Final Report

The Effect of Cell Towers on Birds and Bats at Rock Creek Park, Washington, D.C.

SUBMITTED TO

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Abstract

This report is the culmination of a three-year study on the potential effects of two existing telecommunication (cell phone) towers on migratory birds and bats in Rock Creek Park (ROCR), Washington, D.C. The impact of tall towers (≥200 ft [61 m]) with obstruction lighting and guy wires on these species has been well documented, but short, monopole tower designs remain largely uninvestigated. The towers in ROCR are of this shorter, monopole design and lack obstruction lighting and guy wires. Mortality surveys were conducted on a daily basis during spring and fall migration periods, and weekly surveys were conducted during the summer. No evidence was found during the course of this study to suggest that these towers have a significant impact on migrating birds and bats in these locations.

Introduction

Migratory birds must navigate across a landscape dominated by man-made structures as they move between wintering and breeding grounds and back again each year. Collision deaths associated with such structures have been documented in the United States since the late 1800's (Avery 1979), and efforts continue to quantify the magnitude of these losses today. A conservative estimate for avian fatalities due to communication towers ranges from 4-5 million per year (Erickson et al. 2005), but a more realistic estimate could range from 40-50 million tower kills per year (Manville 2001).

Beginning in the 1950's, and extending through the 60's and 70's, several investigators began conducting detailed studies of bird kills at individual communication towers. As the field began to widen, it became evident that several factors were involved including tower characteristics such as height, the presence of guy wires, and lighting scheme, as well as weather conditions, bird behavior at towers, and peak migration periods for nocturnal migrants. Insights into the mechanisms by which birds are killed at communication towers are now being used to make recommendations to curb the number of birds killed at these structures, as well as to develop monitoring guidelines to assist in on-going research.

Rock Creek Park Project

Rock Creek Park (ROCR) (38°57′10″N, 77°2′30″W) is a National Capital Region National Park (NCRNP) administered by the National Park Service (NPS). Its 1,141.4 ha (2,820.34 ac) bisects Washington, D.C. and consists of urban natural areas and public park facilities along the Rock Creek valley.

Bell Atlantic Mobile, Inc., (now Verizon Wireless) identified through transmission tests that the Rock Creek valley was an area lacking acceptable wireless telecommunications coverage. In 1998, Bell Atlantic Mobile submitted to the NPS separate right-of-way applications for the construction, operation, and maintenance of two wireless telecommunications facilities within ROCR. The proposed facilities included a monopole, antennas, and supporting infrastructure at the Rock Creek Park Tennis Center complex on the east side of the park and monopole, antennas, and supporting infrastructure at the park's Maintenance Yard on the west side of the park. As

a result of these permit applications, pursuant to the Telecommunications Act of 1996, and the National Environmental Policy Act (NEPA) of 1969, an Environmental Assessment (EA) was prepared by the NPS to analyze the potential impacts of the two proposed facilities on the resources of ROCR.

After completing an EA, the NPS initially concluded that the telecommunications facilities would not have a significant impact on the quality of the human environment and in 1999 issued a Finding of No Significant Impact (FONSI). This FONSI was revised later in 1999. Following a series of meetings before the Commission of Fine Arts and National Capital Planning Commission, the NPS issued a right-of-way permit on 8 November 1999 to Bell Atlantic Mobile, Inc., authorizing the construction of a 100-foot (30.5-m) monopole-mounted wireless telecommunications antenna and supporting infrastructure at the Rock Creek Park Tennis Center and the construction of a 130-foot (39.6-m) monopole and supporting infrastructure at the park's Maintenance Yard. Construction of the two telecommunications facilities began on 20 December 1999. The Tennis Center facility went into service on 15 March 2000 and the Maintenance Yard facility went into service 17 May 2000.

The Audubon Naturalist Society of the Central Atlantic States and private individuals filed suit challenging the NPS decision to grant Bell Atlantic Mobile, Inc., a permit to construct and operate two telecommunications facilities within ROCR. The plaintiffs claimed that the NPS violated NEPA by relying on a legally insufficient EA, which led the NPS to erroneously issue a FONSI and grant the permit.

Audubon argued that the NPS failed to take the necessary "hard look" at the direct impacts to birds and the Breeding Bird Census Area. The EA stated that "the American Bird Conservancy Policy Council and the North American Ornithological Council have identified any telecommunications tower over 200 feet with lights for aviation warning as having potential for killing migratory birds at night under certain climatic conditions." It concluded that: "since the monopoles proposed at the tennis center and maintenance yard are well under 200 feet (100 feet and 130 feet respectively) and are unlighted, they would not pose a threat to migratory birds."

Audubon argued that this conclusion was arbitrary and capricious because the NPS ignored the following relevant factors: 1) that neither group concluded that towers under 200 feet posed no risk, 2) that the area surrounding the Maintenance Yard is a major migratory pathway for birds, 3) that the Maintenance Yard is adjacent to a recognized Breeding Bird Census Area, 4) that the American Bird Conservancy actually opposed the towers, and 5) that there was a letter from the American Bird Conservancy stating that birds can be killed by towers under 200 feet. Thus, the court ruled there is really no dispute that the EA failed to comply with the applicable statutory and regulatory requirements because it does not reflect that the NPS took a hard look at the direct impacts on migratory birds and the Breeding Bird Census Area.

On 2 April 2003, pursuant to the court order, ROCR released the Rock Creek Park Telecommunications Facilities EA, which rigorously explored and objectively evaluated a range of alternatives. Subsequently, a FONSI was approved by the NPS to allow the continued operation and maintenance of two telecommunications facilities located in the park. As part of this decision, the NPS was required to:

"Seek funds to develop and adopt a program to monitor the impact of the existing telecommunications facilities on migratory birds. The monitoring program will be developed in cooperation with the U.S. Fish and Wildlife Service, other agencies, and interested parties. Should the monitoring program disclose effects to migratory birds from the monopole towers or appurtenant structures, the NPS will further coordinate with U.S. Fish and Wildlife Service to determine necessary steps to address the issue."

Albert M. Manville, a wildlife biologist for the U.S. Fish and Wildlife Service, Division of Migratory Bird Management, stated in a protocol developed for monitoring the impact of cellular telecommunication towers on migratory birds in Arizona that little or no monitoring of the impact of "short towers" (less than 200 feet) has been conducted on migratory birds. Most of the studies that have been conducted in the past have focused almost exclusively on tall towers. Manville believes that the monitoring protocols used for these previous studies are applicable for studying "short" towers as well, with some slight modifications.

On 2 July 2002 in the case of Audubon Naturalist Society of the Central Atlantic States, Inc. v. NPS and Bell Atlantic Mobile, Inc., the court ordered the NPS to prepare and file a new EA. The court found that the previous EA was insufficient in reviewing the direct impacts on migratory birds and the Breeding Bird Census Area of a telecommunication facility cited at the Rock Creek Maintenance Yard by Bell Atlantic Mobile. The subsequent FONSI resulting from the new EA stated that the NPS will seek funding to conduct a study of the impacts to migratory birds by the telecommunication facilities cited in ROCR. This completed study may also be applicable to several other telecommunications facilities that are being constructed and proposed for construction in several parks located in the National Capital Region. The permit authorizing the citing of the two telecommunication towers in the Park will come up for renewal in 2009. This study should be started in FY 2006 in order to complete the required 3-year study to inform the permit review and renewal process that will take place.

On 1 March 2006, The University of Maryland Center for Environmental Science, Appalachian Laboratory, entered into a contract with NPS to conduct the three-year study. The objectives were to 1) document the possible effects on migratory birds of the two existing telecommunications towers in ROCR and 2) assess the potential effects of additional telecommunications facilities that might be cited in and around the park. This project is one of the few studies to examine the effect of unlit, unguyed “short towers” (<200 ft [61 m]) on bird and bat mortality. This Final Report describes the results of field monitoring for the years 2006, 2007, and 2008.

Study Sites

One cell tower (TC) was located adjacent to the Rock Creek Park Tennis Center with its 25 outdoor tennis courts (Figure 1a). It is 100 ft (30 m) in height and is located within a row of light posts that illuminate the outdoor tennis courts (Figure 1b). No FAA obstruction lighting is present on this tower, but a light has been mounted on the pole at the same height as the light posts. The TC tower is also near to a grassy picnic area with clumps of tall deciduous trees (e.g., *Fagus grandifolia, Quercus alba, Carya* sp., *Liriodendron tulipifera*) and shorter shrubby vegetation (e.g., *Smilax* sp., *Ampelopsis brevipedunculata, Lonicera* sp., *Toxicodendron radicans*), and various saplings. There is

a large paved parking lot and a larger tennis arena that fall within the search area of this particular tower. Many of the lights at the larger arena are significantly taller than the TC tower.

The second cell tower (MY) is located at the Rock Creek Park Maintenance Yard (Figure 2a). It is 130 ft (40 m) in height and is located on the sloping edge of a deciduous forest, consisting of oaks (*Quercus* sp.) and some of the same species noted near the TC tower (Figure 2b). Scattered areas of undergrowth (e.g., *Polygonum cuspidatum, Vitus* sp., *Parthenocissus quinquefolia*, *Wisteria* sp., *Rubus phoenicolasius*) are also present. The park maintenance yard, as well as park offices, equipment, and a large paved parking lot, are prominent features at this site. This tower also lacks obstruction lighting and is unguyed, however, there is night security lighting in the maintenance yard.

The Nature Center "control" plot (NC) is located along the same ridge as the MY tower and is separated from the MY area by the Horse Center (Figure 3). This site is characterized by the Nature Center building, a wooden walkway/observation area, an upper and lower paved parking lot with an island of deciduous forest and picnic area in between, and a larger expanse of forest and trails extending beyond the Nature Center (the Nature Center building and observation area were not located within the search area).

Methods

To determine the number of birds killed as a result of collisions with the ROCR cell towers, the areas surrounding the towers were searched for carcasses from 24 May-15 November 2006 (in the 2006 season, searches did not begin until 24 May due to availability of funding), 15 April-15 November 2007, and 15 April-15 November 2008. A control plot grid and transect lines were added on 29 May 2007; this area was searched for carcasses from 29 May-15 November 2007 and 15 April-15 November 2008.

A double sampling approach was used for this study involving both ground and net sampling (Manville 2002). Net sampling, allowed for adjustment of the ground sampling estimates by correcting for carcass removal by scavengers and searcher efficiency bias based on the relative ratio of the number of carcasses found per unit area using the two sampling methods (Avery 1978, Avery and Beason 2000).

Ground Sampling

The search grids for each tower consisted of 21 N-S transect lines 100 m in length centered on the tower, forming a 100 m × 100 m square (i.e., 10,000 m^2) (prior to 2 June 2006, the grid was 50 m x 50 m square). Each transect was 5 m apart, yielding a 2.5 m search width on either side. Where necessary, plastic stakes, spray paint, or vinyl flagging were used to indicate direction, distance, and end points. Ground searches were conducted daily at each tower site from 24 May-15 November 2006, 15 April-15 November 2007, and 15 April-15 November 2008, except for a one-month summer period (15 June-15 July) when searches were performed once per week. The entire ground area within the grid was searched as well as any rooftops falling inside the search area; however, approximately 2,500 m^2 of the MY grid falls within the MY fence and is inaccessible for searches.

On 29 May 2007, a "control" plot (no tower) was added to the study (Figure 3). The ROCR Nature Center and the surrounding area were chosen for the control site because it lies on the same ridge as the MY tower, and encompasses the same relief and structural elements as the other sites: parking lot, wooded areas, buildings, etc. The search grid for the control plot consisted of 21 NW-SE transects, 100 m in length, forming a 100 m × 100 m square. Each transect was 5 m apart, yielding a 2.5 m search width on either side. Where necessary, plastic stakes, spray paint, or vinyl flagging were used to indicate direction, distance, and end points.

Avery (1978) found 63% of all the carcasses at their study site within 300 ft (91 m) of a 1,210 ft (369 m) guyed tower. Based on the relationship between the distance that a carcass is found from the tower and the tower height, we expected to find most carcasses in our study within 40 ft (12 m) of the towers, e.g., 1,210 ft/300 ft (369 m/91 m) is equivalent to 130 ft/33 ft (40 m/10 m).

Note: Due to the Legg Mason Tennis Classic held near the TC tower from 29 July-6 August 2006, 28 July-5 August 2007, and 9 August-17 August 2008, as well as the week preceding and following, ground searches were more or less restricted to the southern half of the grid at this site. From mid-September 2005 to mid-May 2006 (prior to the beginning of the study), 18 September 2007-13 May 2008, and 22 September 2008 to mid-May 2009, a bubble dome was in place over the tennis courts near the TC tower (see Figure 1b).

Net Sampling

In addition to the daily ground searches, two 25 ft × 25 ft (7.62 m × 7.62 m) nylon nets were also erected at each tower site in order to catch any birds that might collide with the towers (Figure 4a-d). The two nets were placed as close to the tower as possible, adjusting for the terrain and vegetation cover at each site. Net searches were conducted daily at each tower site from 24 May-15 November 2006, 15 April-15 November 2007, and 15 April-15 November 2008, except for the one-month summer period (15 June-15 July) when searches were performed once per week. No nets were erected in the control plot, as there was no tower at this site.

Data Collection

Carcass searches began at dawn (30 minutes before sunrise) in all seasons. Searches were conducted daily from 15 April to 15 June for the spring migration (in 2006, searches did not begin until 24 May) and from 15 July to 15 November for the fall migration. During the summer season, 15 June-15 July, searches were conducted once per week. Efforts were made to select nights with low ceiling height (cloud cover) and poor visibility for our weekly summertime searches whenever possible.

Each day that a tower was examined, beginning and ending time of each search, time spent searching, time since last search, and weather data were recorded. Weather data were recorded at the beginning of the search, for the previous night, and for the last 24 hours (including temperature, wind direction/speed, cloud cover %, ceiling height, barometric pressure, relative humidity, precipitation, and front activity). Current

temperature, wind, cloud cover, and relative humidity were all recorded at the time of the search using a Kestrel (WeatherEssentials, Chandler, AZ) hand-held weather meter, while all other weather variables were taken from NOAA's National Weather Service Weather Station, KDCA (38º51'0" N, 77º1'48" W), at Ronald Reagan Washington National Airport. All bird carcasses discovered during the searches were collected, numbered, and placed in the freezer; and the species, date, exact location, distance from tower, perpendicular distance from nearest transect, body condition, probable cause of death, and any evidence of scavenging were recorded. Recovered carcasses were also assigned a value corresponding to the potential visibility of the carcass in the location in which it was found. Live birds observed in the area were also noted on datasheets.

Visibility Index (VI)

Each transect was mapped out according to ground cover type and an ordinal visibility index (VI) ranking generated (1-6) based on relative likelihood of finding a carcass in that cover type. Ground cover types included: 1) bare ground/pavement (open), 2) maintained (mowed) lawn, 3) sparse cover (25-50 % vegetation), 4) dense cover (51-74 % vegetation), 5) thickets (75-100 % vegetation), and 6) inaccessible area. Carcasses most likely to be found were in open locations, e.g., on pavement or bare ground (VI=1); whereas, carcasses least likely to be found were in brambly or viny thickets, e.g., in greenbrier (VI=5).

Statistics: Monte Carlo Simulation

The null hypothesis for this study is that bird and bat carcasses discovered in the plots were incidental or background mortalities not associated with the cell phone towers. Our alternative hypothesis is that some bird and bat mortalities are the result of collision with the towers. We made the assumption that carcasses of birds or bats killed by tower collisions would tend to be concentrated nearer the tower, whereas there would be no tower orientation of carcasses of birds or bats killed by other causes. Under this assumption, the null hypothesis predicts that the average distance between the tower and carcasses is the same as the average distance between the tower and randomly chosen points in the plot. Conversely, the alternative hypothesis predicts that the average distance between the tower and carcasses is less than the average distance between the tower and randomly chosen points in the plot, except in the control plot where there should be no difference because there was no tower. We set up our statistical tests to determine if we could reject the null hypothesis by showing that bird or bat carcasses were found closer to the tower than expected by chance.

Demonstrating that carcasses are closer to the tower than expected by chance is not straight forward, because there is a greater area further from the tower than close to it. Furthermore, our plots were square rather than circular and contained areas that were inaccessible to researchers, as well as different ground cover types that made carcasses more or less visible. To control for these factors, we used a Monte Carlo simulation to generate sets of random points in the plots and compared the average distance of these randomly generated points from the tower (or mid-point) to the average distance of

empirically discovered carcasses to the tower (or mid-point in the case of the control plot) (Edgington 1995, Manly 1997).

The Monte Carlo model simulates bird or bat mortalities that are being searched for by a "virtual researcher." First, the model positions a carcass at a point in the plot by randomly selecting both transect and a point on it. The simulation then uses a look-up table of empirical visibility data to determine the characteristics of the selected point in the plot. If the point is unavailable to the virtual researcher (e.g., inside the MY fence), the model discards it and chooses a new random position for another carcass. When a point is available, the model determines whether the virtual researcher "finds" the carcass based on the empirically determined visibility index for the ground cover in that location.

We had no basis for specifying a probability of finding a carcass for each different type of ground cover; instead we generated an ordinal ranking of the relative likelihood of finding a carcass in each ground cover based on expert opinion (carcasses in locations on paved or bare ground were considered the most likely to be found, carcasses in thickets the least likely). To ensure that the model predictions were independent of distribution assumptions, the model generated six probabilities from a flat distribution between 0 and 1 for each iteration of the simulation. The generated probabilities were then ranked and applied to each ground cover so that the paved ground cover received the highest of the generated probabilities and thickets received the lowest generated probability. These probabilities were then used to determine whether the virtual researcher found carcasses in each ground cover type during that iteration.

For each iteration, the Monte Carlo simulation generated points at random locations in the plot and, if they were accessible to the virtual researcher, determined if they were "found" until the number of "found" points was the same as the number of carcasses empirically discovered in that plot. The average distance between the center of the plot and these virtual carcasses (generated under the null hypothesis) was then compared to the average distance between the tower and the empirically discovered carcasses. The simulation ran 100,000 iterations and determined the number of times that the empirical distance was less than the average distance generated by the Monte Carlo. We considered the null hypothesis to be rejected if the empirical distance was less than the simulated distance in 95% of iterations ($\alpha = 0.05$).

Statistics: Chi-square Test

To test if there were differences in mortality among the different plots we used Pearson's Chi-square Test. Expected values were generated using the same Monte Carlo technique used for the hypothesis testing. For each plot we generated 100 random carcass positions and determined the total number that a researcher would expect to find based on whether the position was accessible and the ground cover at that location. This process was repeated 10,000 times to determine a relative proportion found in each plot. The value was then controlled for the number of days that each plot was censused, and the total number of carcasses found empirically, to generate a relative expected value for each plot.

Search Area Images

Images of the search areas in ROCR were created using 2007 Google Earth software.

Results

Between 24 May 2006 and 15 November 2008, transect searches produced a total of 43 dead birds, categorized as either feather spots, partial carcasses, or complete carcasses (Figure 5). Twenty-four feather spots, eight partial carcasses, and 11 complete carcasses were recovered from beneath the cell towers and within the control plot in ROCR during 530 daily searches and 1,897 search hours (Table 1). Net searches were also conducted in this time frame, but no birds were collected from the nets. No bat carcasses were found on the transect searches or in the nets during any season of the study. Fatalities occurred during the spring (n = 19), summer (n = 2), and fall (n = 22) months during the three-year study period. All search areas, including the control plot, suffered losses. Interestingly, the spring (15 April-15 June) and summer months (16 June-15 July) resulted in virtually the same number of fatalities (n = 21) as the fall months (16 July-15 November, n = 22), unlike most other studies where fall is the deadliest season. Furthermore, no Neotropical migrants were among the birds or bird remains, despite their presence in the area (Tables 2-4).

TC Tower

A total of 567 search hours were spent at the TC tower. The second highest number of casualties took place at this site, with five feather spots, six partial carcasses, and four complete carcasses being collected during the study (Table 1). Two unidentified feather spots were found in 2006, as well as a northern cardinal (*Cardinalis cardinalis*) feather spot. The 2007 season also produced two unidentified feather spots, while none were recovered in 2008 at this site. All feather spots at this location appeared to have been the result of predation.

The 2006 season produced one unidentified partial carcass, but none were found in 2007. The 2008 season resulted in four partial carcasses that were unable to be identified, as well as one American robin (*Turdus migratorius*) partial. The partial carcasses were considered to have an unknown cause of death and most likely had undergone some degree of scavenging.

A single complete carcass of a juvenile house sparrow (*Passer domesticus*) was found at this site in 2006, and a complete dark-eyed junco (*Junco hyemalis*) was collected in 2007. Two complete carcasses, a Carolina wren (*Thryothorus ludovivicans*) and an American goldfinch (*Carduelis tristis*), were found in 2008. These birds did not have any visible injuries, and there was no indication of cause of death.

The casualties suffered at this site were significantly closer to the tower than would be expected by chance ($P = 0.01$). The mean distance of carcasses from the tower at this site was 26.9 m, while the expected mean distance was 40.5 m. Closer examination of the TC data by year, however, reveals that the significance of the pooled data is primarily driven by the 2008 season. In 2006 and 2007, the fatalities were not significantly closer to the tower ($P= 0.14$ and $P= 0.08$, respectively). The 2008 fatalities

were significantly closer to the tower than expected (P= 0.001), with a mean distance of 19.1 m and an expected mean distance of 40.5 m. This trend is strongly driven by an individual data point of 0.2 m for an unidentified partial carcass found on 8 June 2008. This carcass was directly under the tower, but the remains consisted of a fragment of wing and a scattering of pin feathers, indicating that this individual was a nestling/fledgling and could not have collided with the tower. Another data point of 6 m from the tower may also have contributed to the significance of the 2008 season. This fatality was also an unidentified partial carcass and was recovered on 17 April 2008. This carcass was found between the fence around the outside court and the bubble erected over this court during the fall/winter months. The remains consisted of a fragment of wing and some additional feathers, most likely due to a predation event or scavenging. None of the carcasses recovered were identified as Neotropical migrants.

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MY Tower

This site suffered the highest number of casualties of all three sites. A total of sixteen feather spots were retrieved, one partial carcass, and six complete carcasses were found during 932 search hours (Table 1). In 2006, two eastern towhees (*Pipilo erythrophthalmus*) feather spots were recovered. The 2007 season produced three feather spots of unidentifiable species, as well as four mourning dove (*Zenaida macroura*) feather spots. Two unidentified feather spots were collected in 2008, in addition to two mourning dove, two American robin (*Turdus migratorius*), and one northern cardinal (*Cardinalis cardinalis*) feather spot. All feather spots at this location appeared to be the result of predation, possibly by red-shouldered hawks (*Buteo lineatus*) nesting in the area.

No partial carcasses were found in 2006 and 2007, but in 2008 one unidentified partial carcass was found. As before, partial carcasses are considered to have an unknown cause of death and have suffered some degree of scavenging.

The 2006 season produced two complete American robin carcasses, while 2007 returned no complete carcasses. In 2008, three American robin and one tufted titmouse (*Parus bicolor*) complete carcasses were found. While most complete carcasses found at this site did not exhibit any visible injuries suggesting the cause of death, one of the American robin carcasses did appear to have experienced some trauma. This bird suffered some form of head injury, as a portion of the skull and its contents were missing. In addition, blood was found on the ground beneath the head and some feathers were scattered around the carcass. Whether these injuries were incurred and resulted in the death of the bird, or whether they were inflicted post-mortem due to scavenging is unknown.

The casualties suffered at this site were significantly closer to the tower than would be expected by chance (P = 0.02). The mean distance of the carcasses from the tower at this site was 31.5 m, while the expected mean distance was 37.8 m. In the 2006 and 2008 seasons, none of the carcasses were significantly closer to the tower than expected (P = 0.32 and P = 0.28, respectively), so the significance of the pooled data is driven by the 2007 season, the singularly significant year (P = 0.01) of the study for this site. Closer examination of the composition of the carcasses found in the 2007 season, reveals that all fatalities were categorized as feather spots (n = 7), while the fatalities incurred in the other two seasons were more evenly distributed between carcass types.

Furthermore, mourning doves contributed to more than half the number of these feather spots (n = 4), and being heavy-bodied birds (i.e., not as agile as smaller-bodied birds) are likely easy prey for raptors in this flat, open space at the yard. Despite these fatalities being closer to the tower, the significance of carcass position in relation to the tower is more likely due to the topography of the maintenance yard and not due to the presence of the tower itself (the MY tower is positioned at the edge of the parking lot on one side and the ground slopes down into deciduous forest on the other side). Once more, none of the casualties at the MY tower were Neotropical migrants.

NC Control Plot

Although the NC control plot was only monitored for the last two of the three years (added 29 May 2007) of the study, this site did suffer fatalities in each of those years. This site produced the fewest number of fatalities: three feather spots, one partial carcass, and one complete carcass during 396 search hours (Table 1). In 2007, two feather spots were found in the fall season; one was identified as the remnants of a common grackle (*Quiscalus quiscula*) and the other was identified as a mourning dove (*Zenaida macroura*). Also found in the fall 2008 season was a single feather spot of an unidentifield species. All feather spots were most likely due to predation, possibly by raptors, based on the location of the spots as well as the amount and distribution of feathers.

The only partial carcass at this site was unidentified and was collected in the early fall 2007. The complete carcass, also found in early fall 2007, was identified as a white-breasted nuthatch (*Sittia sitta*).

None of the casualties suffered at this site were significantly closer to the center of the plot than would be expected by chance ($P = 1.0$), and none of the casualties were identified as Neotropical migrants. The mean distance of the carcasses from the "tower" at this site was 53.2 m, while the expected mean distance was 39.9 m.

Distribution of Carcasses Among Plots

The distribution of carcasses among the three plots (Figure 6) was different from the expected values generated by the Monte Carlo model ($\chi^2 = 18.6$, 2 df, $P < 0.001$); more carcasses were found at the MY site, while fewer than expected were found at the TC and NC sites. Since many of the carcasses appeared to be the result of predation events, particularly with mourning doves and robins as prey (60%), we used the number of days that researchers heard or saw hawks, doves, and robins at each plot to generate expected values (corrected for the number of days that each plot was searched). The distribution of carcasses was again significantly different from the distribution of observations of these birds ($\chi^2 = 11.04$, 2 df, $P < 0.01$). However, the distribution of carcasses was not significantly different ($\chi^2 = 4.99$, 2 df, $P > 0.05$) from model predictions based on the number of days that doves and robins were seen, corrected for accessibility and ground cover (using the Monte Carlo results); there were more observations of hawks, doves, and robins at the MY site than the TC and NC sites, and we recovered more carcasses at this site. However, though this model provides a better fit to the empirical data, the fit was

not closer than expected by chance; there were still many more carcasses at the MY plot and many fewer at the NC plot.

Note: The Chi Square test is a statistical technique that compares 'goodness of fit' between two distributions. This technique provides a test both that the two distributions are more different than expected by chance and more similar than expected by chance. In the case of comparing the corrected model to the empirical data, the distributions were not more different than expected by chance, but were also more similar than expected by chance.

Discussion

Telecommunication towers are a hazard to nocturnally migrating birds, especially those which are >200 ft (61 m) in height, guyed, and lighted. The spring and fall migration periods produce the most losses, and the birds most impacted are Neotropical migrants. While each of these factors presents their own dangers, it is their interaction that produces large, spectacular kills. The "worst case" scenario develops when nocturnally migrating birds are aloft on nights with low visibility and cloud cover associated with passing cold fronts, in the vicinity of a tall communication tower. Their celestial cues obstructed, the birds hone in on the lights of the tower and gravitate toward it. Once inside the halo of the tower's light, the birds are reluctant to leave it and inevitably some will strike the guy lines or the tower itself.

The effect of short (≤200 ft [61 m]) towers remains largely uninvestigated, along with any interactions between tower design, location, and weather, which are so important in determining collision risk with taller towers. The data from this study, however, suggest that the short monopole tower construction (unlit and unguyed) is not obstructive to migratory birds in this location. Overall, only 11 carcasses (resident birds or short-distance migrants) were collected during the study, in addition to eight partial carcasses and 24 feather spots. With the exception of the 2007 mourning dove feather spots at the MY site and the 2008 TC fatalities (the only seasons where recovered carcasses were significanly closer to the towers), all fatalities appeared to be unconnected to the towers. Furthermore, the MY feather spots were most likely the result of predation attributed to the topography surrounding the tower, as opposed to collision with the tower; this ridge-top location with flat, open areas might encourage predation by raptors. A pair of red-shouldered hawks (*Buteo lineatus*) is known to have nested somewhere between the Maintenance Yard and the Nature Center, and were frequently observed at both locations along with other Accipiters. In the case of the 2007 TC fatalities, the significance of the data was driven by the recovery of a carcass directly under the tower (distance from carcass to tower of 0.2 m) which could not have been a collision death, as the bird was identified as a nestling/fledgling based on the remains. Searcher efficiency is presumed to have been high, as no birds were found in the nets, suggesting that there was minimal scavenging bias.

It may not be appropriate, however, to generalize the results of this study across all short towers at this time, or for any future towers erected in ROCR. The inference of statistical tests depends on the level of replication. The replication used for the statistics in this study was individual observations of bird and bat carcasses at each plot. From the

data collected, we were not able to conclude that either tower is a source of increased mortality. However, there was limited replication of towers (that is, only two towers were monitored). Therefore, though we have sufficient data to conduct statistics on the towers in the study, the inference of our results is only for those two towers and does not extend to other short towers in other locations, including other locations in ROCR. To conclude that short towers generally, or that short towers in ROCR specifically, cause or do not cause increased bird mortality would require replication at the level of the tower, that is, further study would be required on a greater number of towers generally, or a greater number of towers in ROCR specifically.

In addition, it is possible that some location effects are involved, and that the same towers in a different location (e.g., on another ridge top or near wetlands) might actually produce some kills. For instance, the height at which migrating birds in ROCR fly has not been documented, and therefore may be different from the height migrants fly elsewhere. Most passerine nocturnal migrants fly <1,000 m (Able 1973), but migration height can vary anywhere from <500 m to 3,000 m (Harper 1958, Tedd and Lack 1958, Graber and Cochran 1959, Hassler et al. 1963, Griffin 1973). Furthermore, it is possible that the interaction between the towers and weather conditions were just not right to produce kills during the course of the study, and periodic monitoring might reveal that occasional fatalities do indeed occur.

Management Implications

With approximately 80,000 communication towers across the country required to be lit by the Federal Communications Commission, and more than 7,000 new towers erected each year (American Bird Conservancy 2007), the demand for cellular telephone and digital television networks is not likely to diminish. As this high-tech environment remains a reality for imperiled bird populations, current research has begun to focus on those elements of the tower-kill equation that can be controlled and regulated. A recent meta-analysis of the existing literature by Longcore et al. (2008) emphasized the influence of tower design and location on avian mortality, making a strong argument that conservation efforts need to be directed toward regulation in this area. Suggested regulatory measures include restricted tower height, avoidance of guy wires, use of only red or white strobe lights for obstruction lighting, and avoidance of siting towers along ridgelines.

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Table 1. Avian casualties recorded at the Tennis Center (TC) and Maintenance Yard (MY) cell towers, and Nature Center (NC), in Rock Creek Park, Washington, D.C.

Common name	Scientific name	Family	Tower	Date	Distance (m)[1]	Type
Unknown	*Unknown*	Unknown	TC	1 Jun 2006	4.7	Partial
Unknown	*Unknown*	Unknown	TC	8 Jun 2006	46	Feather spot
House sparrow	*Passer domesticus*	Passeridae	TC	15 Jun 2006	42.5	Complete
Unknown	*Unknown*	Unknown	TC	7 Jul 2006	47	Feather spot
Eastern towhee	*Pipilo erythrophthalmus*	Emberizidae, sub. Emberizinae	MY	17 Jul 2006	62	Feather spot
American robin	*Turdus migratorius*	Muscicapidae, sub. Turdinae	MY	17 Jul 2006	1.36	Complete
American robin	*Turdus migratorius*	Muscicapidae, sub. Turdinae	MY	24 Jul 2006	53	Complete
Northern cardinal	*Cardinalis cardinalis*	Emberizidae, sub. Cardinalinae	TC	25 Jul 2006	28.5	Feather spot
Eastern towhee	*Pipilo erythrophthalmus*	Emberizidae, sub. Emberizinae	MY	27 Oct 2006	10	Feather spot
Unknown	*Unknown*	Unknown	MY	17 Apr 2007	24	Feather spot
Mourning dove	*Zenaida macroura*	Columbidae	MY	11 May 2007	30.5	Feather spot

Table 1. Continued.

Common name	Scientific name	Family	Tower	Date	Distance (m)[1]	Type
Mourning dove	*Zenaida macroura*	Columbidae	MY	11 May 2007	26	Feather spot
Unknown[2]	*Unknown*	Unknown	TC	23 Jul 2007	55	Feather spot
White-breasted nuthatch	*Sitta carolinensis*	Sittidae	NC	30 Jul 2007	52.38	Complete
Unknown	*Unknown*	Uknown	NC	31 Aug 2007	60.96	Partial
Unknown	*Unknown*	Uknown	MY	21 Sep 2007	6.75	Feather spot
Unknown	*Unknown*	Unknown	MY	1 Oct 2007	38.5	Feather spot
Common grackle	*Quiscalus quiscula*	Emberizidae, sub. Icterinae	NC	4 Oct 2007	45	Feather spot
Unknown	*Unknown*	Unknown	TC	28 Oct 2007	4.25	Feather spot
Mourning dove	*Zenaida macroura*	Columbidae	MY	29 Oct 2007	25	Feather spot
Mourning dove	*Zenaida macroura*	Columbidae	MY	11 Nov 2007	25.5	Feather spot
Mourning dove	*Zenaida macroura*	Columbidae	NC	12 Nov 2007	54.5	Feather spot
Dark-eyed junco	*Junco hyemalis*	Emberizidae, sub. Emberizinae	TC	13 Nov 2007	47.2	Complete

Table 1. Continued.

Common name	Scientific name	Family	Tower	Date	Distance (m)[1]	Type
Unknown	*Unknown*	Unknown	MY	15 Apr 2008	47	Feather spot
Mourning dove	*Zenaida macroura*	Columbidae	MY	16 Apr 2008	62.5	Feather spot
Mourning dove	*Zenaida macroura*	Columbidae	MY	16 Apr 2008	11	Feather spot
Unknown	*Unknown*	Unknown	TC	17 Apr 2008	6	Partial
Unknown	*Unknown*	Unknown	MY	19 Apr 2008	37	Feather spot
American robin	*Turdus migratorius*	Muscicapidae, sub. Turdinae	MY	25 Apr 2008	7.25	Feather spot
Unknown	*Unknown*	Unknown	MY	1 May 2008	25	Partial
American robin	*Turdus migratorius*	Muscicapidae, sub. Turdinae	MY	21 May 2008	51	Complete
American robin[2]	*Turdus migratorius*	Muscicapidae, sub. Turdinae	TC	26 May 2008	78	Partial
American robin	*Turdus migratorius*	Muscicapidae, sub. Turdinae	MY	27 May 2008	30	Complete
Unknown[2]	*Unknown*	Unknown	TC	2 Jun 2008	77	Partial
Unknown	*Unknown*	Unknown	TC	5 Jun 2008	39.5	Partial
Unknown	*Unknown*	Unknown	TC	8 Jun 2008	0.2	Partial

Table 1. Continued.

Common name	Scientific name	Family	Tower	Date	Distance (m)[1]	Type
Northern cardinal	*Cardinalis cardinalis*	Emberizidae, sub. Cardinalinae	MY	10 Jun 2008	30	Feather spot
American robin	*Turdus migratorius*	Muscicapidae, sub. Turdinae	MY	17 Jul 2008	41.5	Feather spot
Unknown[2]	*Unknown*	Unknown	NC	4 Aug 2008	60.3	Feather spot
Carolina wren[2]	*Thryothorus ludovivicans*	Troglodytidae	TC	12 Aug 2008	51.5	Complete
American robin	*Turdus migratorius*	Muscicapidae, sub. Turdinae	MY	10 Sep 2008	33.5	Complete
Tufted titmouse	*Parus bicolor*	Paridae	MY	14 Oct 2008	46	Complete
American goldfinch	*Carduelis tristis*	Fringillidae	TC	12 Nov 2008	30.5	Complete

[1]Distances are to plot center or tower.
[2]Fatalities found outside of search area. These fatalities are not included in the statistical analysis.

Table 2. Live birds observed[1] and/or heard during carcass searches at the Tennis Center (TC) tower site, Rock Creek Park, Washington, D.C., from 24 May-15 November 2006, 15 April-15 November 2007, 15 April-15 November 2008.

Common name	Scientific name	Family	No. obs.[2]	Seasonal occurrence[3]		
				Spring	Summer	Fall
Acadian flycatcher	*Empidonax virescens*	Tyrannidae	4	X	X	X
American crow	*Corvus brachyrhyncos*	Corvidae	264	X	X	X
American goldfinch	*Carduelis tristis*	Fringillidae	16	X	X	X
American redstart	*Setophaga ruticilla*	Emberizidae, sub. Parulinae	10	X		X
American robin	*Turdus migratorius*	Muscicapidae, sub. Turdinae	364	X	X	X
Baltimore oriole	*Icterus galbula*	Emberizidae, sub. Icterinae	10	X	X	X
Black-and-white warbler	*Mniotilta varia*	Emberizidae, sub. Parulinae	8	X		X
Black-throated blue warbler	*Dendroica caerulescens*	Emberizidae, sub. Parulinae	5	X		X
Black-throated green warbler	*Dendroica caerulescens*	Emberizidae, sub. Parulinae	1	X		
Blackpoll warbler	*Dendroica striata*	Emberizidae, sub. Parulinae	14	X		
Blue jay	*Cyanocitta cristata*	Corvidae	285	X	X	X

Table 2. Continued.

Common name	Scientific name	Family	No. obs.[2]	Seasonal occurrence[3]		
				Spring	Summer	Fall
Blue-gray gnatcatcher	*Piloptila caerulea*	Muscicapidae, sub. Sylviinae	6	X	X	X
Blue-headed vireo	*Vireo solitarius*	Vireonidae	3	X		X
Broad-winged hawk	*Buteo platypterus*	Accipitridae	1			X
Brown thrasher	*Toxostoma rufrum*	Mimidae	161	X	X	X
Brown-headed cowbird	*Molothrus ater*	Emberizidae, sub. Icterinae	22	X	X	X
Canada goose	*Branta canadensis*	Anatidae	12	X		X
Carolina chickadee	*Parus carolinensis*	Paridae	87	X	X	X
Carolina wren	*Thryothorus ludovivicanus*	Troglodytidae	221	X	X	X
Chestnut-sided warbler	*Dendrocia pensylvanica*	Emberizidae, sub. Parulinae	1	X		
Chimney swift	*Chaetura pelagica*	Apodidae	40	X	X	X
Chipping sparrow	*Spizella passerina*	Emberizidae, sub. Emberizinae	15	X		X
Common grackle	*Quiscalis quiscula*	Emberizidae, sub. Icterinae	52	X	X	X

Table 2. Continued.

Common name	Scientific name	Family	No. obs.[2]	Seasonal occurrence[3]		
				Spring	Summer	Fall
Common yellowthroat	*Geothlypis trichas*	Emberizidae, sub. Parulinae	25	X		X
Cooper's hawk	*Accipiter cooperii*	Accipitridae, sub. Accipitrinae	1			X
Dark-eyed junco	*Juncus hyemalis*	Emberizidae, sub. Emberizinae	39	X		X
Downy woodpecker	*Picoides pubescens*	Picidae	34	X	X	X
Eastern kingbird	*Tyrannus tyrannus*	Tyrannidae	1	X		
Eastern phoebe	*Sayornis phoebe*	Tyrannidae	7	X		X
Eastern towhee	*Pipilio erythrophthalmus*	Emberizidae, sub. Emberizinae	231	X	X	X
Eastern wood-peewee	*Contopus virens*	Tyrannidae	81	X	X	X
European starling	*Sturnus vulgaris*	Sturnidae	331	X	X	X
Fish crow	*Corvus ossifragus*	Corvidae	78	X	X	X
Golden-crowned kinglet	*Regulus satrapa*	Muscicapidae, sub. Sylviinae	2			X
Gray catbird	*Dumetella carolinensis*	Mimidae	363	X	X	X

Table 2. Continued.

Common name	Scientific name	Family	No. obs.[2]	Seasonal occurrence[3]		
				Spring	Summer	Fall
Great blue heron	*Ardea herodias*	Fregatidae	1			X
Great-creasted flycatcher	*Myiarchus crinitus*	Tyrannidae, sub. Tyranninae	1	X		
Hairy woodpecker	*Picoides villosus*	Picidae	5	X		X
Hermit thrush	*Catharus guttatus*	Muscicapidae, sub. Turdinae	8			X
House finch	*Carpodacus mexicanus*	Fringillidae	22	X	X	X
House sparrow	*Passer domesticus*	Passeridae	341	X	X	X
House wren	*Troglodytes aedon*	Troglodytidae	43	X	X	X
Indigo bunting	*Passerina cyanea*	Emberizidae, sub. Cardinalinae	1	X		
Magnolia warbler	*Dendroica magnolia*	Emberizidae, sub. Parulinae	4	X		X
Mallard	*Anas platyrhynchos*	Anatidae	1		X	
Mourning dove	*Zenaida macroura*	Columbidae	55	X	X	X
Northern cardinal	*Cardinalis cardinalis*	Emberizidae, sub. Cardinalinae	351	X	X	X
Northern mockingbird	*Mimus polyglottos*	Mimidae	42	X	X	X

Table 2. Continued.

Common name	Scientific name	Family	No. obs.[2]	Seasonal occurrence[3]		
				Spring	Summer	Fall
Northern waterthrush	*Seiurus noveboracensis*	Parulidae	1			X
Ovenbird	*Seiurus aurocapillus*	Emberizidae, sub. Parulinae	3	X		X
Palm warbler	*Dendroica palmarum*	Emberizidae, sub. Parulinae	3	X		X
Pileated woodpecker	*Dryocopus pileatus*	Picidae	10	X	X	X
Prairie warbler	*Dendroica discolor*	Emberizidae, sub. Parulinae	1	X		
Red-bellied woodpecker	*Melanerpes carolinus*	Picidae	171	X	X	X
Red-eyed vireo	*Vireo olivaceus*	Vireonidae	4	X		X
Red-shouldered hawk	*Buteo lineatus*	Accipitridae	1	X		
Red-tailed hawk	*Buteo jamaicensis*	Accipitridae	6	X	X	X
Rose-breasted grosbeak	*Pheucticus ludovicianus*	Emberizidae, sub. Cardinalinae	1	X		
Ruby-crowned kinglet	*Regulus calendula*	Muscicapidae, sub. Sylviinae	14	X	X	X
Ruby-throated hummingbird	*Archilochus colubris*	Trochilidae	1		X	
Scarlet tanager	*Piranga rubra*	Emberizidae, sub. Thraupinae	3	X		X

Table 2. Continued.

Common name	Scientific name	Family	No. obs.[2]	Seasonal occurrence[3]		
				Spring	Summer	Fall
Song sparrow	*Melospiza melodia*	Emberizidae, sub. Emberizinae	13	X	X	X
Swainson's thrush	*Catharus ustulatus*	Muscicapidae, sub. Turdinae	1			X
Swamp sparrow	*Melospiza georgiana*	Emberizidae, sub. Emberizinae	1			X
Tufted titmouse	*Parus bicolor*	Paridae	197	X	X	X
Turkey vulture	*Cathartes aura*	Cathartidae	6	X		X
White-breasted nuthatch	*Sitta carolinensis*	Sittidae	184	X	X	X
White-eyed vireo	*Vireo griseus*	Vireonidae	1	X		
White-throated sparrow	*Zonotrichia albicollis*	Emberizidae, sub. Emberizinae	119	X		X
Wood thrush	*Hylocichla mustelina*	Muscicapidae, sub. Turdinae	6	X		X
Yellow-bellied sapsucker	*Sphyrapicus varius*	Picidae	1			X
Yellow-billed cuckoo	*Coccyzus americanus*	Cuculidae	2		X	X
Yellow-rumped warbler	*Dendroica coronata*	Emberizidae, sub. Parulinae	31	X		
Yellow-shafted flicker	*Colaptes auratus*	Picidae	118	X	X	X

[1] Live birds observed is not an exhaustive list and is limited to those birds identifiable by the searcher.
[2] Number of observations refers to the number of days a particular species was observed within 530 search days.
[3]Spring, summer, and fall seasons represent spring migration, 15 April-31 May; summer/breeding, 1 June-31 July; and fall migration, 1 August-15 November (from "Spring and Fall Migration Timetable" for the District of Columbia, http://www.birdnature.com/timetable.html).

Table 3. Live birds observed[1] and/or heard during carcass searches at the Maintenance Yard (MY) tower site, Rock Creek Park, Washington, D.C., from 24 May-15 November 2006, 15 April-15 November 2007, 15 April-15 November 2008.

Common name	Scientific name	Family	No. obs.[2]	Seasonal occurrence[3]		
				Spring	Summer	Fall
Acadian flycatcher	*Empidonax virescens*	Tyrannidae	141	X	X	X
American crow	*Corvus brachyrhyncos*	Corvidae	185	X	X	X
American goldfinch	*Carduelis tristis*	Fringillidae	71	X	X	X
American redstart	*Setophaga ruticilla*	Emberizidae, sub. Parulinae	22	X		X
American robin	*Turdus migratorius*	Muscicapidae, sub. Turdinae	458	X	X	X
Baltimore oriole	*Icterus galbula*	Emberizidae, sub. Icterinae	16	X	X	X
Barred owl	*Strix varia*	Strigidae	12	X	X	X
Black-and-white warbler	*Mniotilta varia*	Emberizidae, sub. Parulinae	33	X		X
Blackburnian warbler	*Dendroica fusca*	Parulidae	3	X		
Black-throated blue warbler	*Dendroica caerulescens*	Emberizidae, sub. Parulinae	22	X		X
Black-throated green warbler	*Dendroica caerulescens*	Emberizidae, sub. Parulinae	19	X		X
Blackpoll warbler	*Dendroica striata*	Emberizidae, sub. Parulinae	20	X		X
Blue jay	*Cyanocitta cristata*	Corvidae	195	X	X	X

Table 3. Continued

Common name	Scientific name	Family	No. obs.[2]	Seasonal occurrence[3]		
				Spring	Summer	Fall
Blue-gray gnatcatcher	*Piloptila caerulea*	Muscicapidae, sub. Sylviinae	61	X	X	X
Blue-headed vireo	*Vireo solitarius*	Vireonidae	3	X		X
Blue-winged warbler	*Vermivora pinus*	Parulidae	12	X		X
Brown creeper	*Certhia americana*	Certhiidae, sub. Certhiinae	6			X
Brown thrasher	*Toxostoma rufrum*	Mimidae	22	X	X	X
Brown-headed cowbird	*Molothrus ater*	Emberizidae, sub. Icterinae	85	X	X	X
Canada warbler	*Wilsonia canadensis*	Parulidae	7	X		
Canada goose	*Branta canadensis*	Anatidae	12	X	X	X
Carolina chickadee	*Parus carolinensis*	Paridae	286	X	X	X
Carolina wren	*Thryothorus ludovivicanus*	Troglodytidae	249	X	X	X
Cedar waxwing	*Bombycilla cedrorum*	Bombycillidae	2	X		
Chestnut-sided warbler	*Dendrocia pensylvanica*	Emberizidae, sub. Parulinae	10	X		X

Table 3. Continued

Common name	Scientific name	Family	No. obs.[2]	Seasonal occurrence[3]		
				Spring	Summer	Fall
Chimney swift	*Chaetura pelagica*	Apodidae	35	X	X	X
Chipping sparrow	*Spizella passerina*	Emberizidae, sub. Emberizinae	28	X		X
Common grackle	*Quiscalis quiscula*	Emberizidae, sub. Icterinae	84	X		X
Common yellowthroat	*Geothlypis trichas*	Emberizidae, sub. Parulinae	26	X		X
Cooper's hawk	*Accipiter cooperii*	Accipitridae, sub. Accipitrinae	2	X		X
Dark-eyed junco	*Juncus hyemalis*	Emberizidae, sub. Emberizinae	69	X		X
Downy woodpecker	*Picoides pubescens*	Picidae	106	X	X	X
Eastern bluebird	*Sialia sialis*	Turdidae	2	X		
Eastern phoebe	*Sayornis phoebe*	Tyrannidae	14	X		X

Table 3. Continued

Common name	Scientific name	Family	No. obs.[2]	Seasonal occurrence[3]		
				Spring	Summer	Fall
Eastern towhee	*Pipilio erythrophthalmus*	Emberizidae, sub. Emberizinae	254	X	X	X
Eastern wood-peewee	*Contopus virens*	Tyrannidae	128	X	X	X
European starling	*Sturnus vulgaris*	Sturnidae	32	X	X	X
Fish crow	*Corvus ossifragus*	Corvidae	29	X	X	X
Golden-crowned kinglet	*Regulus satrapa*	Muscicapidae, sub. Sylviinae	6			X
Gray catbird	*Dumetella carolinensis*	Mimidae	269	X	X	X
Great blue heron	*Ardea herodias*	Fregatidae	3			X
Great-creasted flycatcher	*Myiarchus crinitus*	Tyrannidae, sub. Tyranninae	5	X	X	X
Great-horned owl	*Bubo virginianus*	Strigidae	1	X		
Hairy woodpecker	*Picoides villosus*	Picidae	27	X		X
Hermit thrush	*Catharus guttatus*	Muscicapidae, sub. Turdinae	9			X
Hooded warbler	*Wilsonia citrina*	Parulidae	3	X		X

Table 3. Continued

Common name	Scientific name	Family	No. obs.[2]	Seasonal occurrence[3]		
				Spring	Summer	Fall
House finch	*Carpodacus mexicanus*	Fringillidae	32	X	X	X
House sparrow	*Passer domesticus*	Passeridae	169	X	X	X
House wren	*Troglodytes aedon*	Troglodytidae	49	X	X	X
Indigo bunting	*Passerina cyanea*	Emberizidae, sub. Cardinalinae	8	X		
Least flycatcher	*Empidonax minimus*	Tyrannidae, sub. Fluvicolinae	1	X		
Magnolia warbler	*Dendroica magnolia*	Emberizidae, sub. Parulinae	15	X		X
Mallard	*Anas platyrhynchos*	Anatidae	1	X		
Mourning dove	*Zenaida macroura*	Columbidae	270	X	X	X
Mourning warbler	*Oporornis philadelphia*	Parulidae	1	X		
Nashville warbler	*Vermivora ruficapilla*	Parulidae	1			X

Table 3. Continued

Common name	Scientific name	Family	No. obs.[2]	Seasonal occurrence[3]		
				Spring	Summer	Fall
Northern cardinal	*Cardinalis cardinalis*	Emberizidae, sub. Cardinalinae	460	X	X	X
Northern mockingbird	*Mimus polyglottos*	Mimidae	19	X		X
Northern parula	*Parula americana*	Parulidae	18	X		X
Ovenbird	*Seiurus aurocapillus*	Emberizidae, sub. Parulinae	40	X	X	X
Palm warbler	*Dendroica palmarum*	Emberizidae, sub. Parulinae	3	X		X
Pileated woodpecker	*Dryocopus pileatus*	Picidae	27	X	X	X
Prairie warbler	*Dendroica discolor*	Emberizidae, sub. Parulinae	3	X		X
Red-bellied woodpecker	*Melanerpes carolinus*	Picidae	238	X	X	X
Red-breasted nuthatch	*Sitta canadensis*	Sittidae, sub. Sittinae	2	X		
Red-eyed vireo	*Vireo olivaceus*	Vireonidae	48	X	X	X
Red-shouldered hawk	*Buteo lineatus*	Accipitridae	105	X	X	X

Table 3. Continued

Common name	Scientific name	Family	No. obs.[2]	Seasonal occurrence[3]		
				Spring	Summer	Fall
Rose-breasted grosbeak	*Pheucticus ludovicianus*	Emberizidae, sub. Cardinalinae	5	X		X
Ruby-crowned kinglet	*Regulus calendula*	Muscicapidae, sub. Sylviinae	29	X		X
Ruby-throated hummingbird	*Archilochus colubris*	Trochilidae	36	X	X	X
Scarlet tanager	*Piranga rubra*	Emberizidae, sub. Thraupinae	19	X	X	X
Song sparrow	*Melospiza melodia*	Emberizidae, sub. Emberizinae	18	X		X
Swainson's thrush	*Catharus ustulatus*	Muscicapidae, sub. Turdinae	4	X		X
Swamp sparrow	*Melospiza georgiana*	Emberizidae, sub. Emberizinae	1			X
Tufted titmouse	*Parus bicolor*	Paridae	350	X	X	X
Turkey vulture	*Cathartes aura*	Cathartidae	5	X		X

Table 3. Continued

Common name	Scientific name	Family	No. obs.[2]	Seasonal occurrence[3]		
				Spring	Summer	Fall
Veery	*Catharus fuscescens*	Turdidae	19	X	X	X
White-breasted nuthatch	*Sitta carolinensis*	Sittidae	316	X	X	X
White-eyed vireo	*Vireo griseus*	Vireonidae	4	X		X
White-throated sparrow	*Zonotrichia albicollis*	Emberizidae, sub. Emberizinae	88	X		X
Winter wren	*Troglodytes troglodytes*	Troglodytidae	7			X
Wood thrush	*Hylocichla mustelina*	Muscicapidae, sub. Turdinae	90	X	X	X
Worm-eating warbler	*Helmitheros vermivorum*	Parulidae	4	X		X
Yellow warbler	*Dendroica petechia*	Parulidae	3	X		X
Yellow-bellied sapsucker	*Sphyrapicus varius*	Picidae	7			X
Yellow-billed cuckoo	*Coccyzus americanus*	Cuculidae	18	X	X	X
Yellow-rumped warbler	*Dendroica coronata*	Emberizidae, sub. Parulinae	47	X		X

Table 3. Continued

Common name	Scientific name	Family	No. obs.[2]	Seasonal occurrence[3]		
				Spring	Summer	Fall
Yellow-shafted flicker	*Colaptes auratus*	Picidae	89	X	X	X
Yellow-throated vireo	*Vireo flavifrons*	Vireonidae	2			X
Yellow-throated warbler	*Dendroica dominica*	Parulidae	1	X		

[1]Live birds observed is not an exhaustive list and is limited to those birds identifiable by the searcher.
[2]Number of observations refers to the number of days a particular species was observed within 530 search days.
[3]Spring, summer, and fall seasons represent spring migration, 15 April-31 May; summer/breeding, 1 June-31 July; and fall migration, 1 August-15 November (from "Spring and Fall Migration Timetable" for the District of Columbia, http://www.birdnature.com/timetable.html).

Table 4. Live birds observed[1] and/or heard during carcass searches at the Nature Center (NC) "tower" site, Rock Creek Park, Washington, D.C., from 29 May-15 November 2007 and 15 April-15 November 2008.

Common name	Scientific name	Family	No. obs.[2]	Seasonal occurrence[3]		
				Spring	Summer	Fall
Acadian flycatcher	*Empidonax virescens*	Tyrannidae	10	X	X	X
American crow	*Corvus brachyrhyncos*	Corvidae	157	X	X	X
American goldfinch	*Carduelis tristis*	Fringillidae	13	X	X	X
American redstart	*Setophaga ruticilla*	Emberizidae, sub. Parulinae	4		X	X
American robin	*Turdus migratorius*	Muscicapidae, sub. Turdinae	269	X	X	X
Baltimore oriole	*Icterus galbula*	Emberizidae, sub. Icterinae	24	X	X	X
Bay-breasted warbler	*Dendroica castanea*	Parulidae	2	X		
Barred owl	*Strix varia*	Strigidae	2	X		X
Black-and-white warbler	*Mniotilta varia*	Emberizidae, sub. Parulinae	6	X		X

Table 4. Continued.

Common name	Scientific name	Family	No. obs.[2]	Seasonal occurrence[3]		
				Spring	Summer	Fall
Black-throated blue warbler	*Dendroica caerulescens*	Emberizidae, sub. Parulinae	5	X		X
Black-throated green warbler	*Dendroica caerulescens*	Emberizidae, sub. Parulinae	8	X		X
Blackpoll warbler	*Dendroica striata*	Emberizidae, sub. Parulinae	12	X		
Blue jay	*Cyanocitta cristata*	Corvidae	144	X	X	X
Blue-gray gnatcatcher	*Piloptila caerulea*	Muscicapidae, sub. Sylviinae	14	X	X	X
Blue-winged warbler	*Vermivora pinus*	Parulidae	3	X		X
Brown thrasher	*Toxostoma rufrum*	Mimidae	6	X		X
Brown-headed cowbird	*Molothrus ater*	Emberizidae, sub. Icterinae	17	X	X	X

Table 4. Continued.

Common name	Scientific name	Family	No. obs.[2]	Seasonal occurrence[3]		
				Spring	Summer	Fall
Canada warbler	*Wilsonia canadensis*	Parulidae	1			X
Canada goose	*Branta canadensis*	Anatidae	3			X
Carolina chickadee	*Parus carolinensis*	Paridae	199	X	X	X
Carolina wren	*Thryothorus ludovivicanus*	Troglodytidae	103	X	X	X
Cedar waxwing	*Bombycilla cedrorum*	Bombycillidae	1	X		
Chestnut-sided warbler	*Dendrocia pensylvanica*	Emberizidae, sub. Parulinae	2	X		X
Chimney swift	*Chaetura pelagica*	Apodidae	21	X	X	X
Chipping sparrow	*Spizella passerina*	Emberizidae, sub. Emberizinae	5	X		X
Common grackle	*Quiscalis quiscula*	Emberizidae, sub. Icterinae	25		X	X

Table 4. Continued.

Common name	Scientific name	Family	No. obs.[2]	Seasonal occurrence[3]		
				Spring	Summer	Fall
Common yellowthroat	*Geothlypis trichas*	Emberizidae, sub. Parulinae	4	X		X
Cooper's hawk	*Accipiter cooperii*	Accipitridae, sub. Accipitrinae	2			X
Dark-eyed junco	*Juncus hyemalis*	Emberizidae, sub. Emberizinae	22			X
Downy woodpecker	*Picoides pubescens*	Picidae	70	X	X	X
Eastern bluebird	*Sialia sialis*	Turdidae	4	X	X	
Eastern phoebe	*Sayornis phoebe*	Tyrannidae	5	X	X	X
Eastern towhee	*Pipilio erythrophthalmus*	Emberizidae, sub. Emberizinae	90	X	X	X
Eastern wood-peewee	*Contopus virens*	Tyrannidae	147	X	X	X
European starling	*Sturnus vulgaris*	Sturnidae	7	X	X	X

Table 4. Continued.

Common name	Scientific name	Family	No. obs.[2]	Seasonal occurrence[3]		
				Spring	Summer	Fall
Fish crow	*Corvus ossifragus*	Corvidae	16	X	X	X
Golden-crowned kinglet	*Regulus satrapa*	Muscicapidae, sub. Sylviinae	1			X
Gray catbird	*Dumetella carolinensis*	Mimidae	85	X	X	X
Hairy woodpecker	*Picoides villosus*	Picidae	7	X	X	X
House finch	*Carpodacus mexicanus*	Fringillidae	6		X	X
House sparrow	*Passer domesticus*	Passeridae	108	X	X	X
House wren	*Troglodytes aedon*	Troglodytidae	9	X	X	X
Lincoln's sparrow	*Melospiza lincolnii*	Emberizidae	1			X
Mourning dove	*Zenaida macroura*	Columbidae	148	X	X	X
Northern cardinal	*Cardinalis cardinalis*	Emberizidae, sub. Cardinalinae	280	X	X	X
Northern mockingbird	*Mimus polyglottos*	Mimidae	1		X	

Table 4. Continued.

Common name	Scientific name	Family	No. obs.[2]	Seasonal occurrence[3]		
				Spring	Summer	Fall
Northern parula	*Parula americana*	Parulidae	6	X		
Ovenbird	*Seiurus aurocapillus*	Emberizidae, sub. Parulinae	6	X		X
Pileated woodpecker	*Dryocopus pileatus*	Picidae	14	X	X	X
Prairie warbler	*Dendroica discolor*	Emberizidae, sub. Parulinae	1			X
Red-bellied woodpecker	*Melanerpes carolinus*	Picidae	172	X	X	X
Red-breasted nuthatch	*Sitta canadensis*	Sittidae, sub. Sittinae	3	X		
Red-eyed vireo	*Vireo olivaceus*	Vireonidae	15	X		X
Red-shouldered hawk	*Buteo lineatus*	Accipitridae	36	X	X	X
Red-tailed hawk	*Buteo jamaicensis*	Accipitridae, sub. Accipitrinae	2			X

Table 4. Continued.

Common name	Scientific name	Family	No. obs.[2]	Seasonal occurrence[3]		
				Spring	Summer	Fall
Rose-breasted grosbeak	*Pheucticus ludovicianus*	Emberizidae, sub. Cardinalinae	1	X		
Ruby-crowned kinglet	*Regulus calendula*	Muscicapidae, sub. Sylviinae	9	X		X
Ruby-throated hummingbird	*Archilochus colubris*	Trochilidae	5	X		X
Scarlet tanager	*Piranga rubra*	Emberizidae, sub. Thraupinae	7	X		X
Song sparrow	*Melospiza melodia*	Emberizidae, sub. Emberizinae	2			X
Swainson's thrush	*Catharus ustulatus*	Muscicapidae, sub. Turdinae	8	X		X
Tufted titmouse	*Parus bicolor*	Paridae	229	X	X	X
Turkey vulture	*Cathartes aura*	Cathartidae	2	X		

Table 4. Continued.

Common name	Scientific name	Family	No. obs.[2]	Seasonal occurrence[3]		
				Spring	Summer	Fall
Veery	*Catharus fuscescens*	Turdidae	5	X		
White-breasted nuthatch	*Sitta carolinensis*	Sittidae	232	X	X	X
White-eyed vireo	*Vireo griseus*	Vireonidae	1	X		
White-throated sparrow	*Zonotrichia albicollis*	Emberizidae, sub. Emberizinae	28	X		X
Wood thrush	*Hylocichla mustelina*	Muscicapidae, sub. Turdinae	45	X	X	X
Yellow warbler	*Dendroica petechia*	Parulidae	1	X		
Yellow-bellied sapsucker	*Sphyrapicus varius*	Picidae	5			X
Yellow-billed cuckoo	*Coccyzus americanus*	Cuculidae	9	X	X	
Yellow-rumped warbler	*Dendroica coronata*	Emberizidae, sub. Parulinae	28	X	X	X
Yellow-shafted flicker	*Colaptes auratus*	Picidae	47	X	X	X

Table 4. Continued.

Common name	Scientific name	Family	No. obs.[2]	Seasonal occurrence[3]		
				Spring	Summer	Fall
Yellow-throated vireo	*Vireo flavifrons*	Vireonidae	1			X
Yellow-throated warbler	*Dendroica dominica*	Parulidae	1	X		

[1]Live birds observed is not an exhaustive list and is limited to those birds identifiable by the searcher.
[2]Number of observations refers to the number of days a particular species was observed within 335 search days.
[3]Spring, summer, and fall seasons represent spring migration, 15 April-31 May; summer/breeding, 1 June-31 July; and fall migration, 1 August-15 November (from "Spring and Fall Migration Timetable" for the District of Columbia, http://www.birdnature.com/timetable.html).

Figure 1a. Cell tower located at the Rock Creek Park Tennis Center (TC) in Washington, D.C. Scale bar represents 50 m.

Figure 1b. Tennis Center (TC) tower located in Rock Creek Park, Washington, D.C., on 29 April 2006. Note the lights low on the tower and the white bubble dome over the tennis courts in the background.

Figure 2a. Cell tower located at the Rock Creek Park Maintenance Yard (MY) in Washington, D.C. Scale bar represents 50 m.

Figure 2b. Maintenance Yard (MY) tower located in Rock Creek Park, Washington, D.C., on 29 April 2006.

Figure 3. Nature Center (NC) control plot located in Rock Creek Park, Washington, D.C. Scale bar represents 50 m. Note: There is no actual tower at this site.

Figure 4a. Upper net catchment located just to the left (photograph) of the Rock Creek Park Maintenance Yard cell tower (MY), Washington, D.C.

Figure 4b. Lower net catchment located just to the right (photograph) of the Rock Creek Park Maintenance Yard cell tower (MY), Washington, D.C.

Figure 4c. Net catchment located just to the west of the Rock Creek Park Tennis Center cell tower (TC, visible in photograph), Washington, D.C.

Figure 4d. Net catchment located just to the east of the Rock Creek Park Tennis Center cell tower (TC, visible in photograph), Washington, D.C.

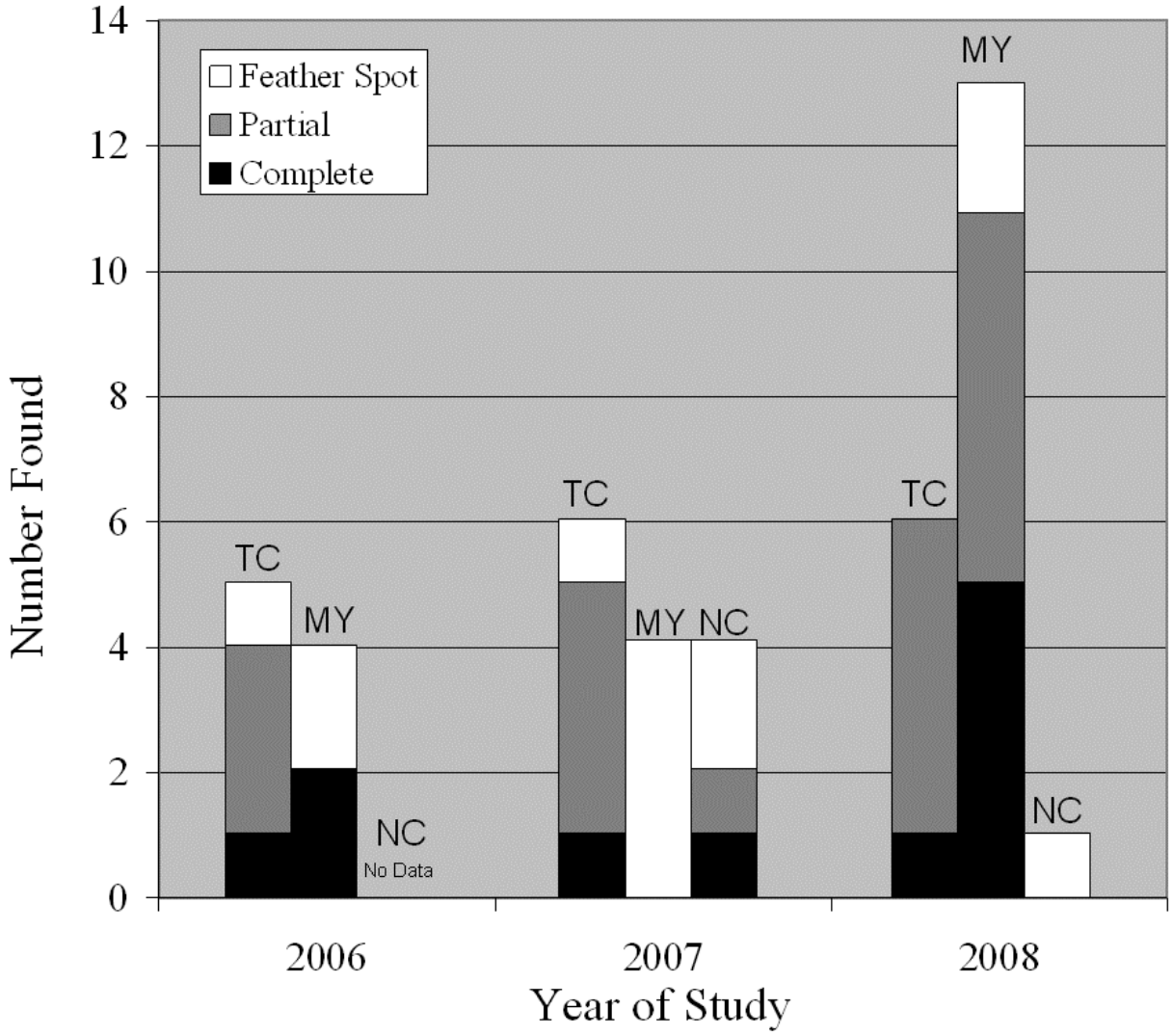

Figure 5a. Number of each carcass type found at the Rock Creek Park Tennis Center (TC), Maintenance Yard (MY), and Nature Center (NC) during the course of the study. There was no NC control site for the 2006 season.

Figure 5b. These remains show a mortality event classified as “feather spots”.

Figure 5c. These remains show a mortality event classified as “partial” carcass.

Figure 5d. These remains show a mortality event classified as “complete” carcass.

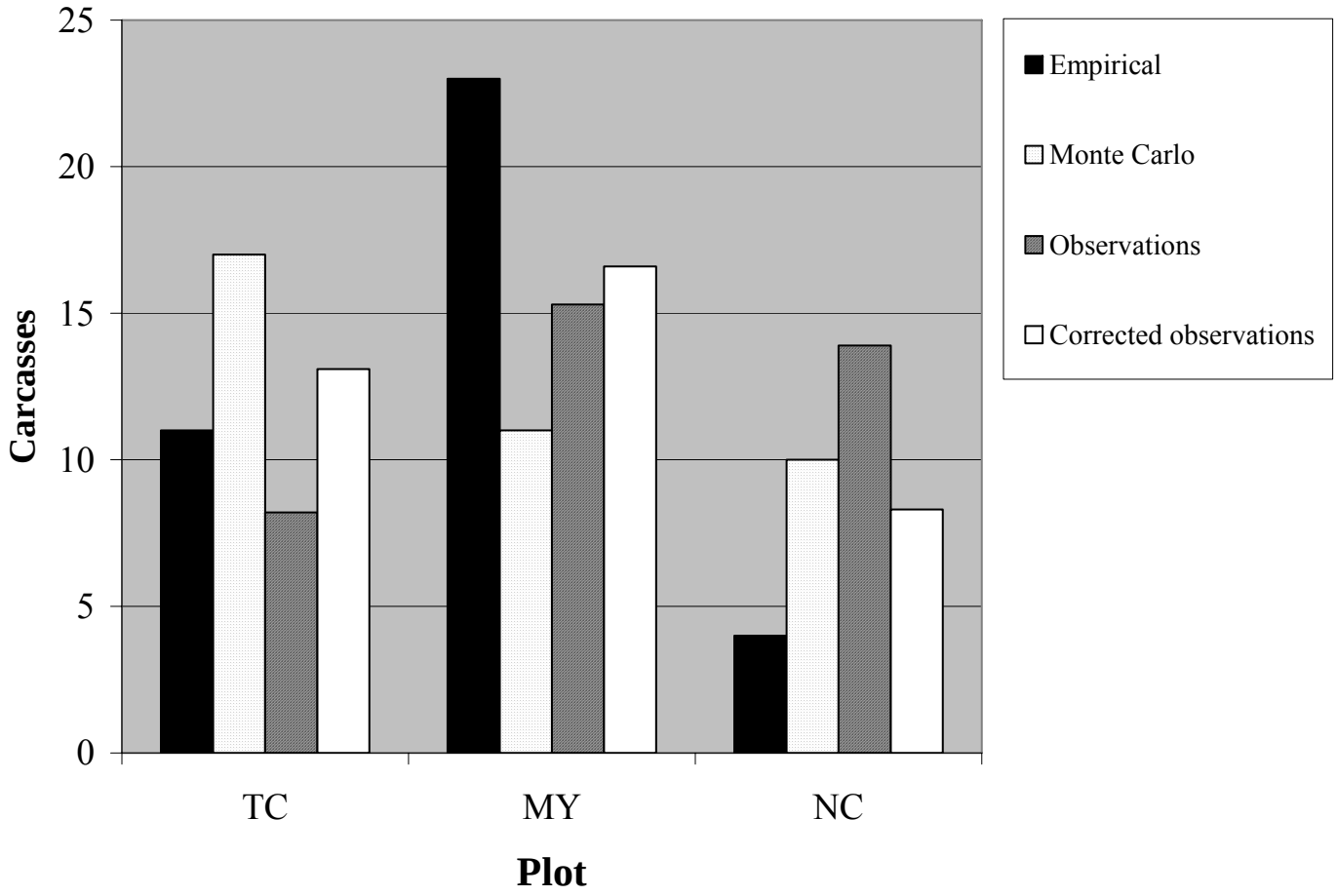

Figure 6. Distribution of predicted and empirical mortalities among the Rock Creek Park Tennis Center (TC), Maintenance Yard (MY), and Nature Center (NC) plots. Legend: Empirical = actual number of carcasses found at each site; Monte Carlo = predicted number of carcasses at each site based on model results; Observations = predicted number of carcasses at each site based on observations of doves and robins; and Corrected observations = predicted number of carcasses using observations of doves and robins and correcting for accessibility and ground cover (from Monte Carlo simulation). See text for further explanation.