



Activity patterns and social organization of raccoons (*Procyon lotor*) in East Texas

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Abstract

Motion-sensor cameras provide several benefits for research not available through mark-recapture and other more traditional methods of assessment of medium-sized mammals. Urban systems provide unique pressures on a population that can alter the activity of the population. The current study investigates the activity and social organization of raccoons taken in photos from cameras located in a small urban system on the Environmental Studies Area of East Texas Baptist University in Marshall, TX (32°33'N; 94°2'W). Multiple raccoons were in close enough proximity to be in a single photo on 33 occasions. Seven photos exhibited mating behaviour. Mating behaviour occurred on the site between 26 Sep. and 27 Feb. Monthly activity periods concurred with previously reported activity from Sep. - May. Activity during the summer months (Jun. - Aug.) showed a shift towards sunset away from ca. 2300 h.

Keywords: urban ecosystem, trail cameras, mating behaviour, marking behaviour, seasonal behaviour

Introduction

Activity of an animal includes an appreciable amount about its natural history. Timing of activity whether nocturnal or diurnal may be influenced by, but not limited to, interspecific interactions, the physiology of the species, and social organization within the species (Kavanau 1971, Greenwood 1978). However, nocturnal species such as the raccoon (*Procyon lotor*) are difficult to observe directly while they are active. Use of trail cameras allows inference of the social organization of a nocturnal species, albeit, on a snap-shot supposition.

Although the raccoon is generally considered a nocturnal, solitary species (Stuewer 1943, Johnson 1970, Urban 1970, Seidensticker *et al.* 1988), diurnal activity is not uncommon (Ladine 1997, Gehrt 2003). Additionally, raccoons must exhibit at least limited social interactions during mating. Raccoons are a relatively common medium-sized mammal in most Nearctic forested regions and have adapted well to urban systems. Thus, provide an excellent subject for camera-based research. Urban systems provide a generalist like the raccoon opportunities that may not be available in a rural system. These include a relatively stable food resource, *i.e.*, garbage cans, road litter, and potentially more scavenging opportunities through vehicle-induced mortality of animals. Garbage cans and road litter generate a potential clustered food resource for raccoons allowing individuals to forage in closer proximity to other raccoons (Wiens 1976). The objective of the current study

is to assess the activity of raccoons in an urban system using tree-mounted trail-cameras. While live traps generally only indicate the presence of a single animal, cameras provide the researcher with the ability to note the presence of multiple animals in an area at one time and assess behaviours such as mating, foraging, scent-marking, and moving to foraging areas.

Material and methods

The study was conducted on the East Texas Baptist University's Environmental Studies Area (EnStA) located in Marshall, TX (32°33'N; 94°22'W). The site (*ca.* 120 ha) is surrounded on the east and west by houses, on the south by the athletic fields of the University and on the north by a five-lane highway. Several locations within the study site contain discarded trash. There is one permanent stream intersecting the EnStA that intermittently is dammed by beaver (*Castor canadensis*). The EnStA occurs within the eastern mixed deciduous forests of the United States (Braun 1950, Dyer 2006). Habitat is a mixture of oak-hickory-elm with isolated stands of loblolly pine (*Pinus taeda*; see Pressley and Ladine 2016 for a detailed description). Dominant canopy trees found on the site are oaks (*Quercus sp.*), sweet gums (*Liquidambar styraciflua*), hickories (*Carya sp.*), elms (*Ulmus sp.*), and loblolly pines (*Pinus taeda*; Pressley and Ladine 2016). Poison ivy (*Toxicodendron radicans*) and grape (*Vitis sp.*) are found in the canopy, with poison ivy being abundant in the herbaceous layer (Pressley and Ladine 2016). Understory vegetation is dominated by saplings of the canopy trees, flowering dogwood (*Cornus florida*), poison ivy (*Toxicodendron radicans*) and green briar (*Smilax sp.* Pressley and Ladine 2016). Ground layer vegetation is sporadic and is primarily poison ivy and green briar.

Starting 1 October 2014, five trail cameras (Cuddeback IR model 1224 20 megapixels,

DePere, WI) were placed in random locations on the EnStA. Four cameras were permanently located. The fifth camera was designated to be moved on an 8-week rotation to cover more of the EnStA. On 22 September 2015, seven additional cameras were added to the study. Six of the additional cameras were placed in permanent locations with the remaining camera moved on the same rotation as the original group. Eight-megabyte SD cards were placed in each camera and changed every 7-10 days to insure the cards did not run out of storage, to minimize disturbance on the site, and to allow the cameras to be in continuous operation. Camera sites were not baited to prevent influence of a stable food source on the behaviour of the animals.

Data collected from the camera included species, time of picture, and location of camera, number of individuals in each picture, and an assessment of the behaviour at the time (Table 1). As these pictures did not allow assessment of sex, no data on sex were collected. Pictures with multiple individuals allowed an estimation of relative size of the individuals. Thus, data an estimate of age, adult or juvenile, were collected from pictures exhibiting multiple individuals. To prevent a single individual from biasing analyses, multiple pictures of raccoons taken within 2 h of the initial picture were excluded from the data analyses. Behaviour and size assessments from pictures of multiple individuals are described in Table 1.

Because sunset and sunrise are not consistently the same time at the location of the study, time of day was standardized. Sunset was established as 0.00, sunrise established as 1.00, and midnight established at 0.50. Diurnal times became -0.5 - 0.0 for afternoon activity and 1.0 - 1.5 for morning activity. Thus, all nocturnal times are reported as percent between sunset and sunrise. Data were analysed by month for time of activity. Time of activity was defined as the time when the trail camera was triggered by the

raccoon. See Table 1 for definition of activities. All data groups were tested individually for normality using a Shapiro-Wilk test and skewness. Because monthly data were not normally distributed, measure of centrum is reported as median values, and Kruskal-Wallis test was used to test for difference among months (Zar 2010). Data for time of activity for pictures with a single individual were analysed separately from those pictures with multiple individuals. Data were assessed for difference between numbers of multiple individuals (two or three) in a picture using a Student's t-test. All statistical analyses were conducted using R (R Core Team 2017).

Table 1. Description of behavior and size of *P. lotor* assessed from pictures.

Behavior	Description
Foraging	Individuals were more than one body length apart with at least one with its nose pointed toward the ground, if closer one or both had nose toward the ground
Mating	Individuals in mating posture with one individual mounting, individuals in direct contact but no mounting
Moving	Individuals that did not exhibit foraging or mating behavior
Marking	Individual appearing to sniff an object, scratching at an object, or rubbing the carpal region of the forearm on an object
Juvenile	Individual noticeably smaller than others in pictures at on equivalent dates
Adult	Individual comparable in size to the majority of raccoons on equivalent dates
Family unit	Two or more individuals in a picture with at least one noticeably larger than the others in the picture

Results

A total of 1837 pictures (64 with two individuals, 14 with three individuals, and one with four individuals) were cataloged. Data for the picture with four individuals were included with the data for pictures with three individuals for statistical analyses. Maximum number of pictures occurred during the fall - winter months from Oct. – Feb. (Table 2). Maximum number of pictures of multiple individuals was Oct. and Nov. (Table 2).

Table 2. Activity of *P. lotor* in an urban ecosystem based on number of pictures taken by trail cameras. Total pictures refer to all pictures with raccoons excluding those occurring within 2 h of a previous picture.

Month	Total pictures	> Two individuals
January	485	10
February	273	8
March	78	0
April	33	0
May	39	0
June	30	0
July	32	1
August	67	4
September	50	3
October	145	23
November	270	23
December	335	17

The majority of activity was nocturnal, 93%. Greatest diurnal activity occurred during Jan. and Feb. (20.2 % and 13.7% of diurnal activity, respectively). There was a second spike in diurnal activity during Sep. and Oct. (10.5% of diurnal activity for both months).

Number of pictures was greatest from Oct. through Feb. (Table 2) with the greatest amount of activity occurring in Jan. The remaining months had a relatively stable amount of activity (range 30 - 78). Median time of activity varied throughout the year with a normal distribution for all months. However, several months exhibited a shift toward sunset with the greatest amount of shift occurring in Jun., Jul., and Aug. (Fig.1). Time of activity varied significantly among months ($H_{11} = 30.12$, $P = 0.002$; Table 3).

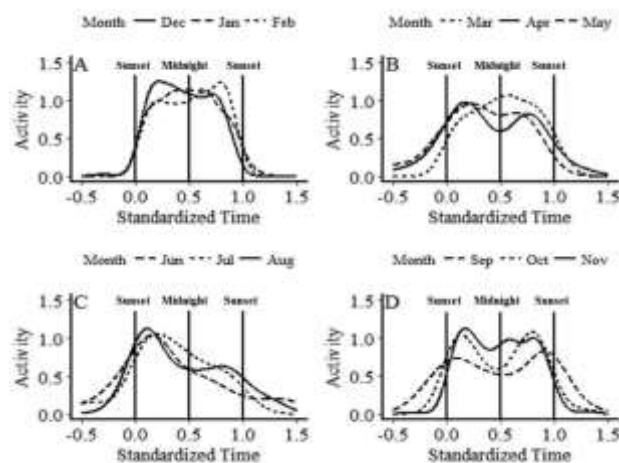


Figure 1. Activity of *P. lotor* by month in an urban ecosystem located in east Texas. Time is standardized to sunset (0.0), midnight (0.5), and sunrise (1.0). Frequency of activity refers to the frequency of the time at which a camera was triggered. A) winter, B) spring, C) summer, and D) autumn.

Activity of individuals was significantly different from a normal distribution ($W = 0.98$; $P < 0.01$) while time of activity for multiples approached significance ($W = 0.99$; $P = 0.13$). Time of activity of raccoons in groups greater than two was normally distributed ($W = 0.87$; $P = 0.35$) with a large part of the diurnal activity

occurring during the afternoon. Time of activity for the group size of two did not deviate significantly from a normal distribution ($W = 0.99$; $P = 0.88$).

Mean time of activity was not significantly different ($t_{20} = 0.004$; $P = 0.99$) between the two sizes of multiple occurrences ($\bar{x} = 0.42 \pm 0.31$ and $\bar{x} = 0.43 \pm 0.33$ for two and three raccoons, respectively). Raccoons in groups ($\bar{x} = 0.42 \pm 0.31$) exhibited a mean time of activity that was significantly earlier ($t_{181} = 2.097$, $P = 0.0374$) than was the mean time of activity for raccoons not found in groups ($\bar{x} = 0.48 \pm 0.31$; Fig. 2).

There were four pictures exclusively of multiple juveniles, one with two individuals (23 Dec.) and one with four individuals (28 Sep.). The remaining two pictures were of three individuals. Because of the timing (8 Dec. and 4 Jan.) and location (same camera) of the pictures with three individuals, they were likely the same group. Juveniles in all other pictures were accompanied by a single adult (10 pictures). Timing of pictures that included juveniles ranged from the earliest of 28 Sep. to 2 Jan. with the majority occurring in Oct. (three) and Nov. (four).

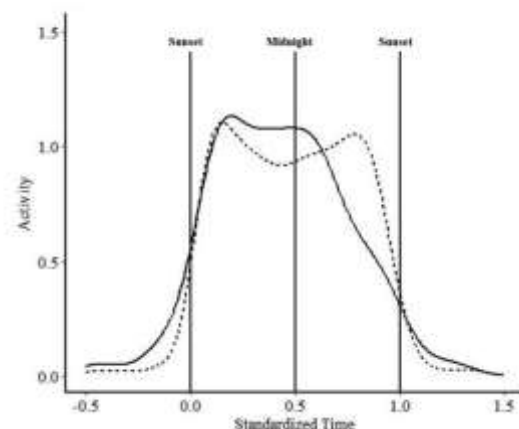


Figure 2. Timing of activity of *P. lotor* in social groups (dashed line) and single raccoons (solid line) in an urban system located in east Texas. Time is standardized to sunset (0.0), midnight (0.5), and sunrise (1.0). Frequency of activity refers to the frequency of the time at which a camera was triggered.

Mating appears to have started on the site near the end of Sep. with the earliest occasion occurring 26 Sep. (Fig 3). The latest occasion of mating occurred on 27 Feb. There were two occurrences of mating in Oct. on the first and fourth. The occurrence on 1 Oct. showed one individual mounted on a second with a third individual *ca.* 7 m away. All other multiple occurrences of raccoons in a picture were of individuals foraging or moving between locations.



Figure 3. Late season mating of *P. lotor* in an urban system located in east Texas.

There were 10 occasions of individuals that appeared to be marking or investigating a scent mark. On one occasion two individuals were in the picture with one individual sniffing a low hanging green briar (*Smilax* spp.) with the other individual beside it. All individuals that appeared to be investigating a potential mark were in similar posture; head elevated and standing on their hind legs with the ankles on the ground. Individuals appeared to mark in one of two manners: scratching on a downed tree or rubbing an upright object with the underside of the carpal region of the forearm.

Discussion

The findings of current study concur with previously reported activity for the raccoon in that the majority of activity was nocturnal

(Lotze and Anderson 1979, Ladine 1997, Ghert 2003, Carver *et al.* 2011). The majority of diurnal activity observed in the present study occurred during Jan. and Feb., concurring with Gehrt (2003). These are the two coldest months of the year at the study site (mean high temp - 13.2° C and 15.4° C for Jan. and Feb. respectively). The spike of diurnal activity occurring during Sep. and Oct. has not previously been reported. Schneider *et al.* (1971) and Gehrt (2003) reported that females may be more active during the day shortly after parturition. However, the timing of the spike occurring during Sep. and Oct. is probably not due to parturition. The majority (119 of 123) of the diurnal occurrences were of single individuals in a picture. Three of the remaining four diurnal occurrences were all adult (most likely a female) with one young with the remaining picture being four juveniles. All diurnal activity indicated raccoons appeared to be moving and not foraging. However, raccoons will change their time of activity to accommodate shifts in availability of food (Sanderson 1987, Ellis 1964). The diurnal behavior observed in the current study may be indicative of a relatively high abundance of raccoons. No estimates of abundance exist for population as trail-camera data do not allow for discernment of individuals. Because garbage and road kill can result in a potential increase in food resources, the density of raccoons may be high during the when diurnal activity is at its greatest in this population resulting in individuals searching for daytime den locations. Raccoons do not exhibit den site fidelity (Fritzell 1978) potentially necessitating the need to search for a den site during the day in a high population density.

Multiple individuals in close enough proximity to be photographed in a single picture peaked from Oct. - Feb. (Table 2). All pictures during these months were primarily adults indicating the possibility of mating. One camera was

located at an area where the majority of raccoons were foraging. However, the remainder of cameras were in locations where foraging rarely occurred. Also substantiating mating during these months were pictures of raccoons actively mating with one individual mounted on the second. While mounting may be an indication of dominance (Bailey and Zuk 2009), this behaviour has not been reported in raccoons, and, no picture showed any aggressive behaviors as described by Fritzell (1978). Potential matings occurring (seven occasions) in this study during Sep. - Dec. are out of the range of reported mating periods for the species (Stuewer 1943, Stains 1956, Johnson 1970, Bigler *et al.* 1981, Gehrt and Fritzell 1996) with the reported peak time of mating being Feb. and Mar. (Gehrt 2003).

Bissonette and Csech (1938) indicated that mating in raccoons is most likely stimulated by lengthening photoperiod and Gehrt (2003) notes that a second mating period is stimulated by lost litters. It is not known if the females in the Oct-Dec matings had lost litters. Although predation is not a major cause of mortality in raccoons (Hasbrouk *et al.* 1992; Gehrt and Fritzell 1999) the possibility of a female losing a litter is high due to a high number of domestic dogs (*Canis familiaris*) that run freely through the study site. Two possibilities for the extended mating period observed in the current study may be 1) pollution of the water source on the site (a constant oil slick is observed on the stream traversing the site), and 2) introduction of endocrine disruptors in garbage that is consumed by raccoons in the study. Raccoons bioaccumulate selected pesticides known to be endocrine disruptors (Nalley *et al.* 1975, Layher *et al.* 1987, Herbert and Peterle 1990). Endocrine disruptors have shown to cause the loss of embryos after implantation in mink (Beard *et al.* 1997). Raccoons will enter a second mating period if a litter is lost (Gehrt 2003). Potentially, if the litter from the second

mating is lost the possibility a female coming into estrus late may occur, thus, resulting in the mating occurring from Oct. - Dec.

Seasonal activity from Sep - May is similar to reported activity for the species throughout its range (Tevis 1947, Sharp and Sharp 1956, Ellis 1964, Berner and Gysel 1967, Bider *et al.* 1968, Sunquist *et al.* 1969, Urban 1970, Schneider *et al.* 1971, Ladine 1997). However, activity during the summer months (Jun. - Aug.) exhibited a shift toward sunset with activity decreasing after ca. 1.5 h after sunset. Activity in the latter half of Aug. starting to increase after this time (Fig. 1). A similar pattern was observed by Ladine (1997) when using timers on traps. However, timers on traps only indicate foraging behavior, eliminating the majority of activity of the raccoon. The decrease cannot be entirely explained by lessened activity of females immediately after parturition (Schneider *et al.* 1971) as males would be expected to make up ca. 50% of the population (Gehrt 2003) and mating, and thus parturition appear to be year-round on this site. As food resources are likely plentiful (T. A. Ladine, unpublished data) on the study site and surround areas, caloric intake can be accomplished in a relatively short period of time. Thus, reducing the time exposed to potential predators. Humidity is relatively high on the study site with the morning levels (\bar{x} = 88%) ca. 35% higher than afternoon. Raccoons do not exhibit seasonal variation in metabolic rates and body temperature (Mugaas *et al.* 1993). However, Mugaas *et al.* (1993) found that body temperature of the raccoon can increase during the summer do to a decrease in evaporative cooling. The decrease in evaporative cooling may be due to higher levels of humidity thus possibly reducing the ability of the raccoon to maintain a constant body temperature resulting in less activity. Alternatively, the combination of temperature and higher humidity could be a reason for the observed seasonal shift in the present study. Temperatures at the study

site are relatively high during the summer nights (mean low temperatures Jun. - 16° C, Jul. - 22° C, Aug. - 21° C). Mugaas *et al.* (1993) note raccoons dissipate between 35% (males) and 56% (females) of their body temperature through evaporative water loss. Higher humidity would slow evaporative water loss forcing the individuals to use less energy in activity. This accompanied with a stable food resource (garbage) may result in a lessened activity during the summer months.

The raccoon is an extremely adaptable species allowing survival in a number of disparate ecosystems. Urban systems provide different and sometimes novel situations for a species. One of the greatest potential problems for a species to overcome is an increase in pollutants when compared to a rural system. While pollutants, especially endocrine disruptors, may influence reproductive patterns more study is needed on the raccoon to verify the effects of pollutants on the species. While the shift in activity during the summer months is probably not entirely related to the urban system, it is an indication of the plasticity of the species.

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