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## Seasonal Space Use and Habitat Selection of Adult Raccoons (*Procyon lotor*) in a Louisiana Bottomland Hardwood Forest

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**ABSTRACT.**—Raccoon ecology is poorly understood in bottomland hardwood systems, despite the fact that bottomland forests are considered high-quality raccoon habitat. We radio-marked 41 raccoons during 2008–2009 and estimated seasonal space use and habitat selection in a bottomland hardwood forest located within the Atchafalaya floodway system in Louisiana. Space use varied seasonally, with home ranges and core areas largest during the breeding season. Forest openings were important when configuring seasonal home ranges, whereas habitat selection within home ranges varied seasonally. The composition of habitats within core use areas was similar to that of home ranges. We concluded that home range size was influenced by reproductive behaviors and seasonal food availability, whereas habitat selection was most influenced by spatio-temporal changes in seasonal food abundance. Raccoons used all available habitat types and landscape heterogeneity is likely important to raccoons when establishing home ranges in bottomland hardwood forest systems.

### INTRODUCTION

The raccoon (*Procyon lotor*) is a generalist mesopredator whose behavioral and dietary plasticity allows it to exploit a wide variety of habitats. Due in part to human alteration of the landscape and their generalist nature, raccoon populations have experienced dramatic increases since the second half of the last century (Gehrt, 2003). Currently, raccoons are found in nearly every habitat type across North America and their range is expanding (Gehrt, 2003; Larivière, 2004). Raccoons are often implicated as important nest predators of a variety of ground nesting birds and reptiles, including passerines (Heske *et al.*, 2001; Schmidt, 2003), colonial water-birds (Ellis *et al.*, 2007), game species such as wild turkey and quail (Miller and Leopold, 1992; Rollins and Carrol, 2001), and turtles (Burke *et al.*, 2005). Additionally, raccoons are regionally important furbearers (Chamberlain and Leopold, 2001), and serve as vectors for several diseases that affect humans and domestic animals (Gehrt, 2003; Atwood *et al.*, 2009; Rosatte *et al.*, 2010). Given the potential ecological impacts raccoons may exert on an area, an understanding of the relationships between habitat and raccoon ecology over the wide range of ecosystems they inhabit is important.

The general habitat requirements and life-history characteristics of raccoons are well described. Aspects of home range characteristics and habitat use have been described in a number of habitat types across the continent including mixed pine forests (Chamberlain *et al.*, 2002; Chamberlain *et al.*, 2003), fragmented agricultural areas (Dijak and Thompson, 2000; Beasley *et al.*, 2007a; Beasley *et al.*, 2007b; Barding and Nelson, 2008; Attwood *et al.*, 2009), prairies (Fritzell, 1978; Henner *et al.*, 2004; Chamberlain *et al.*, 2007), coastal prairies (Gehrt and Fritzell, 1997; Gehrt and Fritzell, 1998), freshwater marshes (Urban, 1970) and urban environments (Hoffman and Gottschang, 1977; Prange *et al.*, 2004; Bozek, 2007). These studies reveal space use to vary based on gender, season, weather, population density, landscape structure and the distribution and availability of food and den sites. Common to

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studies of habitat selection across ecosystems is the importance of forest habitats (particularly hardwoods) and proximity to water. Not surprisingly, raccoons are reported to occur in higher densities in bottomland hardwood forests relative to other habitat types (Johnson, 1970; Sonenshine and Winslow, 1972; Leberg and Kennedy, 1988; Gehrt, 2003). Despite this knowledge, information regarding raccoon space use and habitat selection in bottomland hardwood systems is scarce (but *see* Fisher, 2007).

It is recognized that an animal's habitat selection may occur at levels along a spatial gradient (Johnson, 1980; Orians and Wittenberger, 1991), and several studies have demonstrated this trait in raccoons (Pedlar *et al.*, 1997; Chamberlain *et al.*, 2002; Chamberlain *et al.*, 2003; Beasley *et al.*, 2007a; Bozek *et al.*, 2007). Our objective was to describe space use and multi-scale seasonal habitat selection for adult raccoons in a bottomland hardwood forest in Louisiana.

#### STUDY AREA

We conducted research on a 17,243 ha tract (hereafter Sherburne) of bottomland hardwood forest in Iberville, St. Martin, and Point Coupee Parishes, Louisiana, located in the Atchafalaya floodway system. Sherburne included Sherburne Wildlife Management Area owned by the Louisiana Department of Wildlife and Fisheries, Bayou des Ourses owned by the United States Army Corps of Engineers, and the Atchafalaya National Wildlife Refuge owned by the United States Fish and Wildlife Service. Additionally, there were approximately 770 ha of private lands interspersed throughout the state and federal lands. Sherburne was bordered on the south by Interstate 10, on the north by Highway 190, on the west by the Atchafalaya River, and the east by the East Protection Guide Levee.

Sherburne was comprised of 95.7% forest, 2.36% forest openings and 1.94% open water. The most common overstory species included eastern cottonwood (*Populus deltoids*), nuttall oak (*Quercus texana*), water oak (*Q. nigra*), overcup oak (*Q. lyrata*), sweetgum (*Liquidambar styraciflua*), sugarberry (*Celtis laevigata*), green ash (*Fraxinus pennsylvanicus*), black willow (*Salix nigra*) and baldcypress (*Taxodium distichum*). Forest openings consisted of wildlife food plots, right-of-ways (electric and natural gas) maintained through mowing and herbicide application, levees, and natural regeneration from forest harvesting. Forest management practices including group selection cuts, individual selection cuts, clear cuts and shelterwood cuts have been applied to portions of Sherburne with varying intensity since 1986. Due to construction of levees and water control structures Sherburne did not experience direct flooding from the Atchafalaya River, instead river-induced flooding was manifested in the form of back-water flooding moving north from southern areas of the Atchafalaya Basin and varied in severity from year to year. Most seasonal flooding on Sherburne could be attributed to local precipitation during the rainy season (Feb.–Apr.) as poorly drained alluvial soils allow surface water to persist for extended periods of time. Mean annual high and low temperatures for the region were 8.9 C and 27.8 C respectively, and average annual rainfall was 155.4 cm.

#### METHODS

We trapped raccoons using wire-cage traps from 15 Dec. 2007–10 Mar. 2008, and from 14 Jan.–21 Feb. 2009. We trapped raccoons using wire-cage traps placed in areas that seemed like good raccoon habitat or in areas that contained abundant raccoon sign. We conscientiously trapped across the landscape to ensure that radio-marked individuals occurred throughout the study area. We baited traps with various combinations of fish, corn, and pastries and checked all traps daily within 4 h of sunrise. We anesthetized raccoons with

ketamine hydrochloride at a rate of 10 mg/kg of estimated body mass (Bigler and Hoff, 1974). We recorded the gender of each individual and estimated age based on tooth wear (Grau *et al.*, 1970) and overall body characteristics. We fitted all individuals  $\geq 1$  y old with a 50 g mortality-sensitive radio collar (Advanced Telemetry Systems, Isanti, Minnesota) and released all raccoons at their respective capture sites following processing and recovery. All capture and handling procedures were covered under Louisiana State University Institutional Animal Care and use Protocol number AE2010-09.

We used a hand-held 3-element Yagi antenna and an ATS R4000 receiver (Advanced Telemetry Systems, Isanti, Minnesota) to locate radio-marked individuals. Locations were obtained by triangulation of azimuth readings taken from 2–5 fixed telemetry stations within a time interval  $\leq 20$  min to minimize error caused by raccoon movement. Approximately 90% of all triangulations were based on 3 or 4 azimuth readings. Telemetry stations were spatially referenced points located throughout the study area along roads, ATV trails and gas/powerline rights-of-way. We estimated telemetry error by triangulating 20–30 locations on dummy radios ( $n = 10$ ) placed in the field at the approximate height and orientation of a raccoon on the ground. The individual conducting test triangulations did not know the exact location of dummy radios during testing. We recorded locations of dummy radios using hand-held GPS and the error was calculated as the distance between each triangulated location and the actual radio location. We used regression analysis to examine the correlation between observer distance and error and to predict the expected error at a given distance.

We monitored raccoons throughout the year, and collected locations using two telemetry techniques. Systematic telemetry consisted of locating each animal once a day approximately three times per week. We took locations throughout the diel period to ensure an accurate representation of raccoon space use during day and night-time periods. Sequential telemetry (focal runs) consisted of triangulating a location on a single raccoon every 20 min for a period lasting from 4–12 h. Focal runs were conducted between the hours of sunrise and sunset during Mar., Apr. and May of 2008 and 2009, coinciding with the nesting season of wild turkeys on the study area. We used locations gathered through focal runs to supplement locations gathered during the breeding season by extracting a single location from each focal run every 4 h. Four hours allowed enough time for a raccoon to traverse its entire home range and was considered long enough to ensure independence between locations. We used LOCATE III (Pacer; Truro, Nova Scotia, Canada) to obtain Universal Transverse Mercator (UTM) coordinates for all triangulations. If a radio-marked individual was visually sighted, its location was recorded on a hand-held GPS. We collected locations on raccoons from 1 Mar. 2008–1 Mar. 2010.

We separated the year into three biologically meaningful seasons; breeding, summer and fall-winter. Specifically, the breeding season was defined as the period from 1 Feb.–31 May, summer as the period from 1 Jun.–30 Sept. and fall-winter as the period from 1 Oct.–31 Jan. (Chamberlain *et al.*, 2003). We imported all triangulated locations into ArcGIS 9 (ESRI, Redlands, California) and converted them to point themes. We calculated fixed kernel density home ranges (95%) and core-use areas (50%) seasonally for each raccoon using the Home Range extension tool in ArcGIS. We chose to use fixed kernel densities as opposed to adaptive kernel to minimize over-estimation of space use (Seaman and Powell, 1996). We performed area-observation curves on 5 representative raccoons with  $>40$  locations in a season and determined that home range sizes generally stabilized at  $\geq 18$  locations; as such, only individuals with  $\geq 18$  locations in a season were used for analysis. We used a one-way analysis of variance (ANOVA) to examine variations in space use across seasons.

We created a digital land cover of Sherburne in ArcGIS 9 using 2004 digital orthophoto quarter quadrangles (DOQQs) and digital elevation models (DEMs, 5 m<sup>2</sup> resolution) based off 2003 LIDAR data (available at <http://atlas.lsu.edu>). Habitat types were delineated into four broad categories based off visual characteristics of the landscape on the DOQQ's, elevation data from the DEM's, forest management history and personal ground truthing. Habitat types included water-influenced forests, upland forest, managed forests and openings. Water-influenced forests included relatively low elevation forests that experienced seasonal flooding and held standing water for a portion of the year, cypress-tupelo swamps and riparian areas immediately adjacent to waterways. Upland forests included forests of relatively high elevation not associated with regular flooding, including ridges, natural levees, terraces and higher flats. Managed forests included upland forests that had been subjected to forest management practices since 2000 and were characterized by reduced canopy cover and dense understory growth. Openings included rights-of-way, levees, foot plots and roads.

To delineate upland and water-influenced forests, we first generated 0.25 m contour lines from DEM's using spatial analyst in ArcGIS. We separated the spatial dataset into small enough parcels that a specific elevation value would be hydrologically consistent across the whole parcel; this was necessary because an elevation associated with persistent flooding in the northern part of the study area may have been permanently dry in the southern part of the study area. In each parcel we considered the area below the specific elevation contour that represented the highest elevation to regularly flood each year as water-influenced. Determination of this elevation was made based on personal observations during flood periods and from cross referencing contour data-sets with DOQQ's. To compensate for telemetry error, waterways were classified as water-influenced forest because if a relocation fell within a bayou it was likely that the raccoon was actually on the bank or near water.

We intersected home ranges, core areas and point themes with the land cover in ArcGIS to quantify habitat selection across seasons. We used compositional analysis (Aebischer *et al.*, 1993) to examine habitat selection at three spatial scales; home ranges vs. habitats available on the study area (1<sup>st</sup> order), core use areas vs. habitats available in home ranges (2<sup>nd</sup> order), and individual locations vs. habitat available in home ranges (3<sup>rd</sup> order, Chamberlain *et al.*, 2003). The study area habitat availability was defined in each year by calculating the mean distance of the longest axis of each breeding season home range (2008 = 1995 m, 2009 = 1941 m), then buffering each home range in each respective year by that amount and merging the buffered home ranges together. Thus, study area habitat availability was different in each year of the study.

Because compositional analysis requires calculating log-ratios of habitat use, values of zero-use are problematic. Aebischer *et al.* (1993) originally proposed replacing zero values with a very small positive value (*i.e.*, 0.001); however, substituting such small numbers may potentially inflate type I error rates (Bingham and Brennan, 2004) as well as misclassification error rates (Bingham *et al.*, 2007). When a habitat type was not represented in a raccoon's space use at a given scale we substituted a value of 0.7 as suggested by Bingham and Brennan (2004) to minimize the risk of type I error. We examined differences of log-ratio habitat use and availability percentages using a multivariate analysis of variance (MANOVA) with season as a main effect. If significant differences between habitat availability and selection were found within a particular spatial scale, a ranking matrix of *t*-tests was constructed to determine order of habitat selection for each season.

TABLE 1.—Mean seasonal home range and core area size (ha) plus associated standard errors from radio-marked raccoons on Sherburne Wildlife Management Area, Louisiana, 2008–2010

Season <sup>a</sup>	n (home ranges)	HR $\pm$ SE	CA $\pm$ SE
Breeding	48	175.67 $\pm$ 9.91	33.15 $\pm$ 1.91
Summer	46	120.28 $\pm$ 7.64	22.54 $\pm$ 2.00
Fall-winter	34	148.19 $\pm$ 13.04	27.18 $\pm$ 2.42

<sup>a</sup> Breeding: 1 Feb.–31 May; summer: 1 Jun.–30 Sept.; fall-winter: 1 Oct.–31 Jan.

## RESULTS

We trapped 49 raccoons, 4 of which were too young to collar, and 4 of which experienced radio failure within 2 wk of release. We estimated 128 seasonal home ranges and core areas for 41 raccoons (37 male, 4 female) from 1 Mar. 2008–28 Feb. 2010. Because we only radio-tracked 4 females, both sexes were combined for analysis. A regression analysis showed a significant positive correlation between telemetry error and observer distance ( $r^2 = 0.55$ ,  $P < 0.001$ ). Most locations (90%) were taken from a distance  $\leq 400$  m, often considerably closer and the expected telemetry error based on the regression equation at that distance was 86.5 m. We excluded from analysis all estimated locations that were  $>400$  m from the closest spot in which an observer took an azimuth reading. The mean number of locations used for seasonal analysis was 37 (range 18–83).

Home range ( $F_{2, 125} = 8.45$ ,  $P < 0.001$ ) and core area ( $F_{2, 125} = 7.17$ ,  $P = 0.001$ ) sizes differed among seasons, with greatest space use during the breeding season and the least during summer (Table 1). Raccoons selected different habitats seasonally within home ranges relative to availability across the study area (1<sup>st</sup> order selection;  $F_{3, 118} = 74.26$ ,  $P < 0.001$ ). Openings were consistently selected by raccoons when establishing their home ranges. However, the composition of core use areas did not differ from the composition of habitats selected when establishing home ranges (2<sup>nd</sup> order selection;  $F_{3, 118} = 1.88$ ,  $P = 0.137$ ). Raccoons also used habitats different than availability within their home ranges (3<sup>rd</sup> order selection;  $F_{3, 118} = 56.52$ ,  $P < 0.001$ ), using water-influenced forests most during the breeding season, managed forests during summer and upland forests during fall-winter (Table 2).

## DISCUSSION

Raccoons maintained larger home ranges and core areas during the breeding season. Since male raccoons mate promiscuously (Gehrt, 2003) they may be expected to increase their range during breeding to increase reproductive success by increasing encounters with females. Conversely, space use was least during summer, a period when soft mast and invertebrates are abundant and relatively ubiquitous, allowing raccoons to fulfill energetic requirements without extensive movements. Previous research in northern latitudes has reported a reduction in winter space use, primarily attributed to raccoons reducing their activities during the coldest time periods (Stuewer, 1943; Glueck *et al.*, 1988; Kamler and Gipson, 2003; Prange *et al.*, 2004). This behavior is not typically observed in southern locations (Gehrt and Fritzell, 1997; Chamberlain *et al.*, 2003; Fisher, 2007), presumably because the mild winters and lack of extreme temperature fluctuations maintain adequate food resources and allow raccoons to stay active during winter (Gehrt and Fritzell, 1997). Our findings are consistent with this trend as raccoons on Sherburne increased their home ranges during fall-winter relative to summer. As vegetation senesced and hard mast

TABLE 2.—Seasonal and mean ranks (0 = lowest, 3 = highest) of habitat selection across two spatial scales (habitat selection in home ranges vs. habitat availability across study area [1<sup>st</sup> order], and habitat used vs. habitat availability across home ranges [3<sup>rd</sup> order]) based on compositional analysis of raccoons on Sherburne Wildlife Management Area, Louisiana, 2008–2010

Habitat type	1 <sup>st</sup> order selection				3 <sup>rd</sup> order selection			
	Season <sup>a</sup>				Season			
	<i>B</i>	<i>S</i>	<i>FW</i>	<i>Mean</i>	<i>B</i>	<i>S</i>	<i>FW</i>	<i>Mean</i>
Water-influenced forest	1	0	1	0.67	3	1	1	1.67
Upland forest	2	2	2	2.00	2	2	3	2.33
Managed forest	0	1	0	0.33	1	3	2	2.00
Opening	3	3	3	3.00	0	0	0	0

<sup>a</sup> Seasons are breeding (B) 1 Feb.–31 May, summer (S) 1 Jun.–30 Sept., and fall-winter (FW) 1 Oct.–31 Jan.

disappeared later in fall, raccoons likely had to expand their ranges to meet foraging demands.

Our findings suggest that openings are important to raccoons when selecting and establishing their home ranges. While raccoons have been reported to use agricultural fields for foraging in a number of studies (Ellis, 1964; Greenwood, 1982; Chamberlain *et al.*, 2007; Atwood *et al.*, 2009), agricultural fields were not present on our study area. Openings on Sherburne were dominated by road ways, gas and power right-of-ways, wildlife food plots and hunting camps. Raccoons have been reported to use forest edges for foraging and travel (Pedlar *et al.*, 1997; Dijack and Thompson, 2000; Barding and Nelson, 2008) and Oehler and Litvaitis (1996) found raccoons in New Hampshire to be more abundant in landscapes offering a variety of cover-types. Most home ranges selected by raccoons on Sherburne incorporated several different patches of forest separated by openings. If raccoons are selecting home ranges that offer them access to several forest patches and/or concentrating around forest edges, then it is plausible that openings would be an important home range characteristic during all seasons, despite the fact that openings are less important to raccoons at smaller spatial scales.

That no 2<sup>nd</sup> order selection was detected (*i.e.*, habitats within core areas did not differ compared to availability within home ranges) suggests that raccoons maintained core areas that were essentially microcosms of their respective home ranges, at least at the resolution at which we delineated habitats. This suggests that patterns of habitat selection exhibited by raccoons on Sherburne led to the creation of home ranges sufficiently heterogeneous such that core areas were not proportionally different from home ranges as a whole. Stated differently, raccoons may have established home ranges in such a way that differential selection of core areas within home ranges was unnecessary.

Habitat selection within home ranges (3<sup>rd</sup> order) varied across seasons. Raccoons are true generalist foragers known to change their foraging patterns to exploit food items that are most prevalent at a given time (Stuewer, 1943; Baker *et al.*, 1945; Johnson, 1970; Fleming, 1976). We know that raccoons denned in all forest types based on locations of inactive raccoons during day-light hours and occasional walk-ins on dens, and since standing water was widely available in the form of bayous and ephemeral pools, we assume that raccoons were not limited by these resources and that habitat selection observed at the 3<sup>rd</sup> order reflects a response to spatio-temporal variation in food availability. Water-influenced forests were important during the breeding season (Feb.–May), at the height of seasonal flooding

on Sherburne. Raccoons use these forests to forage on abundant invertebrates (*e.g.*, crawfish) and vertebrates (*e.g.*, reptiles and amphibians) found in shallow water pools which represent a readily available food source at a time when soft mast are not yet available.

Raccoons are known to shift diet from invertebrates during the cold months to soft mast during the warmer months (Johnson, 1970; Gehrt, 2003). During summer, raccoons selected managed forests within their home ranges. The dense understory growth associated with these forests provided an abundance of soft mast, particularly blackberries and elderberries, throughout the summer. Upland forests were the next most selected habitat type at this time of the year and were likely important for raccoons that did not have managed forests available within their home ranges. Blackberries and elderberries occur in upland forests on Sherburne and are particularly prominent along forest edges; we frequently observed raccoons foraging in elderberry thickets along forest edges during peak berry abundance. Raccoon diets during fall and winter are dominated by remaining soft mast with an increasing reliance on hard mast, particularly acorns (Johnson, 1970). The observed selection for upland forests during fall-winter likely reflects exploitation of these resources.

Our findings highlight the importance of landscape heterogeneity to raccoons and the importance of evaluating habitat selection at multiple spatial scales. Raccoons altered their habitat selection on a seasonal basis, tracking the temporal changes in food availability across habitats. Raccoons are habitat generalists, and our results suggest that they select habitats differently across various spatial scales within bottomland hardwood systems, presumably to allow them to exploit resources that vary spatially and temporally.

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