Species Richness Within an Urban Coyote (*Canis latrans*) Territory in Atlanta, Georgia, USA

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Abstract - Atlanta, GA, USA, has been one of the fastest growing metropolitan areas in the US over the past several decades, with a human population now close to 6 million. Urbanization has been rapid and widespread, thereby creating a highly fragmented mosaic of urban green space. As metropolitan Atlanta grew, so too did the region's *Canis latrans* (Coyote) population, which has caused a mix of curiosity, delight, and concern among the city's residents. Although the value of urban wildlife is now recognized by many people, the Coyote's role in the animal community is often misunderstood or unknown, particularly in areas like the southeastern US where it is a relative newcomer. In an attempt to learn more about urban wildlife, particularly Coyotes, we used remote cameras to monitor a suburban green space in Atlanta from 2016 to 2018. A Coyote pair occupied the site throughout the duration of the study and produced offspring during each year. Biodiversity was high, as we detected 12 mammal, 2 reptile, and 22 bird species. Our study provides further insight into an urban Coyote population and its inclusion as part of an urban wildlife community.

Introduction

The geographic distribution of the earth's human population changed steadily over the 20th century, and there are now more people living in urban than rural environments. By the year 2050, the proportion of people living in urban environments is expected to increase from 55% to 68%, and much of this geographic population shift is the result of increasing urbanization around existing cities (United Nations 2018). For example, Kostmayer (1989, as cited in Yang and Lo 2003) estimated that suburbanization in the 1980s resulted in the daily conversion of 2226 ha of farmland or open space into urban uses in the US. A number of North American cities have experienced significant urban development and human population growth over the past several decades, including Atlanta, GA, USA, which was the third fastest growing metropolitan region in the US from 2016 to 2017 (US Census Bureau 2018). Georgia's overall urban population increased from 3.4 million in 1980 to 7.3 million in 2010, and metro Atlanta's population alone now stands at nearly 6 million people. During this time period, urban land cover in Georgia increased from 687,966 ha (1.7 million acres) to 1,618,743 ha (4 million acres), with much of that occurring in and around Atlanta (USDA 2016). A striking illustration of the pace of land conversion in Georgia is that it took 250 years to develop 687,966 ha (1.7 million acres) into urban use, but then only another 30 years (1980–2010) to more than double that amount (USDA 2016).

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Coincident with Georgia's rapid urbanization and human population increase was the immigration of *Canis latrans* Say (Coyote) into the southeastern US. The Coyote was historically restricted to regions west of the Mississippi River, but it steadily expanded its geographic range during the past several decades and is now found throughout North America (Hody and Kays 2018). The extirpation of the congeneric *C. rufus* Audubon and Bachman (Red Wolf) facilitated the southeastern range expansion of the Coyote by eliminating its primary non-human competitor (Thurber and Peterson 1991). The changes in land use that caused deforestation and increased edge habitat (i.e., urbanization) also likely accelerated Coyote expansion (Gompper 2002, Parker 1995).

Immigration of Coyotes into the Southeast probably began in the 1950s, but it was not until the mid-1960s that the species started to appear in middle Georgia as it followed a natural colonization pattern from west to east (Hill et al. 1987, Hody and Kays 2018, Parker 1995). Two decades later, Coyotes were found throughout the state (Hody and Kays 2018), and by the late-1990s Coyotes were becoming prevalent in metro Atlanta (C.B. Mowry and L.A. Wilson, pers. observ.). They have become common throughout the region; Coyote sightings are now reported by the public to our Atlanta Coyote Project website on a nearly daily basis (http://cs.berry.edu/coyote/report.php). The increase and expansion of Georgia's Coyote population was coincident with the state's pattern of urban development. As a result, humans and Coyotes are now often in close proximity to one another, as is the case in many other urban centers, which has led to much interest and debate about their presence and potential top-down trophic effects (Gompper 2002). A 2014–2015 survey of over 2000 metro Atlanta residents that we conducted found that 67% of respondents reported seeing or hearing a Coyote near their home over the past 3 years, while nearly 50% perceived an increase in nearby Coyote activity (Atlanta Coyote Project, unpubl. data).

The rapid pace and scale of urban development has led to an increased awareness and study of urban ecosystems (Magle et al. 2012, Ramalho and Hobbs 2012). Urban biodiversity and the benefits of conserving it to both nature and humans have now been recognized. The protection of rare species, the establishment of corridors for gene flow, greater understanding of environmental changes, development of ecosystem services, and enhanced human well-being have all been determined as motivations for green space and urban biodiversity conservation (Dearborn and Kark 2009). However, the disruptions to ecosystems caused by urbanization coupled with changes in animal community composition, particularly with respect to predators, can cause confusion and uncertainty about what is actually being conserved and how it should be accomplished. In southern California, the absence of Coyotes in urban habitat fragments led to an increased abundance of medium-sized predators (i.e., mesopredator release), which negatively affected bird communities (Crooks and Soulé 1999). Other studies in non-urban areas found similar indirect effects of Coyotes on community composition (Henke and Bryant 1999, Rogers and Caro 1998, Sovada et al. 1995, Vickery et al. 1992).

In an attempt to learn more about animal community composition in a southeastern US urban green space, we monitored local biodiversity using remote cameras over a 2-year period within a suspected Coyote territory in Atlanta. Our goals were to (1) verify the presence and size of the Coyote population at this site; (2) determine if Coyote reproduction was occurring and, if so, to what extent; and (3) to quantify and document sympatric species richness.

Field-Site Description

Our study site was a 20-ha privately owned urban green space in suburban Atlanta, Fulton, County, GA, USA, comprised of a mixed pine (*Pinus taeda* L. [Loblolly Pine])–hardwood (e.g., *Quercus* spp. [oaks], *Carya* spp. [hickories], *Liriodendron tulipifera* L. [Tulip Tree]) forest, an abandoned open field, a pond, and a small creek, all of which was surrounded by medium density human housing development (Fig. 1). Water flowed in the creek throughout the study period, but the

Figure 1. Location of the study site and camera traps within Fulton County (gray inset) in Atlanta, GA, USA. The 8 camera locations used during the May 2016–May 2018 study are indicated.

level fluctuated widely based on precipitation. Annual precipitation in this region was below average in 2016 (98 cm), average in 2017 (127 cm), and above average in 2018 (178 cm), although most of the 2018 rainfall surplus occurred over the final 5 months of the year and after our study had ended (National Weather Service 2019). Average temperatures vary from 1.67 ºC to 10 ºC in winter months and from 21 ºC to 31 ºC during the summer, but above average temperatures were common throughout the study (National Weather Service 2019). Despite the suburban setting, there was little human activity at the site. Coyotes have been observed and heard at this site and within the surrounding neighborhoods by local residents since at least 2004 (C. Nel, local homeowner, pers. comm.). No efforts to control wildlife have ever been conducted within the study site to the best of our knowledge, although Coyote trapping has been conducted in recent years in 2 nearby city-owned parks, including Roswell Area Park, which is nearly adjacent to the southern end of the study area, and Leita Thompson Memorial Park, which is ~4 km northwest of the study site. An active Coyote den, which consisted of an excavated hole in the ground, was discovered at the study site in March 2016, and we began to monitor the area shortly thereafter.

Methods

We deployed motion- and heat-activated cameras from May 2016 to May 2018. Over the course of the study, we used 8 camera locations (Fig. 1). Camera locations were concentrated at the northern end of the study site and not randomized because permission to access some of the privately owned green space was not granted. The majority of cameras deployed were either Bushnell Essential 2 or Aggressor Low Glow models (Bushnell Corporation, Overland Park, KS). We also used a Bushnell Ninja and a Browning Command Ops (Browning, Morgan, UT) camera for several weeks at the beginning of the study. We placed cameras along visible game trails and at stream crossings, as well as at the Coyote den site. The entrance to the den measured 42 cm wide x 25 cm tall x 3.35 m deep. We did not use baits or lures and deployed 2–5 cameras simultaneously. Aggressor cameras were set to take 1 still photograph followed immediately by a 30 sec video (hybrid mode), while the other cameras did not have this capability and were set to take only a 30 sec video. For all cameras, we set trigger interval at 10 sec, LED control to medium, and Night Vision Shutter and Sensor Level to auto. We also deployed a Digital Watchdog streaming camera (Digital Watchdog, Tampa, FL), which recorded continuously to a network video recorder, at the den site (camera location #1) from 5 January to 27 April 2017 and at a stream crossing (camera location #2) from 27 April to 31 August 2017. For all photographs obtained, we recorded the date, time, duration (if video), and animal species content (if any). We counted photographs of animals as separate events when they were at least 30 minutes apart, which is consistent with previous camera trap studies (Kelly and Holub 2008, Silver et al. 2004). Care was taken to not double-count animal detections as 2 separate events when they appeared on different cameras within 30 minutes of one another.

Results

We deployed cameras for a total of 740 continuous days, and trapping effort (# of cameras deployed * # of days) totaled 1989 trap nights (TN) with an average of 79.6 TN per month. Nearly 3000 images of mammals, birds, and reptiles were obtained, including 536 Coyote images (Fig. 2, Table 1). Mammalian species commonly detected included *Sciurus carolinensis* (Eastern Gray Squirrel), *Tamias striatus* (Eastern Chipmunk), *Sylvilagus floridanus* (Eastern Cottontail), Northern Raccoon, *Didelphis virginiana* (Virginia Opossum), and *Odocoileus virginianus* (White-tailed Deer), which were observed in nearly every month of the study. *Lontra canadensis* (North American River Otter), *Lynx rufus* (Bobcat), *Rattus rattus* (Black Rat), and *Vulpes vulpes* (Red Fox) were less common, but each species had multiple detections. We obtained images of *Mustela nivalis* (Least Weasel) on

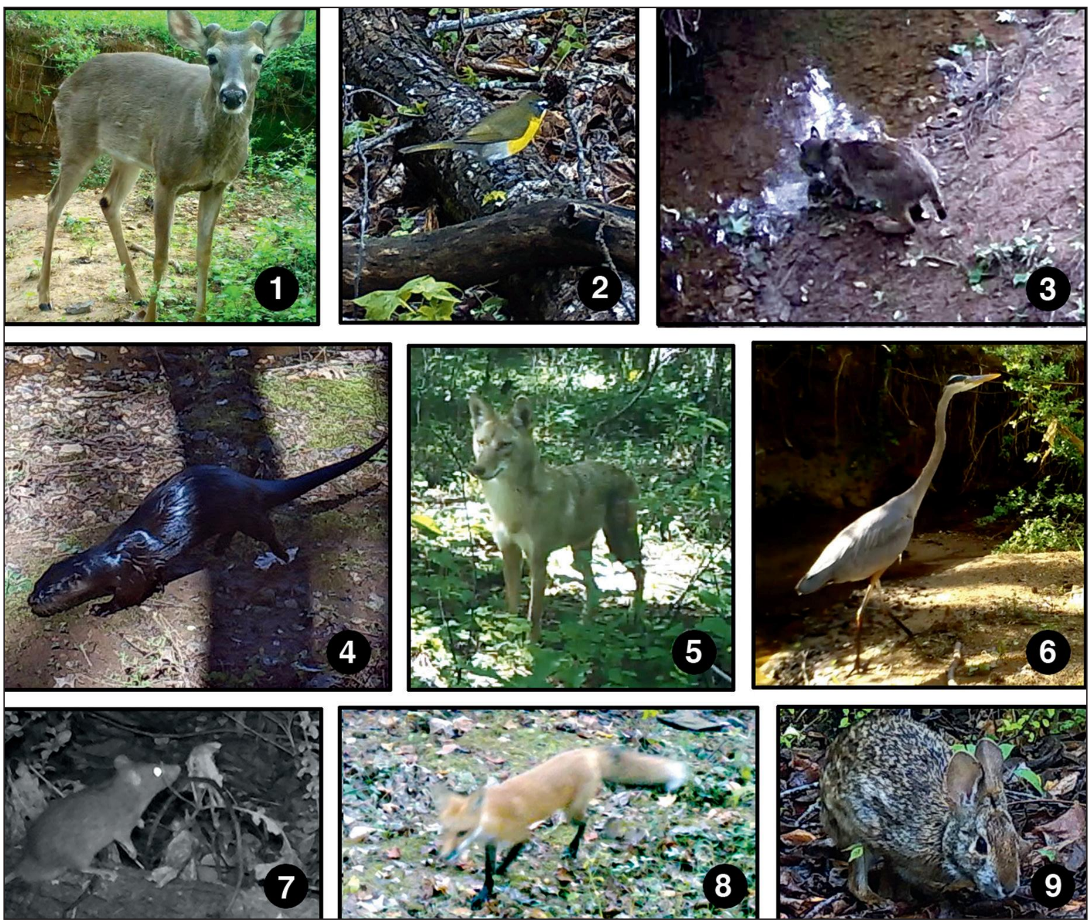

Figure 2. A partial representation of species diversity documented in Atlanta, GA, USA, May 2016–May 2018. (1) *Odocoileus virginianus* (White-tailed Deer), (2) *Icteria virens* (Yellow-breasted Chat), (3) *Lynx rufus* (Bobcat), (4) *Lontra canadensis* (North American River Otter), (5) *Canis latrans* (Coyote), (6) *Ardea herodias* (Great Blue Heron), (7) *Rattus rattus* (Black Rat), (8) *Vulpes vulpes* (Red Fox), and (9) *Sylvilagus floridanus* (Eastern Cottontail). Also see video of vertebrate species detected at study site in Atlanta, GA, USA, May 2016–May 2018, available online at https://youtu.be/CQH3jykDlyU.

Table 1. Vertebrate species detected in Atlanta, GA, USA, from May 2016 to May 2018. Months of detection are indicated for each year, with total number of detections for a given species indicated in parentheses. [Table continued on following page.]

Species	2016	2017	2018
Mammals			
Canis latrans Say (Coyote)	May–Dec (220)	Jan–Dec (263)	Jan–May (53)
Didelphis virginiana (Kerr) (Virginia Opossum)	Jun–Nov (39)	Apr–Sep, Nov–Dec (49)	Jan–May (74)
Lontra canadensis (Schreber) (North American River Otter)	Sep–Nov (5)	Jan–May,Oct–Dec (30)	Feb–May (24)
Lynx rufus (Schreber) (Bobcat)	Jan–Feb,May,Oct–Nov (7)	Jan–Mar (3)	
Mustela nivalis L. (Least Weasel)	Aug (1)	Jun (1)	
Odocoileus virginianus Zimmerman (White–tailed Deer)	Jun–Dec (33)	Jan–Aug,Oct–Dec (69)	Jan–Mar,May (35)
Procyon lotor (Northern Raccoon)	Jun–Dec (95)	Jan–Dec (103)	Jan–May (131)
Rattus rattus (L.) (Black Rat)	Sep (5)	Mar–Apr (11)	
Sciurus carolinensis Gmelin (Eastern Gray Squirrel)	Jun–Dec (396)	Jan–Dec (222)	Jan–May (355)
Sylvilagus floridanus (Allen) (Eastern Cottontail)	Jun–Nov (77)	Jan–Dec (103)	Jan–May (87)
Tamias striatus (L.) (Eastern Chipmunk)	Aug–Nov (55)	Feb–Dec (199)	Mar–May (129)
Vulpes vulpes (L.) (Red Fox)	Nov (1)	Oct (2)	Feb–May (7)
Reptiles			
Chelydra serpentina (L.) (Common Snapping Turtle)	May (5)		
Terrapene carolina (L.) (Eastern Box Turtle)	Aug (1)	Aug (2)	

Table 1, continued

Species	2016	2017	2018
Birds			
Ardea herodias L. (Great Blue Heron)	Apr, Jun–Jul, Nov–Dec (5)	Jan (1)	
Baeolophus bicolor (L.) (Tufted Titmouse)	Jan (1)		
Bubo virginianus (Gmelin) (Great Horned Owl)	Jan, May (2)	May (5)	
Buteo jamaicensis (Gmelin) (Red–tailed Hawk)	Feb (1)		
Buteo lineatus (Gmelin) (Red–shouldered Hawk)	Apr (1)		
Butorides virescens (L.) (Green Heron)	Aug (1)		
Cardinalis cardinalis (L.) (Northern cardinal)	Oct (2)	Apr, Jun–Jul, Dec (6)	Jan–May (12)
Catharus fuscescens (Stephens) (Veery)	Apr (3)		
Catharus guttatus (Pallas) (Hermit Thrush)	Apr (1)		
Catharus ustulatus (Nuttall) (Swainson's Thrush)	Apr (1)		
Colaptes auratus (L.) (Northern Flicker)	Aug, Oct (3)	Jun, Aug (3)	Feb–Mar, May (3)
Cyanocitta cristata (L.) (Blue Jay)	Sep–Nov (6)	Apr–May, Sep–Oct (5)	Apr–May (5)
Dumetella carolinensis (L.) (Gray Catbird)	May (1)		
Hylocichla mustelina (Gmelin) (Wood Thrush)	Sep (1)	Apr (1)	
Icteria virens (L.) (Yellow–breasted Chat)	Apr (1)		
Pipilo erythrophthalmus (L.) (Eastern Towhee)	Jun (2)	May (1)	
Seiurus aurocapilla (L.) (Ovenbird)	Apr (1)		
Setophaga coronate (L.) (Yellow–rumped Warbler)	Apr (1)		
Thyrothorus ludovicianus (Latham) (Carolina Wren)	Apr (1)		
Toxostoma rufum (L.) (Brown Thrasher)	Aug–Nov (7)	Mar–Apr (2)	Apr–May (6)
Turdus migrato L. (American Robin)	Jun, Aug–Oct (24)	Mar–Oct (25)	Mar, May (3)
Zenaida macroura (L.) (Mourning Dove)	Sep (2)	Jan, May (5)	

2 occasions. Two reptilian species were detected (*Chelydra serpentina* [Common Snapping Turtle] and *Terrapene carolina*. [Eastern Box Turtle]), while avian diversity documented was high and included 2 species of waders, 3 raptors, and 17 passerines (Table 1, Fig. 2).

We collected Coyote images on 267 different days, with detections in every month of the study (Fig. 3). The total number of Coyotes we detected in any single month varied from 2 to 7, including pups (Fig. 4). Reproduction in this pack occurred annually with pups first appearing on cameras beginning in late May 2016 and 2017. We estimated litter size to be 4–5 pups in 2016 and 6 pups in 2017. Although pups were not detected on cameras in 2018, we filmed a pregnant female on several occasions in March of that year. Pups were seen emerging from the den in April 2016, and the suspected alpha male/female pair was routinely filmed inspecting and preparing the same den from January to April 2017, but the den was abruptly abandoned in April 2017 following a heavy rain event. Nevertheless, pups captured on cameras beginning on 1 June 2017 provided evidence of a nearby alternative den, although the new den was never located. Despite not being used in April 2017, the original den was routinely visited and explored by adults and pups for the next several months. Based on the total number of images obtained during a given time of the day throughout the study, Coyotes were most active 01:00–02:00, 06:00–08:00, and 20:00–23:00 and least active 09:00–18:00 (Fig. 5).

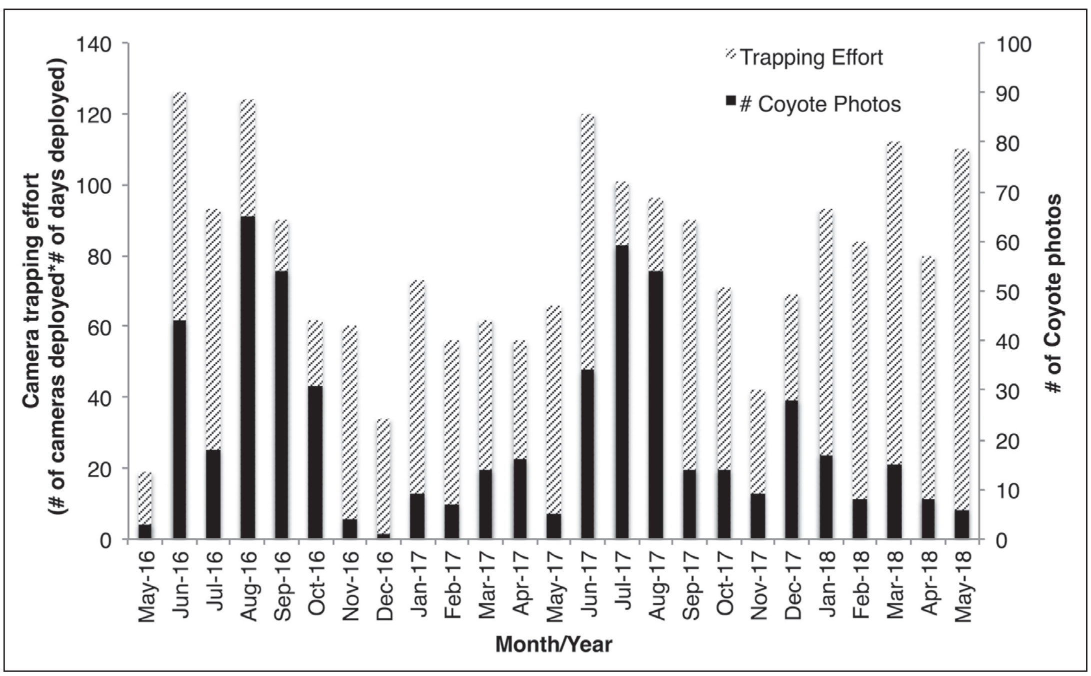

Figure 3. The number of monthly *Canis latrans* (Coyote) photographs obtained and camera trapping effort (# of cameras deployed * # of days deployed) from May 2016 to May 2018 in Atlanta, GA.

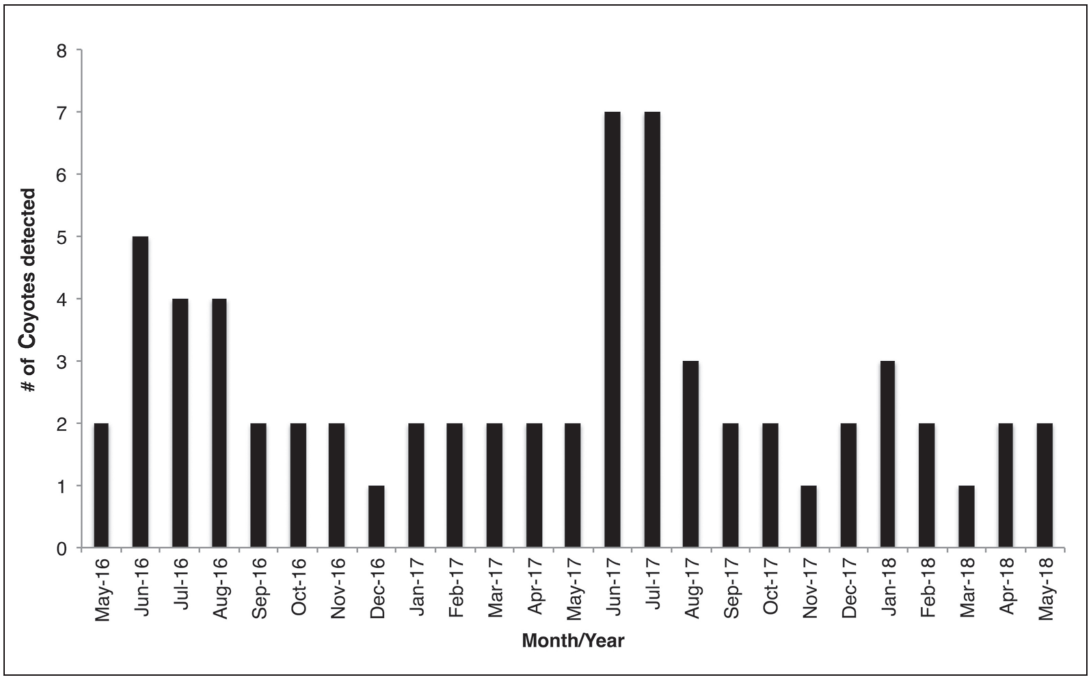

Figure 4. The number of *Canis latrans* (Coyote) detected in each month from May 2016 to May 2018 in Atlanta, GA, USA.

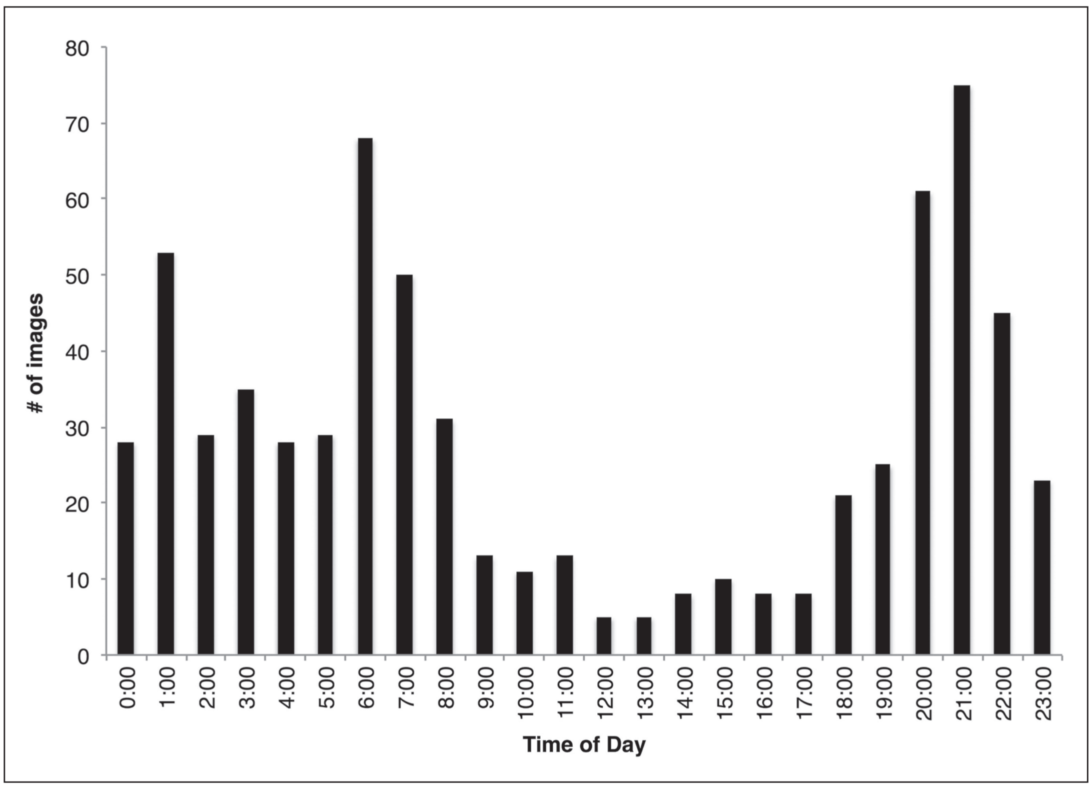

Figure 5. Coyote activity based on time of day. Each bar represents the number of images obtained during a 1-hour time block (e.g., 12:00–12:59).

Discussion

We detected many of the vertebrate species that are native to the Georgia Piedmont ecoregion during our study, which underscores the importance of maintaining and conserving urban green spaces. Our initial interest in this particular site was due to the discovery of an active Coyote den by a local homeowner in March 2016. Subsequently, we began to monitor the den site and surrounding area with remote cameras in order to learn more about the local Coyote population and continued our efforts unabated for the next 2 years. As our study progressed, we found evidence of high species diversity, which is contrary to common misconceptions that portray Coyotes as detrimental towards rich community composition.

Our study site potentially fell within the territory of a breeding resident Coyote pair and their offspring. We do not know the extent of the territory, but the presence of a den, newly weaned pups in 2016 and 2017, a pregnant female in 2018, and consistent Coyote images throughout the study indicate that our camera-trapping efforts were likely positioned within the core area of the home range. We cannot conclude with certainty that the breeding male and female pair remained consistent for the duration of the study, although only the right eye of the suspected alpha male reflected LED light from the cameras (i.e., the tapetum lucidum of his left eye appeared to be malformed), which enabled us to identify him as a consistent resident throughout the majority of the study. Our study seems to confirm previous studies that have found Coyotes select for remnants of natural habitat in urban landscapes, particularly those with some open canopy and natural edge habitats along water courses (Gallo et al. 2017, Gese et al. 2012, Grubbs and Krausman 2009, Kays et al. 2008).

On multiple occasions between 27 August and 20 October 2017, we detected a Coyote who was missing the lower half of its rear right leg. The cause of the injury was not known, but it could have been the result of the trapping effort that was in effect during that time in 2 nearby parks or a vehicle collision. We were also notified of a dead Coyote that had been struck by a vehicle on a road adjacent to the study site on 7 February 2017, although we were only able to observe photographs of this individual. It was a subadult female who was potentially one of the 2016 pups of the resident breeding pair. We were aware of no other instances of Coyote mortality and injury in the area during this time, and Coyote numbers in our study site were indicative of a relatively stable and unexploited population that produced small to moderate-sized litters in 2016 and 2017. As a point of comparison, in 2014 we observed a litter size of 7 in a Coyote group living in a highly urbanized landscape within the city of Atlanta and a litter size of 5 in another group living in a more suburban area in 2018 (C.B. Mowry and L.A. Wilson, unpubl. data). The litter sizes we have documented in metro-Atlanta are similar to those found by the Urban Coyote Research Project in Chicago, although they once detected a litter of 11 pups (Gehrt 2006). Pup dispersal in the current study apparently began in September of each year when the number of individuals we detected dropped back down to 2 (Fig 4), which is consistent with a previous 3-year study of juvenile Coyote dispersal in Maine (Harrison 1992). Although human intrusion within our study site was minimal, Coyotes were apparently less active during daylight hours throughout the study, likely to avoid disturbances associated with urbanization (Grinder and Krausman 2001).

Our consistent detection of common Coyote prey items suggests a robust availability of food at our study site. Despite the year-round presence of Coyotes, or possibly because of it, animal species richness was high. Twelve mammal and 2 reptile species were detected on multiple occasions along with 22 avian species. Surveying biodiversity using only camera traps has its obvious limitations, but even the exclusive use of this method allowed us to detect nearly one third of the terrestrial mammalian species that are endemic to this region (GeorgiaInfo 2018) as well as a number of uncommon or seasonal birds. Garwood et al. (2015) reported Gray Squirrels, Eastern Cottontails, and White-tailed Deer to be the most common prey items for Coyotes in urban Wisconsin, and these species were consistently detected throughout the duration of our study, as were Eastern Chipmunks. While we were able detect Black Rats in 2016 and 2018, images of small mammals can be difficult to capture on remote cameras, and the paucity of them in our study is not necessarily an indication of their absence. However, we did capture footage of a Red Fox with a Black Rat in its mouth in March 2018.

The co-occurrence of Coyotes and Red Foxes at our study site was initially somewhat unexpected based on prior studies reporting avoidance between these 2 species (Gosselink et al. 2003, Harrison et al. 1989, Voigt and Earle 1983). For example, Harrison et al. (1989) found no instances of Red Fox within Coyote core areas during a 3-year study in eastern Maine, yet we detected Red Fox 10 times. Some temporal avoidance of Coyotes by Red Fox could have been happening at our study site, although 6 of 10 Red Fox detections occurred within 24 hours of a Coyote detection at either the same camera location or one that was <100 m away. A more recent study by Mueller at al. (2018) of Coyotes and Red Fox did find some degree of spatial and temporal overlap in an urban landscape, which coincides with our observations. Bobcats and Coyotes exhibited a low level of temporal overlap, with only 2 of 10 Bobcat detections occurring on the same day that Coyotes were seen. The remaining Bobcat detections occurred 2–6 days after a Coyote detection, and Bobcats might have had non-overlapping core areas to avoid agonistic encounters with Coyotes (Thornton et al. 2004). Raccoons, River Otters, and Opossums were all ubiquitous throughout the study, which is consistent with previous studies that have shown little negative effect of Coyotes on site use by native mesopredators (Cove et al. 2012, Gehrt and Prange 2007, Prange and Gehrt 2007). However, we never detected *Felis catus* L. (Domestic Cat) or *Mephitis mephitis* Schreber (Striped Skunk) during our study, which possibly contributed to the high level of biodiversity we observed, particularly avian species. Kays and DeWan (2004) detected Cats more often near forest edges and in smaller forest fragments, and these Cats preyed upon small mammals and birds at a rate of 1.7 kills/Cat/month during summer months. Gehrt et al. (2013) found a partitioning of the urban landscape by Coyotes and Cats, with little interspecific overlap between their core areas of activity.

The relatively large size, habitat heterogeneity, and proximity of our study site to other green spaces (1–4 km away) were likely major determinates of overall species richness (Matthies et al. 2017). Urban green spaces can act like islands in a sea of development and show patterns of species–area relationships like those observed in island biogeography (MacArthur and Wilson 1967).

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