Case Study

Holiday lights create light pollution and become ecological trap for eastern fox squirrels: case study on a university campus

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Abstract: Ecological light pollution is now recognized as a significant source of ecosystem alteration. We documented that holiday lights are a seasonal source of light pollution that constitute an ecological trap for eastern fox squirrels (*Sciurus niger*). Texas A&M University-Kingsville (TAMUK) wildlife students surveyed a 2-km walking transect 5 times per month each month for the relative abundance and diel behavior of eastern fox squirrels and feral cats (*Felis catus*) on the TAMUK campus during 2018–2019. Eastern fox squirrels exhibited diurnal behaviors throughout the year but extended their foraging behavior nearly 4 hours after sunset with the addition of holiday lights. Feral cats and owls (Strigiformes) exhibited diurnal and nocturnal behaviors but conducted the majority of their hunting during crepuscular hours. We documented that monthly squirrel mortality increased 7-fold with the addition of holiday lights, possibly due to the extension of foraging time by squirrels. Although seasonal lighting is intended to be festive for humans, it can have negative consequences for eastern fox squirrels. Educating the public concerning the issue of light pollution on wildlife species is needed because the majority of the public appears unaware that bright lights can negatively alter wildlife behaviors. Reducing light intensity by either using less outdoor lights or perhaps using colored lights rather than clear white bulbs may lessen the negative effect on foraging behavior of squirrels.

Key words: Christmas lights, depredation, eastern fox squirrel, ecological trap, *Felis catus*, feral cat, holiday lights, light pollution, *Sciurus niger*, survival, Texas

Christmas is a season of celebration and traditions. A common tradition within the United States is to place holiday lights outside of homes and businesses and on buildings, trees, and bushes (Figure 1). Typically, lights are placed outdoors during November and are lit nightly until the beginning of January. Although this tradition provides a festive appearance, it can be considered a source of light pollution.

Light pollution is the periodic or chronic artificial illumination of the night, which disrupts the normal cycle of dark and light (Riegel 1973). Because about a third of vertebrate species and nearly two-thirds of invertebrate species are nocturnal (Hölker et al. 2010), a disruption in the natural dark:light cycle can have serious consequences. Anthropogenic light pollution has been categorized as astronomical light pollution, which obscures the view of the night sky, and ecological light pollution, which has altered terrestrial and aquatic ecosystems (Longcore and Rich 2004). Direct effects of light pollution on ecosystems have included: (1) disorientation of animals, (2) the onset of reproductive behaviors during the wrong period, (3) altered feeding and pollination behaviors, and (4) altered migration patterns (Hölker et al. 2010). Specific examples of the deleterious effects light pollution have include altering the breeding behavior of male green frogs (*Rana clamitans melanota*; Baker and Richardson 2006);

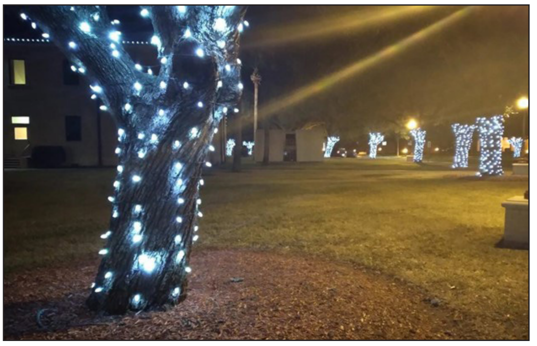

Figure 1. Holiday lights are placed on trees within the center of the Texas A&M University-Kingsville (Kingsville, Texas, USA) campus and illuminated daily during the evening hours from Thanksgiving (fourth Thursday of November) to January 2 each year.

increased avian mortality associated with lighthouses (Jones and Francis 2003); seaward disorientation of hatchling leatherback (*Dermochelys coriacea*), loggerhead (*Caretta caretta*), and green sea turtles (*Chelonia mydas*; Lorne and Salmon 2007, Hu et al. 2018); changing the singing behavior of American robins (*Turdus migratorius*; Miller 2006); altering the diel vertical migration of common water fleas (*Daphnia* spp.; Moore et al. 2000); disruption of migratory patterns of Atlantic salmon (*Salmo salar*) smolts leaving their natal stream (Riley et al. 2012); delayed commuting activity of the threatened lesser horseshoe bat (*Rhinolophus hipposideros*) with no evidence of habituation (Stone et al. 2009); disruption of the circadian rhythm and disoriented flight patterns of numerous nocturnal migratory avian species (Cabrera-Cruz et al. 2018); and adversely affected photosynthetic efficiency of numerous plant species (Meravi and Prajapati 2020). Although increased illumination of the night is done to benefit humans (Longcore and Rich 2004), artificial light can have serious implications on other vertebrates and their natural histories (Ditmer et al. 2021).

Herein we demonstrate the issue of holiday lights as a source of light pollution on a university campus. Our objectives were to document: (1) the typical diel behavior patterns of eastern fox squirrels (*Sciurus niger*; squirrels) and feral cats (*Felis catus*; cats) throughout the year on a university campus in southern Texas, USA, (2) the increased light intensity created by holiday lights, (3) the change of foraging behavior by squirrels during the time of holiday light illumination, and (4) the monthly survival of squirrels throughout the year.

Study area

We used the campus of Texas A&M University-Kingsville (TAMUK) in Kingsville, Texas as our demonstration site. The campus, located along the southern Gulf Coast of Texas, is 648 ha of land, but the bulk of approximately 85 buildings are located within 100 ha of the center of the entire property. The climate of Kingsville, Texas is considered humid subtropical with hot (~35°C) summers and mild (~22°C) winters. The area is landscaped with St. Augustine grass (*Stenotaphrum secundatum*), cabbage palms (*Sabal palmetto*), live oaks (*Quercus virginiana*), and honey mesquites (*Prosopis glandulosa*). The seeds and acorns from the aforementioned trees provide year-round food sources for eastern fox squirrels that reside on the main campus as each tree produces fruits and seeds at different periods throughout the year.

Methods

Data collection

During November of each year on the TAMUK campus, the base of all trees from ground level to approximately 4 m above ground are wrapped with C-9, white-colored, transparent, 7-watt lighting as part of the university's annual holiday decorating. Lights are illuminated nightly at sunset beginning the day after the American Thanksgiving holiday (November 22 and 28 for 2018 and 2019, respectively) through January 2.

With the help of students in the Department of Rangeland and Wildlife Sciences at TAMUK, we surveyed monthly relative abundance and diel behavior of squirrels and cats within the center of the TAMUK campus during 2018–2019. A 2-km walking transect was conducted by 6 observers 5 times per month, inclusive of weekdays and weekends, working in groups of 2–3 observers during each of 6 time intervals (0001–0400, 0401–0800, 0801–1200, 1201–1600, 1601–2000, and 2001–0000 hours) for a total of 30 sampling occasions each month. The starting direction of each transect was randomly selected to avoid confounding effects of survey methodology and reduce the autocorrelation between animal behavior and time of day. Squirrels and cats observed were counted, time recorded, and their behavior identified. Observers had access to Creative XP Digital Night Vision Binoculars Pro (Creative S&P LLC, Hayward, California, USA) to aid their vision in darkness when needed. Animal behaviors were placed into 5 categories that included resting-sleeping, grooming, socializing-interactions, foraging, and seeking shelter. Human observers (N = 6) received training to consistently differentiate animal behaviors throughout the study, and 2 observers were required to agree on behaviors observed. Mortality events witnessed by observers were documented. If observers located carcasses during surveys, attempts were made to identify the most likely mortality source. For example, if the carcass was found on a road with no discernable bite wounds, then it was assumed a vehicular death. If found within a tree or at a tree base with talon wounds and skin tears, it was assumed a raptor kill. Because other predators of squirrels, such as raccoons (*Procyon lotor*), striped skunks (*Mephitis mephitis*), and snakes (Serpentes), are extremely rare within the center of the TAMUK campus (personal observation, S. Henke [first author] with 30 years of wildlife research experience and trapping on the study area), feral cats were considered the most likely mammalian predator of squirrels. In addition, during nighttime surveys, human observers recorded the light intensity of 50 random areas exposed to streetlights and holiday lights with an Extech Easy View 30 light meter (Forestry Supplier, Jackson, Mississippi, USA). Light intensity was taken at ground level on a horizontal plane. Random areas were determined by the number of steps from 0–99 steps via a random number generator until the light intensity of 50 areas were collected.

We obtained the official sunrise, sunset, and twilight start and end times from https://sunrise-sunset.org/us/kingsville-tx/. Kingsville, Texas is located in the Central Standard Time zone. Because of Daylight Saving Time, an hour shift forward and backward occurred in March and October, respectively.

Data analysis

Only 1 university campus was used because no other campuses or properties of similar size, elevation, vegetation composition, predator community, or climate exist in the study region. In such cases as this, true replication is both impossible and impractical (Mendenhall et al. 2014). Our results, therefore, are applicable only to the TAMUK campus (Wester 1992). Also, because the TAMUK campus is relatively small (<40 ha), portions of campus with and without holiday lights could not be analyzed because such locations would not be independent, as the home range of feral cats could include the entire campus (Lepczyk et al. 2015). The light environment on this campus is a result of artificial lighting—provided by streetlights year-round and street lights plus holiday lights in December. Thus, we assessed the effects of holiday lights on eastern fox squirrels by testing effects of month and time of day. We used a linear mixed model with repeated measures because we collected count data using the same transect within each of 6 daily time intervals, each month, during 2 years. Our model included fixed effects of year, month, and time of day (as well as their interactions). Random effects included survey, the crossed interaction between survey and year, and the crossed interaction between survey and month nested within year. The crossed interaction between survey and month nested with year was the subject for a repeated measures effect; we used AIC criteria to select a variance-covariance matrix among variance-components: first-order autoregressive and first-order autoregressive moving average candidates. We used Satterthwaite's method to estimate degrees of freedom. Count data are discrete random variables and thus are not normally distributed. Because our model included interactions, we transformed counts to normal scores for analysis (Mansouri and Chang 1995); observed means are presented. Chi-square analysis was conducted to determine if mortality of squirrels was equal between months.

Results

The number of squirrels we observed during surveys within a given time period and month ranged from 0–12 squirrels. Relative abundance of squirrels during surveys interacted between month and time of day ($F_{55,572} = 13.1$, $P < 0.0001$). Relative abundance of squirrels was relatively consistent throughout the year, except for a peak during the summer months of July and August (Figure 2). Squirrels, on average, did not leave their roost and become visible on the survey route until 133 ± 14.8 minutes after official sunrise. The earliest observed squirrel during our study was recorded 93 minutes

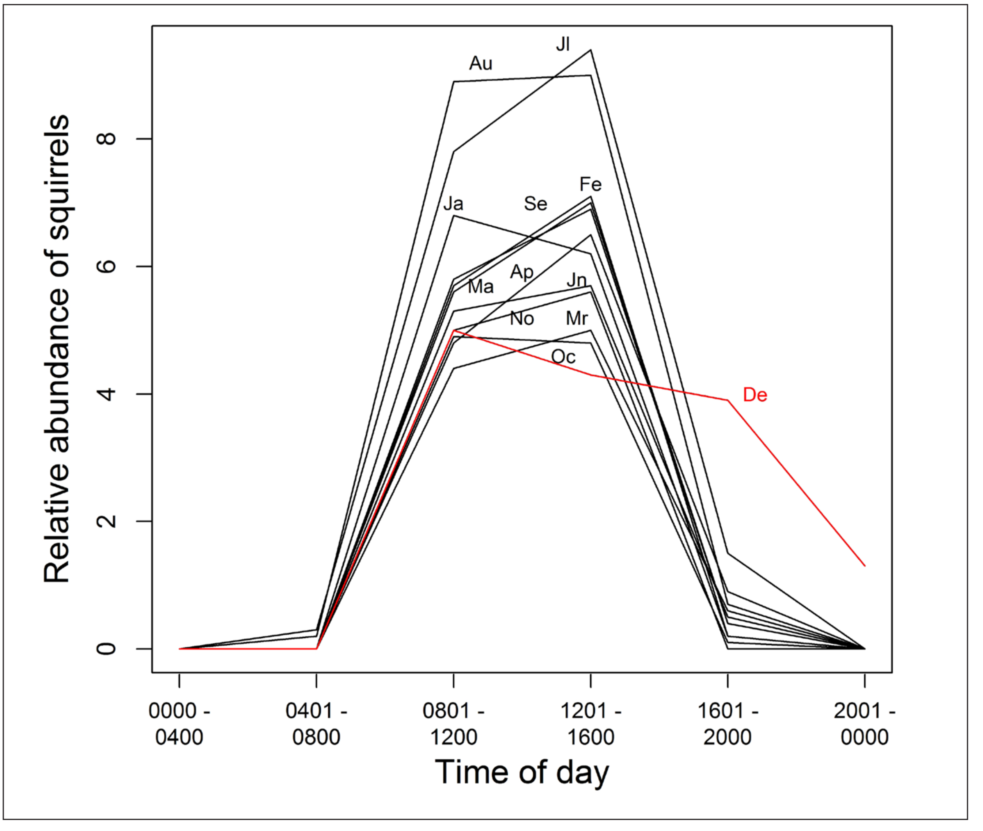

Figure 2. Average monthly relative abundance of eastern fox squirrels (*Sciurus niger*) that were observed along a 2-km walking transect during 6 4-hour daily time periods on the campus of Texas A&M University-Kingsville (Kingsville, Texas, USA) during 2018–2019. The red line differentiates December from the other months due to the difference in activity pattern observed within eastern fox squirrels. Lines represent different months and are designated as Ja = January, Fe = February, Mr = March, Ap = April, Ma = May, Jn =June, Jl = July, Au = August, Se = September, Oc = October, No = November, and De =December.

after sunrise. On average throughout most of the year, squirrels conducted their diurnal activities until 127.1 ± 17.3 minutes before official sunset, at which time they would return to their roost. From January to November, the latest squirrel observation was 67 minutes prior to official sunset. However, during December, with the illumination of the holiday lights, squirrels were observed foraging as late as 267 minutes after official sunset (Figures 2 and 3). The relative abundance and activity pattern of squirrels was not different ($F_{1\text{-}55,\ 572} < 0.26$, $P > 0.89$) between years or between interactions involving year as a factor.

Squirrels spent most of their time foraging (~70%), followed by grooming (~12%; Table 1). The remaining behaviors of social interaction, resting, and seeking shelter were evenly distributed (~6% each; Table 1). Their behaviors appeared consistent across months (Table 1).

Overall, the average number of cats we observed during surveys within a given time period, month, and year was 14.7 ± 2.3 cats with a range of 6–22 cats. However, the relative abundance of cats interacted by time of day, month, and year ($F_{55,\ 356} = 4.2$, $P < 0.0001$). Relative abundance of cats peaked during the summer months (May to July) during both years with a second peak in abundance during December, but only in 2018 (Figure 4). Cats were observed during each time period within a diel cycle. In general, cats were observed resting-sleeping (~77%), grooming (~12%), and socializing (~10%) during diurnal hours and foraging (~88% and 52% of observations) during crepuscular hours and nocturnal hours, respectively (Figure 2). Cats sought shelter (<5% of observations during all time periods) and only if ap-

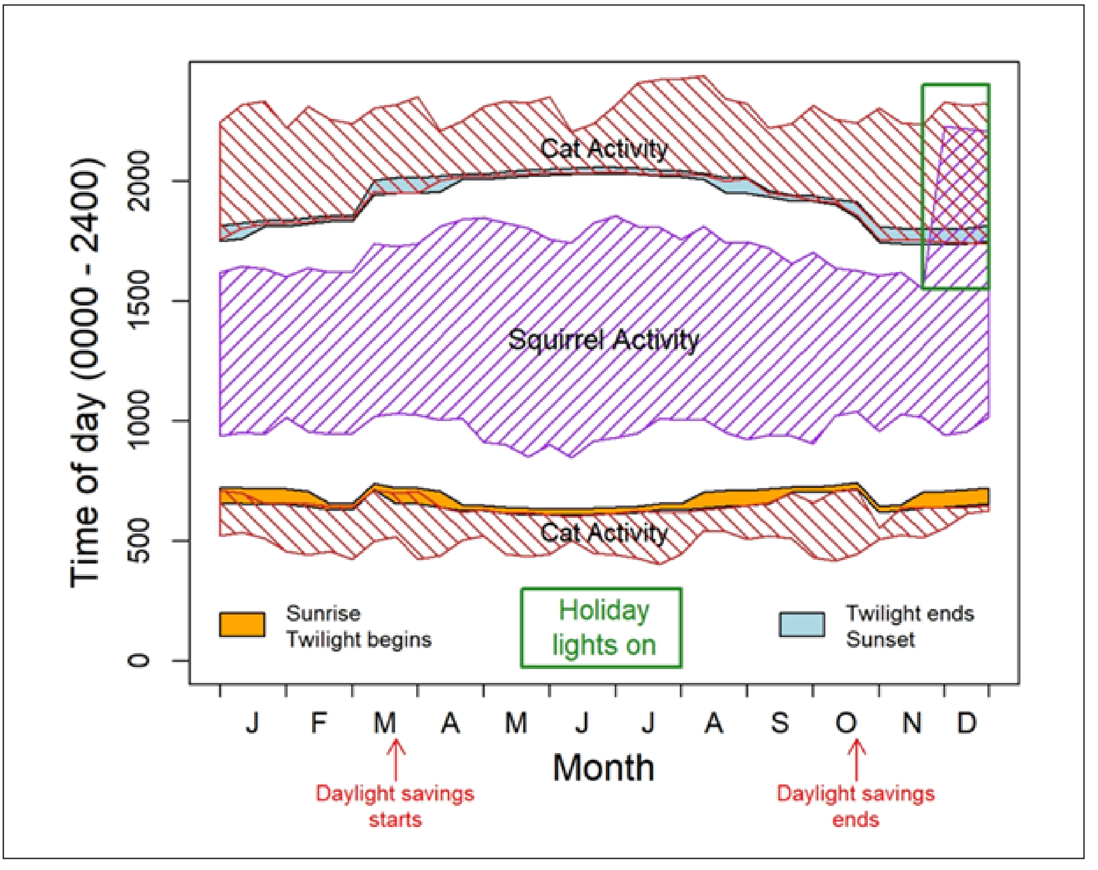

Figure 3. General activity patterns of eastern fox squirrels (*Sciurus niger*) and feral cats (*Felis catus*) during a diel cycle each month on the campus of Texas A&M University-Kingsville (Kingsville, Texas, USA) during 2018–2019. The 1-hour increase and decrease in sunrise and sunset, respectively, during March and October represents the time change due to Daylight Saving Time. The green box represents the times when holiday lights are illuminated on the campus.

proached too closely by a human observer.

Average nighttime light intensity from streetlamps along the survey route was 57.7 ± 32.2 lux (range 8–102 lux) during January to November. However, with the illumination of holiday lights during the month of December, the average light intensity along the survey route was 188.9 ± 23.4 lux (range 122–356 lux), which, on average, constituted a 3.3-fold increase in light intensity. Depending on the proximity to the nearest illuminated tree, light intensity increased 3- to 15-fold along the survey route.

We documented 24 squirrel mortalities during our study, which on average was 1 mortality per month. On average, monthly mortality of squirrels was 1, 0.5, 1, 0, 2, 0.5, 0, 0.5, 0, 1.5, 0.5, and 4.5 during January to December. More mortalities of squirrels (X^2 = 35.0, df = 11, $P <$ 0.0002) occurred in December, constituting 70% of the X^2-value. Of the squirrel mortalities that occurred from January to the third week of November, 9, 5, and 1 were hit-by-vehicle, raptor, and unknown cause, and all occurred during diurnal hours. Of these mortalities, 2, 3, and 0 were witnessed events by observers. Of the 9 squirrel mortalities that occurred during December, 6 and 3 were attributed to feral cats and owls (2 by great-horned owl [*Bubo virginianus*] and 1 by barn owl [*Tyto alba*]), respectively, and each mortality event occurred after twilight ended. Of these 9 mortalities, 3 feral cat and all owl kills (N = 3) were witnessed events by observers. During January through November of our 2-year study, we documented 15 squirrel mortalities and 766 squirrel observations (~2% mortalities amongst the observations); however, during December this ratio of deaths to observations increased to 37.5% (9 mortalities among 24 observations).

Table 1. Average monthly observations of eastern fox squirrels (*Sciurus niger*) and their associated behavior within 6 time intervals during a 24-hour period along a 2.5-km transect located on the campus of Texas A&M University-Kingsville (Kingsville, Texas, USA) during 2018–2019.

	Months											
Time period (hours)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0001–0400	0	0	0	0	0	0	0	0	0	0	0	0
N	0	0	0	0	0	0	0	0	0	0	0	0
Foraging (%)	0	0	0	0	0	0	0	0	0	0	0	0
Grooming (%)	0	0	0	0	0	0	0	0	0	0	0	0
Social (%)	0	0	0	0	0	0	0	0	0	0	0	0
Rest (%)	0	0	0	0	0	0	0	0	0	0	0	0
Shelter (%)	0	0	0	0	0	0	0	0	0	0	0	0
0401–0800												
N	0	0	0	0	0	0	1	1	0	0	0	0
Foraging (%)	0	0	0	0	0	0	0	0	0	0	0	0
Grooming (%)	0	0	0	0	0	0	100	100	0	0	0	0
Social (%)	0	0	0	0	0	0	0	0	0	0	0	0
Rest (%)	0	0	0	0	0	0	0	0	0	0	0	0
Shelter (%)	0	0	0	0	0	0	0	0	0	0	0	0
0801–1200												
N	34	29	21	25	29	25	39	43	28	25	25	25
Foraging (%)	50.0	72.4	85.7	84.0	72.4	68.0	61.5	60.5	71.4	80.0	76.0	76.0
Grooming (%)	14.7	3.4	14.3	8.0	10.3	8.0	15.4	16.3	14.3	12.0	12.0	12.0
Social (%)	26.5	6.9	0	0	0	0	5.1	11.6	0	0	0	4.0
Rest (%)	0	6.9	0	0	6.9	16.0	7.7	2.3	7.1	8.0	4.0	0
Shelter (%)	8.8	10.3	0	8.0	10.3	8.0	10.2	9.3	7.1	0	8.0	8.0
1201–1600												
N	31	35	26	34	36	28	47	45	36	24	28	22
Foraging (%)	45.2	57.1	65.4	70.6	69.4	67.9	59.6	60.0	66.7	75.0	75.0	81.8
Grooming (%)	19.4	14.3	15.4	8.8	8.3	7.1	12.8	13.3	19.4	12.5	7.1	13.6
Social (%)	12.9	11.4	7.7	11.8	13.9	7.1	10.6	8.9	8.3	0	7.1	0
Rest (%)	12.9	5.7	7.7	2.9	5.6	10.7	8.5	6.7	2.8	8.3	10.7	4.5
Shelter (%)	9.6	11.4	3.8	5.9	2.8	7.1	8.5	11.1	2.8	4.2	0	0
1601–2000												
N	0	2	2	4	2	2	7	4	2	1	0	19
Foraging (%)	0	100	100	100	100	100	85.7	75.0	100	100	0	89.5
Grooming (%)	0	0	0	0	0	0	14.3	25.0	0	0	0	10.5
Social (%)	0	0	0	0	0	0	0	0	0	0	0	0
Rest (%)	0	0	0	0	0	0	0	0	0	0	0	0
Shelter (%)	0	0	0	0	0	0	0	0	0	0	0	0
2001–2400												
N	0	0	0	0	0	0	0	0	0	0	0	5
Foraging (%)	0	0	0	0	0	0	0	0	0	0	0	100

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Grooming (%)	0	0	0	0	0	0	0	0	0	0	0	0
Social (%)	0	0	0	0	0	0	0	0	0	0	0	0
Rest (%)	0	0	0	0	0	0	0	0	0	0	0	0
Shelter (%)	0	0	0	0	0	0	0	0	0	0	0	0

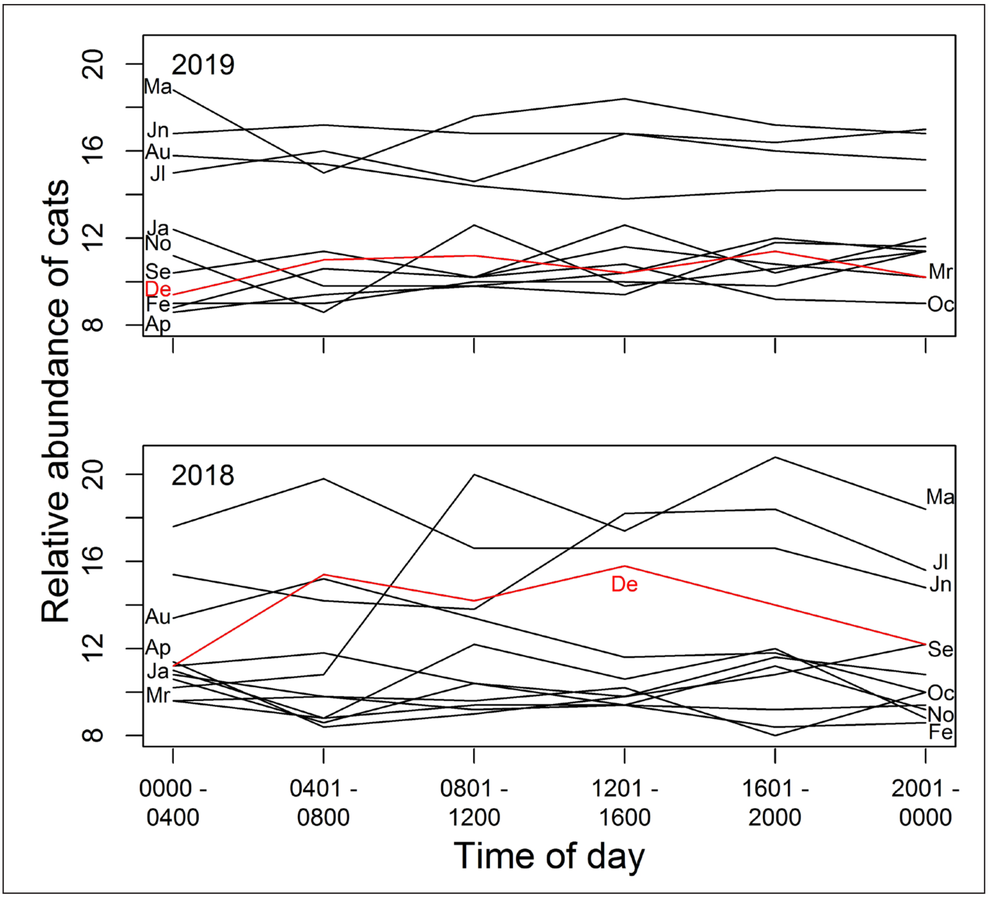

Figure 4. Average monthly relative abundance of feral cats (*Felis catus*) that were observed along a 2-km walking transect during 6 4-hour daily time periods on the campus of Texas A&M University-Kingsville (Kingsville, Texas, USA) during 2019 (top figure) and 2018 (bottom figure). Years are displayed separately because a 3-way interaction between time of day, month, and year occurred. The red line differentiates December from the other months due to the difference in activity pattern observed within eastern fox squirrels (Sciurus niger). Lines represent different months and are designated as Ja = January, Fe = February, Mr = March, Ap =April, Ma = May, Jn = June, Jl = July, Au = August, Se = September, Oc = October, No = November, and De = December.

Discussion

Holiday lights on the TAMUK campus appear to create an ecological trap for eastern fox squirrels (Gates and Gysel 1978). We hypothesize that during December, squirrels foraged longer than their typical behavior because of increased light intensity caused by holiday lighting. Squirrels foraging after sunset created an overlapped use of space in time between squirrels and novel predators such as domestic cats and owls. Even though owl species and domestic cats reside on campus during diurnal hours, they rarely hunt during this time because they prefer the crepuscular and nocturnal hours (Marti 1974, Turner and Bateson 2000). Cats have a high number of rods in their retina, a curved cornea, and large lenses, which allow them to see well in dim light conditions (Morimoto et al. 2014); thus, cats would be little affected by increased lighting conditions during December.

The exposure to novel predators appeared to increase squirrel mortality during December. Therefore, potential energy gained from increased foraging incurred the cost of an increase in mortality. Such tradeoffs have been documented in which diurnal species capable of exploiting artificial light extended their foraging into nocturnal hours, and predators found it easier to detect prey with the aid of artificial light (Lyytimäki 2013). Ecological traps created by light pollution also have been documented within intertidal areas for wading shorebirds, where light pollution improved the foraging conditions for shorebirds, but the increased foraging created a cascade effect within the food web that resulted in a decreased resilience of the ecosystem (Santos et al. 2010).

Alternate hypotheses are that the majority of students depart from campus for the latter half of December, which in turn could cause the foraging behavioral changes in squirrels due to lack of human activity during this time, or possibly, if squirrels were conditioned to being fed by students or on their left-behind food, causing squirrels to forage for longer periods during student absence from campus. Although both explanations seem to be reasonable hypotheses, similar situations occur on weekends and during the summer months on the TAMUK campus. About 15% of the 7,000 students live on campus (https://www.tamuk.edu/housing), of which the majority (>80%) are freshmen and sophomore undergraduate students who return home for weekends. In addition, on-campus enrollment during summers is typically <10% of the regular academic year, and summer classes end by 1700 hours. Therefore, the TAMUK campus has little to no human activity during most weekends and during the summer. Thus, if lack of human presence and/or their food debris were the cause for squirrels to forage longer during the day, then similar spikes in squirrel activity should be observed during weekends and summer months on the TAMUK campus. However, this was not the case.

Recent advances in light technology from incandescent to fluorescent to light emitting diode (LED) lights have exacerbated the light pollution issue. An incandescent lamp generates light when an electric current heats a tungsten filament wire so that it glows; fluorescent lamps generate light when an electric arc excites the mercury of the gas in a tube to emit ultraviolet radiation, which causes the phosphor coating of the lamp to glow; and LEDs produce light when voltage is applied to negatively charged semiconductors, which cause electrons to combine and create photon light units (https://www.viribright.com/lumen-output-comparing-led-vs-cfl-vs-incandescent-wattage). The LED bulbs are more popular because they have greater energy efficiency, greater lifespan, and are generally brighter (i.e., produce more lumens) than their earlier counterparts (https://www.homelectrical.com/cfls-vs-halogen-vs-fluorescent-vs-incandescent-vs-led.6.html). It is the latter characteristic of LED lights that, although aesthetically pleasing to humans, can create environmental issues for wildlife in the form of light pollution.

Although not tested within our study, we suggest to either use fewer bulbs or switch from clear white LED bulbs to a colored LED bulb to reduce the light intensity. Reducing light intensity of bulbs may maintain normal foraging behavior patterns of squirrels and thus lessen their risk to nocturnal mortality factors. However, it first must be tested to confirm this hypothesis.

One anomaly became apparent from conducting this study. The relative abundance of feral cats increases substantially on the TAMUK campus during May. This may be due to the academic year of TAMUK ending during mid-May, when the majority of students leave campus for the summer to their respective homes or to summertime employment. Although speculative, it appears that students, who are living in the dormitories and maintaining a pet cat while attending classes, often do not take their cat for the summer or find alternative housing for their pet when classes end for winter or summer break. In such cases, the pet cats are "set free" to roam and breed on campus. Although such a practice is strongly discouraged, it occurs each May, and to a lesser extent during December, when students return to their respective homes for the holidays. Thus, an increase in the relative abundance of feral cats was expected on this campus during these times of the year. However, if only an increase in the relative abundance of feral cats was the cause of increased predation of squirrels, then a marked increase in predation also should have been observed during May.

The increase in relative abundance of fox squirrels during June and July also was expected. The main breeding period for fox squirrels is during January and February, and to a lesser extent, during May and June (Davis and Schmidly 1994). Incorporating their gestation (6–7 weeks) and maturation periods to become independent (~3 months), an influx of juvenile squirrels would become apparent by July, and to a lesser extent, again during November and December. We offer our observations as a case study of the potential effects of light pollution rather than a scientific study because of the lack of replication required by science. Other university campuses and public spaces throughout our region differ in a number of important ways (i.e., size, elevation, climate, vegetation composition, predator community, squirrel species and density) that make inferences to them risky. Also, it is obvious that factors such as placement of lights—around trees or in tree canopies, as outlines around buildings, or as spotlights—will alter the natural lighting environment, each in different ways. When these effects are coupled with differences in type (incandescent or LED) and intensity of lighting, it is likely that each public space use holiday lighting is an altered environment unto itself. Furthermore, predator–prey interactions vary depending upon size of public space and nature of surroundings. Our campus lies near the edge of a small community with native rangelands within approximately 1,000 m; in contrast, Texas Tech University (Lubbock, Texas), which uses holiday lights but as outlines around buildings, is >3,500 m from nonurbanized landscapes that are cultivated fields rather than rangelands. The combined effects of type of lighting, surrounding habitat, and local predator–prey relationships make it impractical or impossible to replicate a study as ours in a traditional experimental design context. For these reasons, our study should be considered a case study. Our findings, however, strongly suggest a change in behavior of squirrels because of an increase in nighttime lighting that ultimately led to increased mortality of squirrels, and it is reasonable to expect that other public spaces that use holiday lighting also may impact local wildlife populations.

Management implications

Our findings suggest that illumination of holiday lighting on the TAMUK campus altered squirrel behavior and increased exposure of squirrels to nocturnal predators, which ultimately resulted in greater mortality of squirrels. Although the increased mortality was an unintentional result by humans, it perhaps could be avoided in the future. We recommend education concerning the potential issues of light pollution. We believe the majority of the public, inclusive of campus administrators, is unaware that bright lights can alter behavior of wildlife. Such an educational program will help the public understand and hopefully refrain from an attitude that “more is better” when it comes to decorating for the holidays with outdoor lights. Lastly, we suggest that additional research be conducted to determine the threshold of lumens required to cause the change in foraging behavior by multiple species. Once the threshold is established, then guidelines can be instituted to maintain the quantity of lumens below this threshold so as to not affect wildlife behavior during festive periods.

Acknowledgments

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