilitating raccoon movements in agriculturally fragmented landscapes, even when agricultural crops are present.

Raccoons are opportunistic foragers and ecological generalists (Kaufmann 1982, Gehrt 2003), which allows them to exploit a variety of resources as they become available. Within agricultural landscapes many of these resources are transient, given the ephemeral nature of crops. In agricultural systems, corn is a primary food source for raccoons when available (Giles 1939, Kaufmann 1982) and can comprise over 65% of the total food volume consumed by raccoons during the fall (Rivest and Bergeron 1981). Within core areas, the selection of agricultural lands by both sexes during the maturation season suggested that habitat use by raccoons was directly influenced by crop availability. The non-random use of agriculture during the maturation season observed in this study is strongly reinforced by the observations of substantive raccoon damage to field corn at the onset of the milk-stage in my study area (Humberg et al. 2005). However, over 85% of the damage that was observed in that study occurred within 30 m

of forested edges (Beasley, unpublished data). Thus, although raccoons in the UWB exhibited seasonal variation in their selection of agriculture, the concentration of damage along crop edges likely masked the true magnitude to which corn influenced the selection of agriculture during the maturation season.

Core areas typically contain spatial elements biologically important to raccoons such as den sites and quality foraging areas (Ewer 1968); thus, the selection for and high ranking of forest cover by both sexes within all seasons further exemplifies the importance of forested areas, or habitats associated with forested areas (i.e., water), to raccoons in agriculturally fragmented landscapes. The non-random utilization of habitats at the core area scale presumably was due to the limited presence of those landscape elements containing resources important to raccoons within the landscape. Although second-order home range and second-order core area analyses produced similar findings, the examination of core areas elucidated the importance of forested habitats to a greater degree than did analyses performed at the second order home range scale, and identified the selection of agriculture during the maturation season, which was not detected at the second-order home range scale. Thus, my examination of core area habitat selection helped to identify vital landscape elements that might have been overlooked if habitat selection was only examined at the second-order home range scale.

At the finest spatial scale I measured (third-order home range) habitat use did not differ from habitat availability during any season. The random utilization of habitats at the third-order scale suggested that raccoons established home ranges within the landscape that optimized their utilization of habitats available to them within each season. Interestingly, raccoons in the UWB also maintained small home range sizes relative to those previously reported for this species in fragmented landscapes, likely due to proximal denning and foraging areas and high degree of isolation among forest patches throughout the landscape (Chapter 1). The observation that raccoons in the UWB maintain small home range sizes coupled with the finding of differential selection of habitats between second and third order scales may provide inferences to the mechanisms that have allowed raccoons to thrive in agriculturally fragmented landscapes. In the UWB raccoons maximized their utilization of a limited habitat (forest) by concentrating

movements proximate to forest patches and maintaining movements around selected patches throughout the year (Chapter 1). Thus, the results of the present study suggest that the presence and availability of forested habitats likely limit the abundance and distribution of raccoons in agricultural landscapes.

The importance of anthropogenic resources (i.e., food and shelter) for raccoons in fragmented landscapes has been well documented (e.g. Fritzell 1978, Henner et al. 2004). During the winter, farmyards provide access to critical food resources (e.g., grain bins) and relatively stable thermal conditions. However, within the UWB anthropogenic habitats were not selected during any season, at any spatial scales. In fact, my data indicate that anthropogenic habitats were avoided relative to other habitats during the growing and maturation seasons at both second-order scales examined. The lack of selection of anthropogenic habitats by raccoons during the non-growing season, when such habitats would seem to be most critical to raccoon persistence, was likely a function of variation in the opportunistic behaviors of individual raccoons. For example, 5 raccoons used buildings extensively throughout the winter in 2004 and 2005, whereas raccoons occupying nearby forest patches used these structures infrequently or not at all.

Until recently, habitat selection studies have primarily examined habitat use at fine spatial scales (i.e., measures of third-order selection). However, mounting evidence supports the concept that resource selection may occur differently across spatial scales; thus, failure to examine multiple scales in resource selection studies may result in spurious conclusions regarding the importance of habitat elements, possibly leading to the mismanagement of resources critical to a species (Bowyer and Kie 2006). The examination of habitat selection across multiple spatial scales is particularly relevant to studies conducted in fragmented landscapes because important habitat components are often limited and thus, their utilization is likely optimized at coarse rather than fine spatial scales. In the present study, third-order habitat selection analyses failed to identify the selection of forested habitat by raccoons that was clearly elucidated in analyses of higher order scales. Although analyses of habitat use at fine spatial scales likely reflect seasonal patterns in habitat selection with better resolution than do those conducted at coarse scales, the results of the present study suggest that fine scale analyses

of habitat selection without consideration of habitat use at higher order scales are insufficient to evaluate habitat selection by organisms inhabiting highly fragmented landscapes. I suggest that habitat use within core areas should be routinely examined in studies of habitat selection because such examinations will likely produce selection rankings that are biologically significant to the species in question and may elucidate important habitat components that are masked at coarser or finer spatial scales.

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Table 2.1. Seasonal F -values, degrees of freedom (numerator, denominator) and P -values for the hypotheses that male and female raccoon habitat use did not differ from availability calculated with compositional analysis, Upper Wabash River Basin, Indiana, May 2003-June 2005.

Spatial Scale	Season	Sex	F	df	P
Second-order home range	Non-growing	F	3.35	5,3	0.174
		M	1.87	5,3	0.322
	Growing	F	5.79	5,15	0.004
		M	3.71	5,23	0.013
	Maturation	F	5.51	5,16	0.004
		M	2.55	5,18	0.065
Second-order core area	Non-growing	F	6.78	5,3	0.073
		M	8.22	5,3	0.057
	Growing	F	2.95	5,15	0.047
		M	8.67	5,23	<0.0001
	Maturation	F	16.53	5,16	<0.0001
		M	14.04	5,18	<0.0001
Third-order home range	Non-growing	F	1.23	5,2	0.507
		M	8.59	5,2	0.108
	Growing	F	0.76	5,12	0.593
		M	0.57	5,20	0.725
	Maturation	F	0.22	5,11	0.944
		M	1.52	5,19	0.229

* Habitat use does not differ from availability at $\alpha = 0.05$

Table 2.2. Simplified ranking matrices for radio-collared female raccoons comparing habitat compositions within the seasonal 95% contour of fixed-kernel home ranges with the habitat availability within an 1166 km² region of northern Indiana from May 2003 through June 2005 (second-order home range). Cells in the matrix consist of mean differences in the log ratios of used and available habitats for all raccoons divided by the standard error (i.e., t-values). The sign of the t-values is indicated with positive or negative signs, and triple signs represent significant deviation from random at $\alpha = 0.05$ (non-growing: 26 October - 19 May; growing: 20 May - 21 July; maturation: 22 July - 25 October). Anthro = anthropogenic, Shrub = shrubland, Grass = grassland.

Non-growing

Habitat Type	Habitat Type						Rank ^a
	Forest	Corridor	Agriculture	Shrub	Grass	Anthro	
Forest	.	+++	+++	+	+++	+++	5
Corridor	---	.	+	+	+	+	4
Agriculture	---	-	.	+	+	+	3
Shrub	-	-	-	.	+	+	2
Grass	---	-	-	-	.	+	1
Anthro	---	-	-	-	-	.	0

Growing

Habitat Type	Habitat Type						Rank ^a
	Forest	Agriculture	Corridor	Grass	Shrub	Anthro	
Forest	.	+++	+++	+++	+++	+++	5
Agriculture	---	.	+	+	+	+++	4
Corridor	---	-	.	+	+	+++	3
Grass	---	-	-	.	+	+++	2
Shrub	---	-	-	-	.	+	1
Anthro	---	---	---	---	-	.	0

Maturation

Habitat Type	Habitat Type						Rank ^a
	Forest	Agriculture	Corridor	Grass	Shrub	Anthro	
Forest	.	+	+++	+++	+++	+++	5
Agriculture	-	.	+	+	+++	+++	4
Corridor	---	-	.	+	+	+++	3
Grass	---	-	-	.	+	+++	2
Shrub	---	---	-	-	.	+	1
Anthro	---	---	---	---	-	.	0

^a Rank is equal to the sum of the positive values in each row. Higher ranks indicate a more preferred habitat

Table 2.3. Simplified ranking matrices for radio-collared male raccoons comparing habitat compositions within the seasonal 95% contour of fixed-kernel home ranges with the habitat availability within an 1166 km² region of northern Indiana from May 2003 through June 2005 (second-order home range). Cells in the matrix consist of mean differences in the log ratios of used and available habitats for all raccoons divided by the standard error (i.e., t-values). The sign of the t-values is indicated with positive or negative signs, and triple signs represent significant deviation from random at $\alpha = 0.05$ (non-growing: 26 October - 19 May; growing: 20 May - 21 July; maturation: 22 July - 25 October). Anthro = Anthropogenic, Shrub = shrubland, Grass = grassland.

Non-growing

Habitat Type	Habitat Type						Rank ^a
	Forest	Agriculture	Grass	Corridor	Anthro	Shrub	
Forest	.	+	+	+	+	+	5
Agriculture	-	.	+	+	+	+	4
Grass	-	-	.	+	+	+	3
Corridor	-	-	-	.	+	+	2
Anthro	-	-	-	-	.	+	1
Shrub	-	-	-	-	-	.	0

Growing

Habitat Type	Habitat Type						Rank ^a
	Forest	Grass	Agriculture	Corridor	Anthro	Shrub	
Forest	.	+	+++	+++	+++	+++	5
Grass	-	.	+	+	+++	+++	4
Agriculture	---	-	.	+	+	+	3
Corridor	---	-	-	.	+	+	2
Anthro	---	---	-	-	.	+	1
Shrub	---	---	-	-	-	.	0

Maturation

Habitat Type	Habitat Type						Rank ^a
	Forest	Grass	Agriculture	Corridor	Shrub	Anthro	
Forest	.	+	+	+	+++	+++	5
Grass	-	.	+	+	+	+++	4
Agriculture	-	-	.	+	+	+	3
Corridor	-	-	-	.	+	+	2
Shrubland	---	-	-	-	.	+	1
Anthro	---	---	-	-	-	.	0

^a Rank is equal to the sum of the positive values in each row. Higher ranks indicate a more preferred habitat

Table 2.4. Simplified ranking matrices for radio-collared female raccoons comparing habitat compositions within the seasonal 50% contour of fixed-kernel home ranges (core areas) with the habitat availability within an 1166 km² region of northern Indiana from May 2003 through June 2005 (second-order core area). Cells in the matrix consist of mean differences in the log ratios of used and available habitats for all raccoons divided by the standard error (i.e., t-values). The sign of the t-values is indicated with positive or negative signs, and triple signs represent significant deviation from random at $\alpha = 0.05$ (non-growing: 26 October - 19 May; growing: 20 May - 21 July; maturation: 22 July - 25 October). Anthro = Anthropogenic, Shrub = shrubland, Grass = grassland.

Non-growing

Habitat Type	Habitat Type						Rank ^a
	Forest	Corridor	Shrub	Grass	Anthro	Agriculture	
Forest	.	+++	+++	+++	+++	+++	5
Corridor	---	.	+	+	+	+	4
Shrub	---	-	.	+	+	+	3
Grass	---	-	-	.	+	+	2
Anthro	---	-	-	-	.	+	1
Agriculture	---	-	-	-	-	.	0

Growing

Habitat Type	Habitat Type						Rank ^a
	Forest	Corridor	Shrub	Grass	Agriculture	Anthro	
Forest	.	+++	+++	+++	+++	+++	5
Corridor	---	.	+	+	+	+++	4
Shrub	---	-	.	+	+	+	3
Grass	---	-	-	.	+	+	2
Agriculture	---	-	-	-	.	+	1
Anthro	---	---	-	-	-	.	0

Maturation

Habitat Type	Habitat Type						Rank ^a
	Forest	Corridor	Agriculture	Shrub	Grass	Anthro	
Forest	.	+++	+++	+++	+++	+++	5
Corridor	---	.	+	+	+	+++	4
Agriculture	---	-	.	+	+	+++	3
Shrub	---	-	-	.	+	+	2
Grass	---	-	-	-	.	+	1
Anthro	---	---	---	-	-	.	0

^a Rank is equal to the sum of the positive values in each row. Higher ranks indicate a more preferred habitat

Table 2.5. Simplified ranking matrices for radio-collared male raccoons comparing habitat compositions within the seasonal 50% contour of fixed-kernel home ranges (core areas) with the habitat availability within an 1166 km² region of northern Indiana from May 2003 through June 2005 (second-order core area). Cells in the matrix consist of mean differences in the log ratios of used and available habitats for all raccoons divided by the standard error (i.e., t-values). The sign of the t-values is indicated with positive or negative signs, and triple signs represent significant deviation from random at $\alpha = 0.05$ (non-growing: 26 October - 19 May; growing: 20 May - 21 July; maturation: 22 July - 25 October). Anthro = Anthropogenic, Shrub = shrubland, Grass = grassland.

Non-growing

Habitat Type	Habitat Type						Rank ^a
	Forest	Grass	Anthro	Agriculture	Corridor	Shrub	
Forest	.	+++	+++	+++	+++	+++	5
Grass	---	.	+	+	+	+	4
Anthro	---	-	.	+	+	+	3
Agriculture	---	-	-	.	+	+	2
Corridor	---	-	-	-	.	+	1
Shrub	---	-	-	-	-	.	0

Growing

Habitat Type	Habitat Type						Rank ^a
	Forest	Corridor	Shrub	Grass	Anthro	Agriculture	
Forest	.	+++	+++	+++	+++	+++	5
Corridor	---	.	+	+	+++	+	4
Shrub	---	-	.	+	+	+	3
Grass	---	-	-	.	+	+	2
Agriculture	---	-	-	-	+	.	1
Anthro	---	---	-	-	.	-	0

Maturation

Habitat Type	Habitat Type						Rank ^a
	Forest	Corridor	Agriculture	Shrub	Grass	Anthro	
Forest	.	+++	+++	+++	+++	+++	5
Corridor	---	.	+	+	+	+++	4
Agriculture	---	-	.	+	+	+++	3
Shrub	---	-	-	.	+	+	2
Grass	---	-	-	-	.	+	1
Anthro	---	---	---	-	-	.	0

^a Rank is equal to the sum of the positive values in each row. Higher ranks indicate a more preferred habitat

Table 2.6. Simplified ranking matrices for radio-collared female raccoons comparing habitat compositions of radio locations with habitat availability within seasonal 95% contour of fixed-kernel home ranges in a 1166 km² region of northern Indiana from May 2003 through June 2005 (third-order home range). Cells in the matrix consist of mean differences in the log ratios of used and available habitats for all raccoons divided by the standard error (i.e., t-values). The sign of the t-values is indicated with positive or negative signs, and triple signs represent significant deviation from random at $\alpha = 0.05$ (non-growing: 26 October - 19 May; growing: 20 May - 21 July; maturation: 22 July - 25 October). Anthro = Anthropogenic, Shrub = shrubland, Grass = grassland.

Non-growing

Habitat Type	Habitat Type						Rank ^a
	Forest	Corridor	Anthro	Agriculture	Shrub	Grass	
Forest	.	+	+	+++	+	+	5
Corridor	-	.	+	+	+	+	4
Anthro	-	-	.	+	+	+	3
Agriculture	---	-	-	.	+	+	2
Shrub	-	-	-	-	.	+	1
Grass	-	-	-	-	-	.	0

Growing

Habitat Type	Habitat Type						Rank ^a
	Anthro	Shrub	Forest	Corridor	Agriculture	Grass	
Anthro	.	+	+	+	+	+	5
Shrub	-	.	+	+	+	+	4
Forest	-	-	.	+	+	+	3
Corridor	-	-	-	.	+	+	2
Agriculture	-	-	-	-	.	+	1
Grass	-	-	-	-	-	.	0

Maturation

Habitat Type	Habitat Type						Rank ^a
	Forest	Anthro	Agriculture	Shrub	Corridor	Grass	
Forest	.	+	+	+	+	+	5
Anthro	-	.	+	+	+	+	4
Agriculture	-	-	.	+	+	+	3
Shrub	-	-	-	.	+	+	2
Corridor	-	-	-	-	.	+	1
Grass	-	-	-	-	-	.	0

^a Rank is equal to the sum of the positive values in each row. Higher ranks indicate a more preferred habitat

Table 2.7. Simplified ranking matrices for radio-collared male raccoons comparing habitat compositions of radio locations with habitat availability within seasonal 95% contour of fixed-kernel home ranges in a 1166 km² region of northern Indiana from May 2003 through June 2005 (third-order home range). Cells in the matrix consist of mean differences in the log ratios of used and available habitats for all raccoons divided by the standard error (i.e., t-values). The sign of the t-values is indicated with positive or negative signs, and triple signs represent significant deviation from random at $\alpha = 0.05$ (non-growing: 26 October - 19 May; growing: 20 May - 21 July; maturation: 22 July - 25 October). Anthro = Anthropogenic, Shrub = shrubland, Grass = grassland.

Non-growing

Habitat Type	Habitat Type						Rank ^a
	Forest	Anthro	Agriculture	Corridor	Shrub	Grass	
Forest	.	+	+++	+++	+++	+++	5
Anthro	-	.	+	+	+	+	4
Agriculture	---	-	.	+	+	+++	3
Corridor	---	-	-	.	+	+	2
Shrub	---	-	-	-	.	+	1
Grass	---	-	---	-	-	.	0

Growing

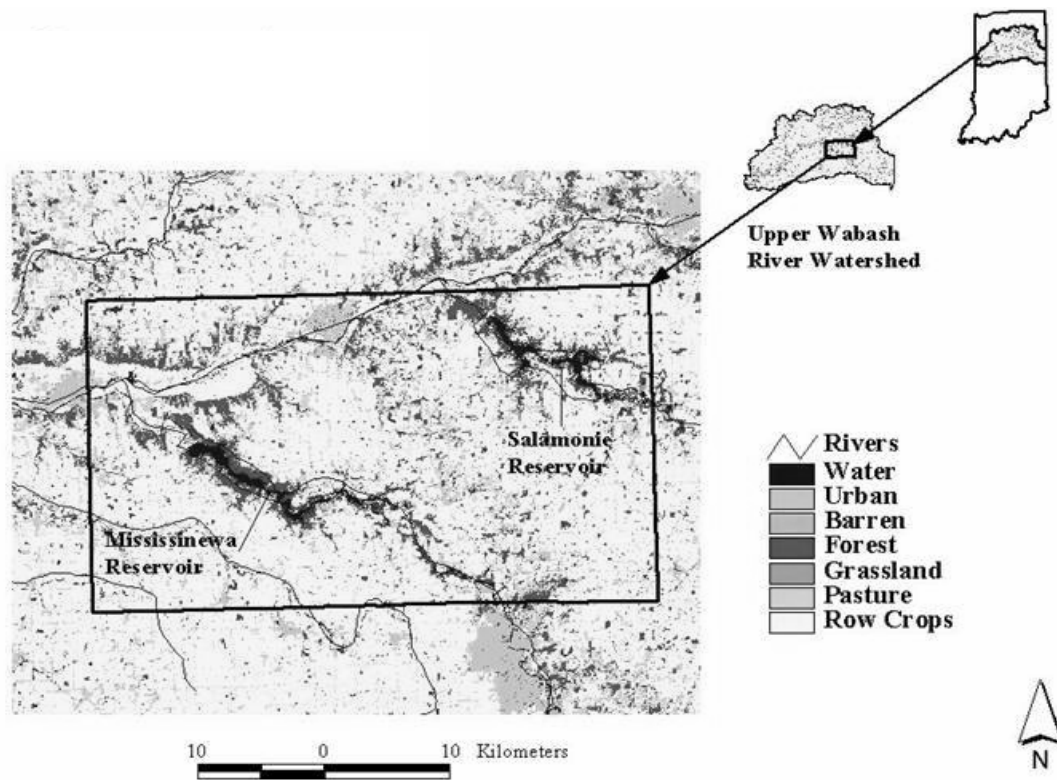
Habitat Type	Habitat Type						Rank ^a
	Corridor	Forest	Shrub	Anthro	Agriculture	Grass	
Corridor	.	+	+	+	+	+	5
Forest	-	.	+	+	+	+	4
Shrub	-	-	.	+	+	+	3
Anthro	-	-	-	.	+	+	2
Agriculture	-	-	-	-	.	+	1
Grass	-	-	-	-	-	.	0

Maturation

Habitat Type	Habitat Type						Rank ^a
	Shrub	Corridor	Agriculture	Forest	Anthro	Grass	
Shrub	.	+	+	+	+	+++	5
Corridor	-	.	+	+	+	+++	4
Agriculture	-	-	.	+	+	+++	3
Forest	-	-	-	.	+	+	2
Anthro	-	-	-	-	.	+	1
Grass	---	---	---	-	-	.	0

^a Rank is equal to the sum of the positive values in each row. Higher ranks indicate a more preferred habitat

Figure 2.1. Study area (1166 km²) in northcentral Indiana, USA, encompassing the counties of Grant, Huntington, Miami, and Wabash. The land cover map illustrates the intensity of row crop agriculture, as well as the 2 principal areas of contiguous forest, which surround the Mississinewa and Salamonie reservoirs.



SUMMARY

1. Raccoons in the UWB exhibited smaller home ranges and core-use areas than those previously reported for raccoons in fragmented landscapes. Resources within the UWB were highly concentrated around forest patches throughout the year; thus, the small home range sizes observed in my study suggested that despite their mobility, raccoons can maintain small home range sizes within landscapes containing proximate sources of food, water, and shelter.
2. Mean FK home ranges and core-use areas of males were larger than those of females and males maintained larger home ranges and core areas than females across seasons. The larger home range sizes exhibited by males was likely due to a polygamous or promiscuous mating system, or to satisfy additional energetic requirements associated with their larger body sizes, which supports previous studies that have examined gender-specific differences in raccoon home range sizes.
3. Raccoons in the UWB did not exhibit significant fluctuations in seasonal home range sizes, seasonal core area sizes, or the mean number of forest patches intersected by home range boundaries across seasons, despite the presence of a superabundant and predictable food source (corn) during the maturation season. The maintenance of small home range sizes and number of forest patches used across seasons suggested that in the absence of standing agricultural crops, waste grain and food sources associated with forested areas likely provided sufficient food resources to maintain energetic requirements.

4. Inter-sexual differences in habitat selection were most evident at the second-order home range scale, where female raccoons selected home ranges containing more agricultural habitat than males during the maturation season. The higher selection of agriculture during the maturation season by females likely reflected the higher resource needs of females during this period due to reproductive constraints.
5. Seasonal habitat selection patterns in my study were most evident at the second-order core area scale, where agricultural lands were selected higher during the corn maturation season than during other seasons. The seasonal shifts observed in the selection of agriculture by raccoons suggested that in landscapes that undergo shifts in resource availability the presence of those resources can directly influence habitat selection. In addition, the selection of agriculture during the maturation season provided supporting evidence to the substantive damage observed to field corn in the UWB during the maturation season.
6. Where non-random habitat utilization was observed, both male and female raccoons consistently selected forest cover across all seasons. The preferential selection of forest by raccoons at both second order scales suggested that the presence and availability of forested habitat likely limit the abundance and distribution of raccoons in agricultural landscapes.
7. Non-random habitat use was detected during the growing and maturation seasons at the second order home range scale and across all seasons at the second-order core area scale; however, habitat use did not differ from availability during any season at the third-order scale. The non-random utilization of habitats at higher order scales and proportional utilization of habitats at a fine scale suggested that raccoons established home ranges within the landscape that optimized their utilization of habitats available to them. The inconsistencies I observed in habitat selection across spatial scales further exemplify the need to examine multiple scales in habitat selection studies.