Is there a link between deer-vehicle collisions and deer movement?

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Introduction and Methods

The location of 41 individual White-tailed deer (*Odocoileus virginianus*) was monitored in a natural area preserve located about 25 km (15 miles) northeast of central Philadelphia, Pennsylvania, near Bryn Athyn College and in the adjacent suburban areas. The preserve is managed by the Pennypack Ecological Restoration Trust (PERT), which is a private, non-profit conservancy. PERT manages 3.3 km^2 (827 acres) of mature forests, regenerating woodlands, riparian forests, and fields of cool- and warm-season grasses in the Pennypack Creek valley with a network of trails. Adjacent areas represent a variety of building densities ranging from homes on large lots with mature woodland vegetation to densely-populated residential and commercial areas that merge with towns. The study area includes several schools with large institutional campuses, and industrial and office parks, and is intersected by a variety of roads ranging from a limited access highway (Pennsylvania Turnpike) to small unpaved roads and footpaths (Figure 1).

A total of 17 female and 24 male deer were individually trapped in a modified Clover trap (Clover 1956) under Pennsylvania Game Commission permits, and fitted with Tellus GPS/GSM collars (Followit, Sweden), which transmitted spatial and temporal data at 5 min intervals for periods of 3 to 6 months. Some individuals had collars collecting 5 min fixes for 2 week periods interrupted by 2-4 week periods during which fixes were collected at 6 hour intervals. In such instances, only the 5 minute fix intervals were used for this study. A total of 549,485 GPS fixes were collected from the monitored deer, with an average of 13,402 fixes per individual. Data were remotely collected and processed in QGIS and R (R Core Team 2016) software environment (packages RGEOS, Geosphere, RGDAL, sp). We intersected the road shape file with the individual deer trajectory and kept the time of the crossing and type of roads (trail or road with open vehicular traffic). The frequencies of crossings per hour and month were later calculated for males and females.

The frequency of human visitations to PERT grounds was monitored by six people counters (EZ-Counter, Burghill, OH) placed at the entrances to PERT. The counters collected a total of 53,446 hours of data and registered a total of 80,277 human visitations. The total human visitations were summed by hour, day of the week, and calendar day.

The roadkill information was routinely collected by the employees of PERT. In total we analyzed 682 geo-referenced roadkills from January 2003 to December 2016. The date and location of the roadkills were recorded. The roadkill sites were geo-referenced to within an accuracy of 50 meters and plotted with GIS. A heatmap was computed using QGIS.

The road layer buffer was segmented into even portions of a 100 meter grid. Probability of deer road crossings and road kills were computed for each segment and are represented (Figures 1 and 2).

Results

1. When do deer cross roads?

The daily and monthly patterns of male and female deer crossings were different for trails and roads (Figures 3-6).

Trails are crossed more frequently at dawn and dusk by both males and females (Figure 3). The daily pattern of road crossings was different for males and females: females cross roads more often than males at night; whereas road crossing frequency in daytime was similar for males and females (Figure 5).

The seasonal pattern of trail crossings does have a distinct difference between males and females: the males have a strong peak in trail crossings during the rut or breeding period at the end of October through November, and strong depression in the number of trail crossings in summer (Figure 4). The females have the lowest number of trail crossings in February - March, with a greater number of trail crossings than males in summer. Seasonal road crossing patterns are similar to those of trail crossings. Males cross roads less in summer, with a fall - winter peak in the number of crossings (Figure 6). The distribution of road crossings across the calendar year shows close association with the sunrise and sunset (Figure 7).

2. Where do deer cross roads?

In general, the deer tend to cross roads at places where there is forest on at least one side of the road; however, it appears that there are no preferred places to cross roads (Figure 1). There were no crossings in areas at hill crests without cover on either side of the road, but these places are rare. In general, trails and roads open to vehicular traffic are crossed at the same rate, however the timing and intensity of the crossing is different for both males and females across the seasons and throughout the day (Figure 3-6).

3. When do deer-vehicle collisions occur?

The seasonal pattern of deer-vehicle collisions shows an increase during the fall and early winter months (Figure 9). Compare this to the similar pattern shown in season distribution of deer road crossings (Figure 6).

4. Where do deer-vehicle collisions occur?

The intensity of roadkills was surprisingly uneven at various sections of the road (Figure 2). The presence of several identifiable hotspots shows a higher probability of a deer-vehicle collision occurring. Most of the roadkill hot spots were associated either with a sharp bend in the road, concavity, or behind the sharp crest of a hill or overpass. The size of the majority of the hotspots was no longer than 100 meters; in one extreme case it was approximately 300 meters in length. All hotspots had dense vegetation obstructing visibility along the edges of the road.

5. How does human presence and traffic affect the pattern of road and trail crossings?

Human visitations to the PERT grounds demonstrated seasonal peaks in April and May; daily peaks occur during mid-morning and late afternoon. In general the frequency of road crossings by the deer demonstrated the inverse pattern to the frequency of human visitation. The clear temporal exclusion of the deer caused by human presence can be seen across both the yearly and daily scales (Figures 7-8).

Discussion

The monthly pattern of road crossings that we demonstrated in this study indirectly supports the pattern first established in Missouri (Hansen 2009). There it was found that the total number of deer-vehicle collisions was at its minimum during summer months. In contrast, male deer-vehicle collisions were at their peak during the rut period. Our study not only supported this trend by using other methods, but also enhanced it by providing hourly patterns of deer crossing. The presence of humans in the Pennypack grounds clearly demonstrates the temporal displacement of the deer. The deer tend to move and therefore cross roads more frequently when the presence of humans is minimal (Figures 7 and 8).

The surprising finding of this study is that although the probability of road crossings is more or less equal for any given location, the probabilities of roadkills at different locations are uneven and thus produce distinct hotspots for roadkills. At the beginning of our research we assumed there would be some areas where deer would cross the roads more often than others. Since we concentrated the trapping effort in the Pennypack Preserve, which is not located in a very densely populated area, it was thought that our sampled individuals were roaming in relatively undisturbed habitat. However, the sample deer were roaming well outside the preserve and spent considerable time in backyards of occupied buildings. The spatial probability of deer crossing turned out to be uniform across the study area. The very fact that there are roadkill hotspots suggests that despite the probability of road crossings by the deer being uniform, their chances to get killed on the road depend on the locations of a few (and finite) hotspots. This, in turn, means that although we cannot force the deer to avoid the roads, we can improve visibility in just a few locations with the potential to decrease the overall number of deer-vehicle collisions in the area.

Conclusions

The rate at which male and female deer tend to cross roads and trails is the same, whereas the daily and seasonal patterns are different between males and females. The overall seasonal pattern of roadkills closely correlates with the general pattern of road crossings. However, this study shows that the spatial relationship between deer road crossings and roadkills is less clear. The lack of spatial hotspots of road crossings and the presence of several discrete hotspots of roadkills highlight the conclusion that the issue surrounding deer-vehicle collisions depends more on the topography and landscape, in particular the level of obstructed visibility, than it does on where deer are crossing these roads.

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Figure 1. Roads and trails in the study area and the number of road and trail crossings per deer per day.

Figure 2. Heatmap of the number of roadkilled animals per grid unit per year.

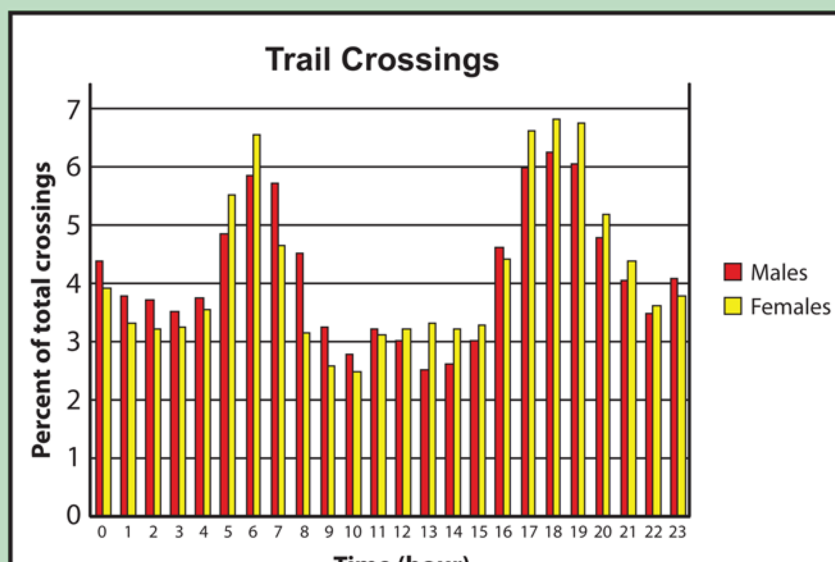


Figure 3. Average annual hourly pattern of trail crossings for all male and female deer.

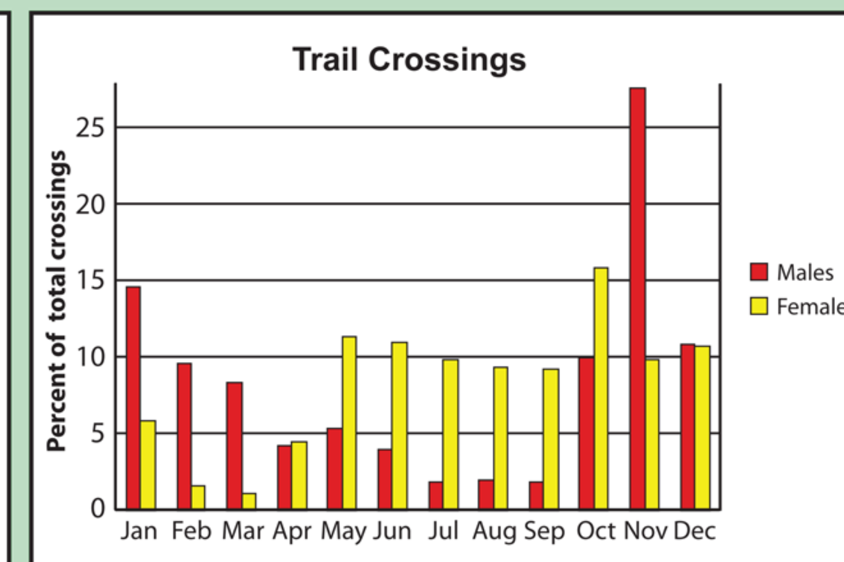


Figure 4. Monthly pattern of trail crossings for males and females.

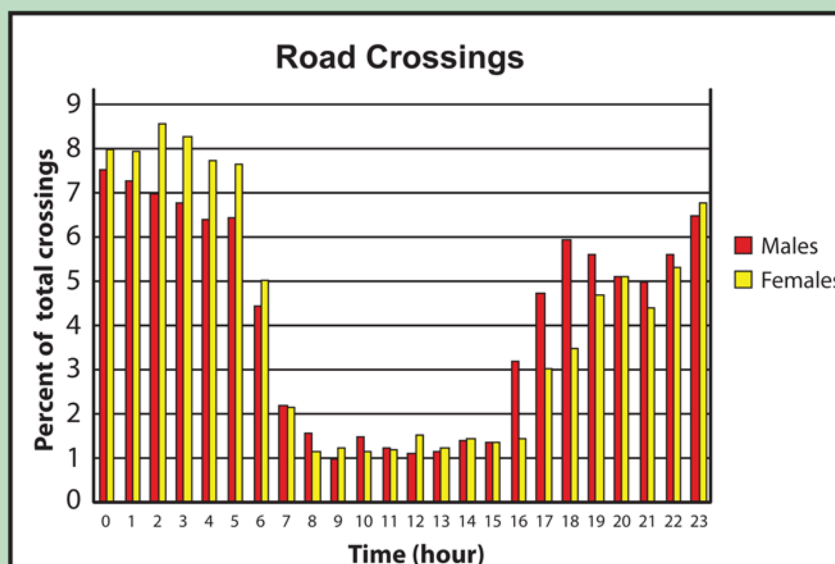


Figure 5. Average annual hourly pattern of road crossings for all male and female deer.

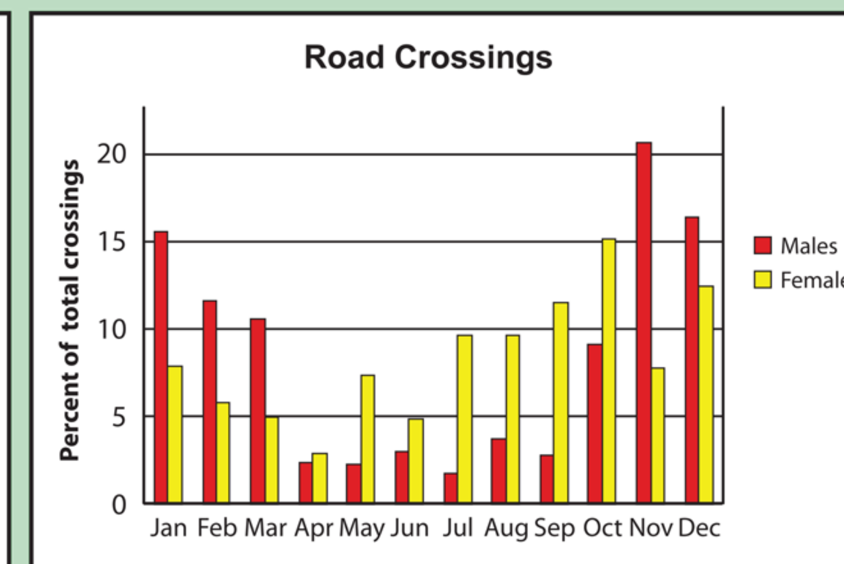
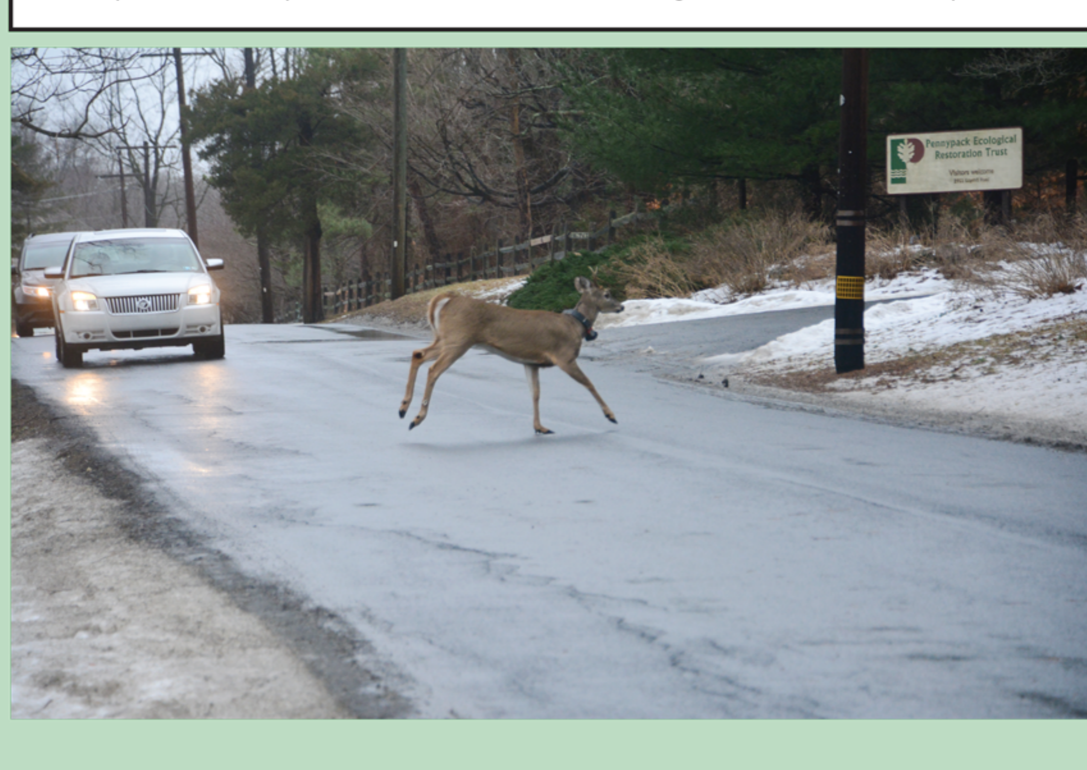


Figure 6. Monthly pattern of road crossings for male and female deer.



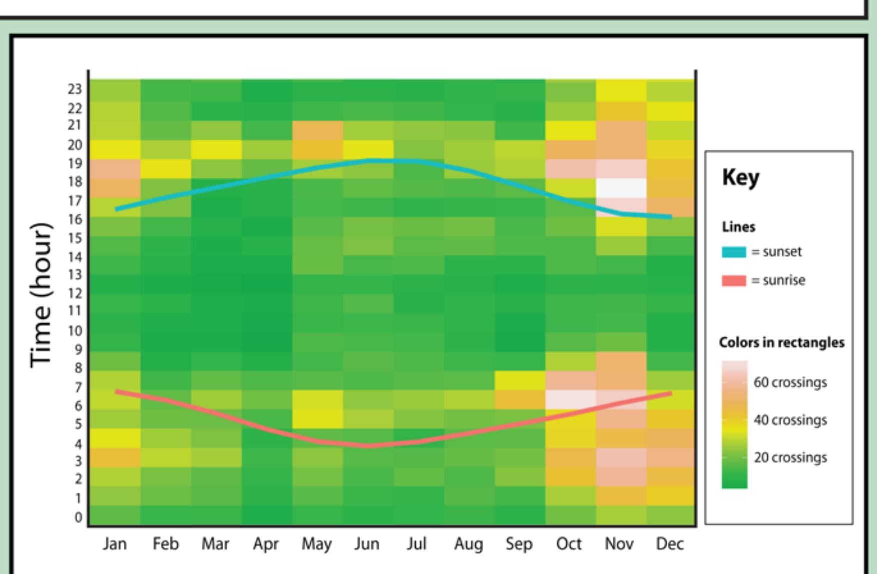


Figure 7. Hourly distribution of road crossings by male and female deer across a calendar year.

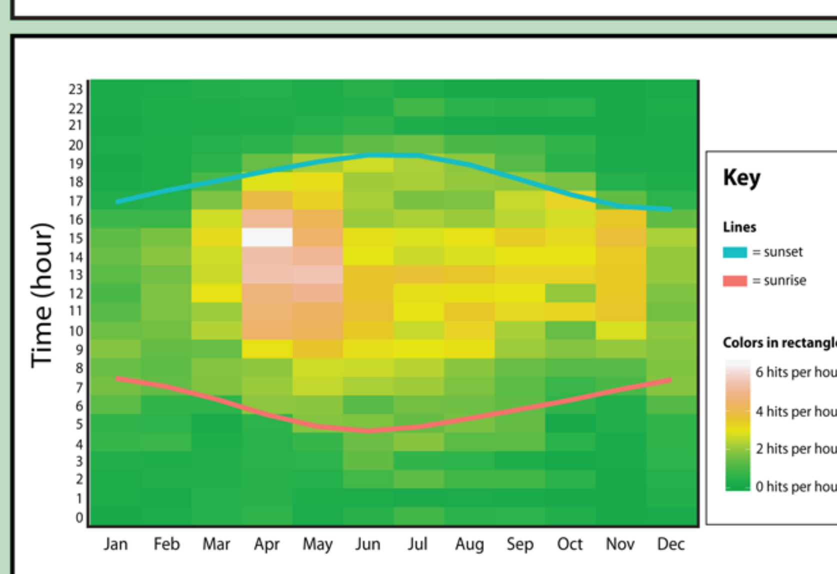


Figure 8. Hourly distribution of human visits to PERT across a calendar year.

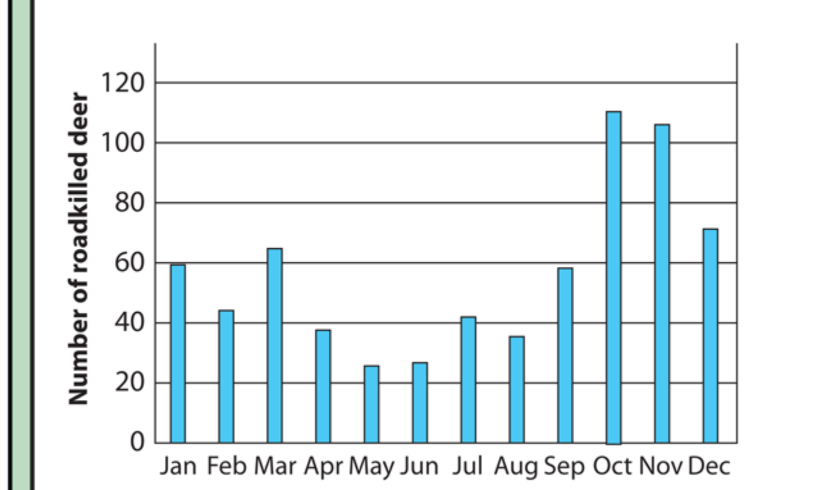


Figure 9. Monthly distibution of all roadkilled deer in the study area from January 2003 to December 2016.