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# Survival of Unexploited Raccoons on a Rural Refuge in Southern Illinois

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## ABSTRACT

Although raccoons (*Procyon lotor*) have been studied extensively throughout their range, few studies have focused on unharvested populations in rural refuge settings. During 2003-2005, we quantified survival of unexploited raccoons on a rural refuge in southern Illinois. We captured 54 adult females and monitored them for survival via radiotelemetry for 26 months. Similar to other unexploited raccoon populations, survival was 0.80 and did not vary seasonally. Twelve of 54 radiocollared raccoons died during the study; causes of mortality were disease ($n$ = 5), predation ($n$ = 2), vehicle collisions ($n$ = 1), and unknown ($n$ = 4). Elevated survival of raccoons was indicative of highly suitable habitat and protection from harvest. Our study enhances the collective understanding of raccoon demographics and facilitates the construction of population models and management plans for unexploited raccoon populations.

Key words: demography, Illinois, *Procyon lotor*, raccoon, survival, unexploited

## INTRODUCTION

Raccoon (*Procyon lotor*) populations have increased nearly 20-fold during the last 70 years (Zeveloff 2002), reaching overabundant levels in many portions of the species' geographic range. Across its range, high raccoon densities pose a threat to spread diseases such as rabies, canine distemper virus, and raccoon roundworm (*Baylisascaris procyonis*) to humans and wildlife (Mankin et al. 1999, McCleery et al. 2005, Rosatte et al. 2006, Nielsen et al. 2007). Elevated raccoon populations may also affect other wildlife species via increased predation and competition (Urban 1970, McCleery et al. 2005, Smith et al. 2006). Raccoons are also a nuisance species that frequently causes property damage (Curtis et al. 1995, Ikeda et al. 2004, Bluett 2007).

Wildlife biologists study demographic characteristics of raccoon populations to provide information for management. Most demographic studies have been conducted on harvested populations, with survival (Clark et al. 1989, Hasbrouck et al. 1992, Chamberlain et al. 1999) being one of the most researched aspects. Several investigations of unexploited raccoon populations have quantified survival rates (Riley et al. 1998, Gehrt and Fritzell 1999, Prange et al. 2003, Gehrt and Prange 2006). However, most of these studies have occurred in urban or suburban settings (Riley et al. 1998, Gehrt and Fritzell 1999, Prange et al. 2003) with one on a wildlife refuge in the Gulf Coastal Plain of Texas characterized by long hot summers and mild winters (Gehrt and Fritzell 1999).

Little information exists about raccoons in rural, protected, refuge settings that are relatively free of the human influence found in urban environments. We quantified survival of an unexploited raccoon population on a state-managed waterfowl refuge in a bottomland hardwood forest-agricultural ecosystem in the Mississippi River floodplain of southern Illinois. Our goal was to provide wildlife biologists with information useful for modeling and managing raccoon populations in floodplain ecosystems where harvest is nonexistent. We predicted that raccoon survival rates on our study area would be higher than those reported for exploited populations due to harvest protection and high-quality habitat.

## MATERIALS AND METHODS

**Study Area**

Research was conducted on the Union County Conservation Area (UCCA), a wildlife refuge located in the Lower Mississippi River bottomlands division in southwest Illinois (UTM Zone 16 4140000N, 290000E). The UCCA encompassed 2,510 ha of which 550 ha were lakes and permanent and seasonal wetlands. Dominant aquatic vegetation in wetlands and lakes were buttonbush (*Cephalanthus occidentalis*), elodea (*Elodea spp.),* and water lily (*Nymphaea spp*.). In addition, 770 ha were bottomland hardwood forests with portions seasonally flooded. Dominant tree species included green ash (*Fraxinus pennsylvancia*), black willow (*Salix nigra*), and cottonwood (*Populus deltoides*) in wet areas, with sweetgum (*Liquidambar styraciflua*), pecan (*Carya illinoensis*), and pin oak (*Quercus palustris*) in drier areas. A total of 1190 ha consisted of agricultural fields, primarily planted in corn, soybeans, winter wheat, and milo.

**Capture and Handling**

Raccoon capture activities were conducted on a 197-ha portion of the UCCA. We live-captured raccoons during 4 periods: 6 October-4 December 2003, 8 March-16 April 2004, 26 September-10 December 2004, and 2 March-10 April 2005. During each trapping period, 40 wire cage traps (30x30x70 cm; Schroeder Fur Co., Grand Island, NE) were set along linear transects adjacent to water or field edges, and spaced at 100-m intervals. We baited traps with commercial cat food and checked them each morning during 0700-1100 hr.

We anesthetized captured animals with an intramuscular injection of Telazol (5mg/kg) based on an initial estimation of the animal's weight (Gehrt et al. 2001). Anesthetized animals were sexed and classified as either juveniles or adults (>1 yr) based on weight, body size, and condition of dentition (Grau et al. 1970). Mortality-sensing radiocollars (120 g; Wildlife Materials, Inc., Carbondale, Illinois, USA) were placed on selected females considered to be of an adequate size (> 3.5 kg), and all animals were ear-tagged. We released all raccoons at their capture site. Research was conducted in adherence with American Society of Mammalogists' guidelines (Animal Care and Use Committee 1998, Gannon et al. 2007) and a university-approved animal welfare protocol (Southern Illinois University Carbondale Animal Assurance #A-3078-01).

During 6 October 2003-1 November 2005, adult female raccoons were monitored for survival weekly during daytime hours (0700-1700 hr) using a TS-1 receiver and scanner (Telonics, Inc., Mesa, Arizona, USA) and a 3-element Yagi antenna. Radiocollars emitted a different signal pulse following 12 hours of inactivity; all deceased raccoons were located by tracking these signals and mortalities were necropsied immediately following detection. We broadly classified causes of raccoon mortality into 4 categories: disease, predation, vehicle accident, and unknown. Raccoons that died within 2 weeks of collaring ($n$ = 3) were not included in the analysis. Raccoons whose radiocollars failed ($n$ = 3) were censored from the analysis.

**Survival Analysis**

We used a known fates model in program MARK (Cooch and White 2007) to estimate survival of adult female raccoons. We developed a set of 4 a priori models based on age, year, and season. We generally followed Prange et al. (2003:326-327) in separating the year into 4 seasons based on raccoon biology and general weather patterns. The pregnancy-parturition season (hereafter, spring) was during 1 March-30 May and characterized by warming weather and herbaceous and deciduous vegetation growth. The post-parturition season (hereafter, summer) was during 1 June-30 Aug and characterized by juveniles beginning to move with their mother during long, hot days and peak vegetation. The period when juveniles were weaned and began to move independently of their mother (hereafter, fall) was defined as 1 September-30 November. Leaf fall and cooling temperatures occurred during this interval. The period when raccoons were largely inactive, weather was cold, and herbaceous and deciduous vegetation reached senescence (hereafter, winter) was defined as 1 December-30 February.

Currently, there is no goodness-of-fit test for known-fate models in program MARK because each model is presumed saturated, and thus believed to fit the data perfectly (Cooch and White 2007). Therefore, we conducted a sensitivity analysis of the variance inflation factor ($\hat{c}$) by adjusting $\hat{c}$ in increments (0.25) from 1 (model fits the data) to 3 (model is overdispersed) and examined the model ranks for change (Brasher et al. 2006). If change in model order occurred after $\hat{c}$ was adjusted, we compared the model set with ĉ set as 1 (model set 1) to the model set with the highest $\hat{c}$ (model set 2) that showed stability in the order. We tested each model independently for its influence on survival by comparing the model's $\Delta AIC_c$ to a model that held survival constant (Cooch and White 2007). We estimated survival rates and 95% confidence intervals using averages from models ≤2 $\Delta AIC_c$ points from the most parsimonious model (Cooch and White 2007). If 2 model sets resulted after $\hat{c}$ adjustments, we compared the estimates and 95% confidence intervals from the most parsimonious models from each model set.

## RESULTS

We captured 279 different raccoons (83 adult females, 122 adult males, 35 juvenile females, and 39 juvenile males) 391 times in 6,023 trap-nights. We monitored 54 adult female raccoons for survival during 20,761 radio-days. We recorded 12 mortalities attributable to disease ($n$ = 5; 42%), unknown sources ($n$ = 4; 33%), predation ($n$ = 2; 17%), and vehicle collisions ($n$ = 1; 8%). The model order remained the same when $\hat{c}$ was adjusted, suggesting no overdispersion of the data nor a necessity for additional model sets. The most parsimonious model held survival constant and the model set provided no evidence for variation in survival by season (Table 1). However the model S(year) was approximately ≤2 $\Delta AIC_c$ and had a lower deviance than S(constant), offering slight evidence for an annual effect on survival (Table 1). Based on the most parsimonious model, annual survival was 0.80 (95% CI=0.70-0.90).

Table 1. Survival models for unexploited raccoons in southern Illinois, USA, 2003-2005.

| Model | $AIC_c$[a] | $\Delta AIC_c$ | $w_i$[b] | $K$[c] | Deviance |
|---|---|---|---|---|---|
| S(constant) | 121.56 | 0.00 | 0.71 | 1 | 21.07 |
| S(year) | 123.56 | 2.01 | 0.26 | 3 | 19.05 |
| S(season) | 127.59 | 6.04 | 0.03 | 4 | 21.06 |
| S(season x year) | 133.17 | 11.62 | 0.00 | 9 | 16.42 |

[a] Models were ranked using Akaike's Information Criterion corrected for small sample size ($AIC_c$).
[b] Akaike model weight.
[c] No. of parameters estimated.

## DISCUSSION

Harvest is commonly the most significant mortality factor in exploited raccoon populations (Sanderson 1961, Johnson 1970), accounting for ≥78% of raccoon deaths (Clark et al. 1989). However, in unexploited raccoon populations, disease is generally the most common cause of mortality (Gehrt et al. 1990, Roscoe 1993, Riley et al. 1998, Gehrt and Fritzell 1999). We found a similar percentage of raccoons dying from disease as other studies of unexploited raccoons and observed a comparable percentage of vehicle-collision mortalities to harvested populations studied by Clark et al. (10%; 1989) and Hasbrouck et al. (6%; 1992).

In the absence of anthropogenic factors, natural mortality agents have little effect on most raccoon populations (Johnson 1970, Gehrt and Fritzell 1999), thus protected raccoon populations tend to have higher survival rates than exploited populations. Within the literature, there is a wide range of adult female survival rates reported for unexploited raccoon populations (0.57 – 0.88), and estimates derived in our study fell within that range (Table 2). As expected, adult female survival on the UCCA was higher than those adult survival rates presented in studies of harvested raccoon populations (Table 2). Compared to harvested populations that combined sexes and age classes for analysis, female raccoon survival at UCCA appeared higher than Mankin et al. (1999) and Pitt et al. (2004) (Table 2).

Similar to other studies of unexploited populations (Riley et al. 1998, Gehrt and Fritzell 1999, Prange et al. 2003), we found no seasonal differences in raccoon survival. These results were unsurprising given that most seasonal differences in survival can be attributed to harvest (Clark et al. 1989, Brown et al. 1990, Hasbrouck et al. 1992). The slight evidence for a year effect on survival was likely attributable to natural fluctuations in annual survival rates observed by other researchers (Hasbrouck et al. 1992, Gerht and Fritzell 1999, Prange et al. 2003).

Table 2. Selected annual survival estimates for raccoons across the species' range, 1989-2008.

| Source (state/province) | Adult survival[a] | Harvested/ protected | Site description |
|---|---|---|---|
| Clark et al. (1989), IA | 0.47-0.75 | Harvested | Agriculture |
| Brown et al. (1990), PA | 0.67-0.69 | Harvested | Forested game lands |
| Hasbrouck et al. (1992), IA | 0.53 | Harvested | Agriculture |
| Riley et al. (1998), DC | 0.71-0.73 | Protected | Urban deciduous forest |
| Chamberlain et al. (1999), MS | 0.50[b] | Harvested | Bottomland hardwood, mixed pine-hardwood forests |
| Gehrt and Fritzell (1999), TX | 0.84 | Protected | Gulf plains, prairies, marshes |
| Mankin et al. (1999), IL | 0.74[c] | Harvested | Agriculture, pasture, shrub, forest |
| Mosillo et al. (1999), IL | 0.70-0.73 | Protected | Mature upland forest, old field, mesic grassland |
| Prange et al. (2003), IL | 0.63-0.88[b] | Protected | Commercial, industry |
| | 0.57-0.74[b] | Protected | Forest, agriculture, grassland |
| | 0.59-0.80[b] | Protected | Wetland, grassland, savanna |
| Pitt et al. (2008), Saskatchewan | 0.51-0.84[c] | Harvested | Agriculture |
| This study, IL | 0.80[b] | Protected | Bottomland hardwood forest |

[a] Survival rates are for both sexes combined, unless otherwise noted.
[b] Adult female survival rate.
[c] Study combined both sexes and age classes into one survival rate.

Our survival estimate was higher than the only other study found in the literature that examined survival of adult female raccoons in a bottomland hardwood forest environment (Chamberlain et al. 1999; Table 2). Chamberlain et al. (1999) also noted a significantly lower overall survival estimate during their breeding-gestation (1 Feb-31 May) period (0.65) compared to their parturition-young rearing (1 Jun-30 Sep) period (0.93), which was most likely due to harvest. After an exploratory analysis adjusting our data to Chamberlain's seasons, we still could conclude no seasonal differences in adult female survival.

We found only 3 records of survival estimates of Illinois raccoons based on radiotelemetry data: Mankin et al. (1999), Mosillo et al. (1999), and Prange et al. (2003). Our survival estimate fell within the ranges reported by both Mankin et al. (1999) and Prange et al. (2003), even though the population Mankin et al. (1999) studied was harvested. Unlike many harvested populations studied, Mankin et al. (1999) observed no notable increase in juveniles harvested in comparison to adults which may account for the similar survival estimates to protected raccoon studies. Our survival estimate was higher than those presented by Mosillo et al. (1999), which may be a result of better habitat. Raccoons were studied by Mosillo et al. (1999) in to a forest preserve dominated by a mature upland forest while our raccoons resided in mature bottomland hardwood forest with ample wetlands.

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