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AVIAN COLLISION MORTALITY AT 50- AND 60-M GUYED TOWERS IN CENTRAL CALIFORNIA

Paul Kerlinger[1, 7], John Guarnaccia[2], Aaron Hasch[3], Renee C. E. Culver[4], Richard C. Curry[5], Loan Tran[4], M. Joan Stewart[4], and Daniel Riser-Espinoza[6]

[1]*Curry & Kerlinger, LLC, P. O. Box 453, Cape May Point, NJ 08212*
[2]*Guarnaccia Ecological Services, 1407 Finntown Road, Waldoboro, ME 04572*
[3]*Hasch's Biological Consulting, 603 Stewart Way, Rio Vista, CA 94571*
[4]*NextEra Energy Resources, 6185 Industrial Way, Livermore, CA 94551*
[5]*Curry & Kerlinger, LLC, 1734 Susquehannock Drive, McLean, VA 22101*
[6]*235 Leroy Weaver Road, Nacogdoches, TX 75961*

Abstract. By searching for carcasses weekly year round, we estimated rates of avian fatality from collision with ten 50-m and eight 60-m temporary meteorological towers supported by guy wires near wind turbines at the Altamont Pass ($n = 3$) and Collinsville Montezuma Hills ($n = 15$) wind resource areas in central California. All towers were searched out to 55 m, beyond the farthest guy-wire anchors. Estimates for the total number of fatalities were based on searchers' efficiency and scavengers' removal rates determined empirically at one of the wind farms. In 1632 searches (90.7 ± 5.4 per tower; 136.0 ± 2.8 per month), we found 85 carcasses of 19 species, for an average of 2.8 carcasses per tower per year. When adjusted for searchers' efficiency and scavenging, fatalities per tower per year were 6.8 ± 1.1 for all birds. Icterids, the Horned Lark (*Eremophila alpestris*), pipits, and sparrows accounted for 60% of carcasses, whereas night-migrating songbirds accounted for only 7% of carcasses. This level of mortality likely did not result in population effects because fatalities were spread among many, mostly common species and the towers were temporary structures. Because the towers we studied were similar in structure to guyed communication towers of the same height, our findings are likely applicable to those structures in California. There is currently no other empirical information available on fatality from towers of these heights and support systems, even though they are one of the most common types of such towers in California and elsewhere.

Key words: *towers, avian fatalities, collision mortality, meteorological, night migrants, California.*

Mortalidad de Aves por Colisión contra Torres de 50 y 60 m Retenidas por Cables en el Centro de California

Resumen. Se estimaron los índices de mortalidad por colisión aérea de aves mediante la búsqueda semanal de cadáveres en diez torres meteorológicas temporarias de 50 m de altura y ocho de 60 m de altura retenido por cables en el Área de Recurso Eólico del Paso de Altamont ($n = 3$) y en el Área de Recurso Eólico de Collinsville y las Colinas de Montezuma ($n = 15$), en la parte central de California. En todas las torres se buscó hasta un perímetro de 55 m, lo cual va más allá de los anclajes más distantes de los cables. Los estimados del total de fatalidades estuvieron basados en los índices de la eficiencia de los buscadores y en la extracción de cadáveres por carroñeros, los que fueron determinados de manera empírica en una de las áreas de recurso eólico. Apareció un total de 85 cadáveres de 19 especies en las 1632 búsquedas llevadas a cabo en las 18 torres (90.7 ± 5.4 búsquedas por torre; 136.0 ± 2.8 búsquedas por mes), lo cual dio un promedio de 2.8 cadáveres por torre por año. Al ser ajustadas por la eficiencia de los buscadores y por la extracción de cadáveres por carroñeros, las fatalidades por torre por año sumaron 6.8 ± 1.1 para la totalidad de los pájaros. Los ictéridos, *Eremophila alpestris*, las bisbitas y los gorriones representaron el 60% de los cadáveres, mientras que las paseriformes que migran por la noche representaron apenas el 7% de los cadáveres. Este nivel de mortalidad probablemente no tuvo efectos poblacionales porque los decesos se compartieron entre muchas especies mayormente comunes y las torres no fueron permanentes. Debido a que las torres estudiadas fueron de una estructura similar a la de las torres de comunicación de altura similar retenidos por cables, nuestros resultados son probablemente aplicables a dichas estructuras en California. Hasta el momento no existen otros datos empíricos tomados a partir de torres de la mencionada altura y con estos sistemas de anclaje, aún cuando son uno de los tipos de torres más comunes en California y en otras regiones.

Manuscript received 23 September 2011; accepted 8 February 2012.
[7]E-mail: pkerlinger@comcast.net

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INTRODUCTION

Avian fatalities at communication towers have been reported in the literature for more than 60 years (Avery et al. 1980). Studies have focused primarily on towers >153 m in height, with some >305 m, all supported by guy wires and nearly all equipped with Federal Aviation Administration (FAA) obstruction lighting (Shire et al. 2000). Before 2000, few studies used systematic methods to search for carcasses, report fatalities, or estimate total numbers of fatalities. Recently, Gehring et al. (2009, 2011) systematically studied fatalities at multiple towers 116–146 m and >305 m in height, with and without guy wires and with different types of FAA obstruction lighting. Crawford and Engstrom (2001) also reported on systematic carcass searches at a >305-m tower that was subsequently replaced with one about 91 m tall. For towers <91 m, no systematic studies appear to have been published. According to the Federal Communication Commission (FCC 2010), in the United States there are many more towers of heights <61 m than of heights >91 m. For example, in California, the ratio is greater than 5:1 (FCC 2010). Thus we know little about the effects on birds of the vast majority of towers.

To learn more about the number and type of birds that collide with towers <61 m in height, we studied 18 temporary meteorological towers at four sites in Solano and Contra Costa counties, California (Fig. 1). Meteorological towers are similar in structure to short communication towers that are supported by multiple sets of guy wires; therefore, they may be used as surrogates for estimating the numbers of birds that are killed at communication towers of the same height and with similar support systems in a given region. Known as met towers, they are used to measure atmospheric conditions, primarily wind speed and direction, at prospective wind-energy sites. Modern met towers range in height from 40 to 80 m, and most are 50–60 m.

In addition to reporting the numbers of avian carcasses found at the towers studied, we estimated the total numbers of birds likely to have been killed by the towers by adjusting for searchers' efficiency and carcass-removal rates derived empirically at these sites. We also examined taxonomic, ecological, and seasonal attributes of fatalities.

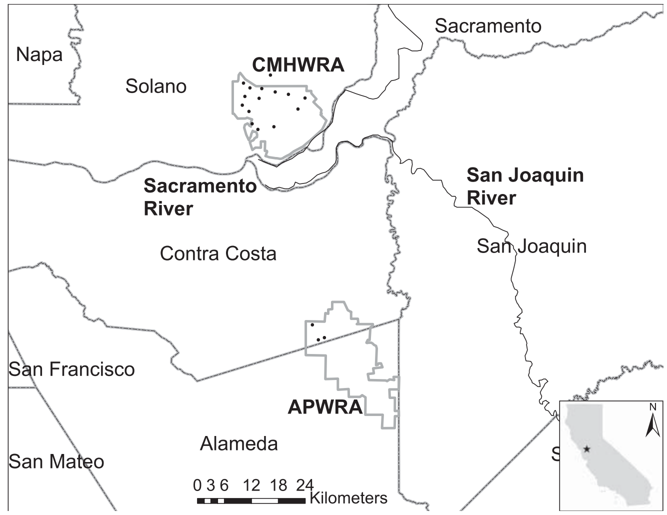

FIGURE 1. Locations of searches for avian carcasses at 18 meteorological towers (points) in the Collinsville Montezuma Hills Wind Resource Area (CMHWRA) and Altamont Pass Wind Resource Area (APWRA) in California. Names of counties indicated.

METHODS

We studied 18 towers in four areas with one to 10 towers each (Table 1). Three of the areas (Hamilton Ranch, Shiloh I, and Shiloh II) were within the Collinsville–Montezuma Hills Wind Resource Area (CMHWRA), near Rio Vista in Solano County, California (Fig. 1). The fourth area was the Vasco Winds Repowering Project Area in the Altamont Pass Wind Resource Area (APWRA) in Contra Costa County, California (Fig. 1). These areas are within about 32 km of each other. During our studies, both wind resource areas had a combination of older and newer wind turbines. There were about 800 turbines operating in the CMHWRA, and mitigation efforts, attrition, and continuing repowering (i.e., replacing original small turbines with modern large ones) had reduced the number of turbines operating in the APWRA so far from 5400 to about 4500.

TABLE 1. Meteorological towers studied in Solano and Contra Costa counties, California.

	Hamilton Ranch	Shiloh I	Shiloh II	APWRA	
Study dates	Feb 2007–Apr 2008	May 2006–Dec 2007	Feb–May 2006–Apr 2008	Feb 2009–Feb 2010	Total
Duration (months)	15	19	26	12	
Met towers 50 m in height (*n*)	1	4	4	1	10
Met towers 60 m in height (*n*)	0	0	6	2	8
Total met towers (*n*)	1	4	10	3	18
Number of searches	65	339	1075	153	1632
Searches per met tower	65.0	84.8	107.5	51.0	90.7
Source	Kerlinger et al. 2008a	Kerlinger et al. 2008b	Kerlinger et al. 2008c	Culver 2010	

The towers we studied were located in rolling hills devoted predominantly to agriculture (Kerlinger et al. 2008a, b, c, Culver 2010). In the CMHWRA, a multi-year rotation was the norm, with tilled grain fields allowed to lie fallow after harvest, after which they were grazed by cattle and sheep (Kerlinger et al. 2008b). In the APWRA hills were only grazed (Culver 2010). Thus, in the CMHWRA, the habitat around the towers changed from year to year with agricultural use, but in the APWRA, grass cover ranged from 5.1 cm high during the dry season to as much as 30.5 cm high during the rainy season (Culver 2010).

The CMHWRA is located adjacent to the Sacramento–San Joaquin delta and the Suisun Marsh, regions rich in bird life, particularly during migration and winter (Evens and Tait 2005). The general area is one of the most important stopover areas for waterbirds migrating along the west coast. The APWRA is located about 30 km south of the delta and is not on an important migration pathway for most birds, although raptors do stop over during migration and winter there in large numbers. It is best known for raptors, on which the effects of the wind turbines have been studied (Orloff and Flannery 1992, Smallwood and Thelander 2007).

Our selection of meteorological towers was nonrandom in that the permits for the towers required all towers in the four subareas of the CMHWRA be studied, while the three towers in the APWRA were monitored voluntarily and were the only meteorological towers of this kind in the APWRA available to be studied. The towers were typical of towers erected prior to construction of wind farms. They were also similar in structure to communication towers of similar heights. Of the 18 towers, 8 (44%) were 50 m in height and 10 (56%) were 60 m in height. All were tubular, about 12 inches in diameter at the base, and all were supported by four sets of six or seven guy wires, rather than by three sets for most communication towers. Guy wires were anchored in the ground from about 28 m to about 50 m from the towers' bases, depending on the height of the tower and terrain. Guy wires were attached to towers at six heights from 9 to 12 m above ground level to 48 to 58 m above ground level, depending on tower height. The towers were not equipped with FAA lights because the FAA generally does not recommend placing obstruction lighting on towers <61 m in height.

Guy wires on 14 of the 18 towers were standard for guyed towers. Exceptions were the tower at Hamilton Ranch, where coiled bird flight diverters 15 cm long were placed on guy wires at 3.7- to 4.6-m intervals (Kerlinger et al. 2008a), and the three towers in the APWRA, which were equipped with bird flight diverters and orange balls on each of the four highest guy wires within about 5 m of where they connected with the tower (Culver 2010). Installed as bird flight diverters, these balls were similar to those used to mark obstructions to aviation.

The three APWRA towers were located near rows of older wind turbines of models Kenetech 56-100 and KVS-33, which had lattice towers and blade lengths of about 9.0 and 16.5 m, respectively. The total heights to which the blades extended were 26.8 and 49.5 m above ground level, respectively. Search areas at those towers were >55 m from wind turbines (Culver 2010). All of the CMHWRA towers were hundreds of meters from wind turbines.

We searched the towers weekly throughout the year, although the duration of the studies ranged from 12 to about 26 months (Table 1). The search method used at all towers was the same. Concentric transects were spaced every 10 m from the base of the turbine out to 50 m. Walking slowly, one or two field biologists searched 5 m on each side of the transects. In addition, we searched the area from the base of the turbine out to 5 m by walking around the base of the tower. Thus the total search area at each met tower was 9503 m^2. Searches took place between 08:00 and 16:00, requiring approximately 30–60 min per tower, not including data recording.

We did not establish control plots to measure background mortality. Our assumption that background mortality was low is supported by a study of three turbines in a reclaimed strip mine in the Cumberland Mountains of Tennessee, where control plots were established (Nicholson 2003). Nonetheless, as explained below, we found evidence of raptors using guy wires as plucking stations.

When we found a carcass, we recorded the species, age, sex, and condition of the carcass, distance of the carcass from the tower, and compass bearing from the tower. Weather conditions on each day of the searches were recorded, but those data were not used in the analyses that follow.

The number of carcasses found beneath towers likely did not reflect all of the birds that collided with them, because searchers likely did not find all carcasses and scavengers may have removed some of them before they could be found. Thus, to estimate searchers' efficiency and carcass-removal rates, we pooled data from 5 years of trials during post-construction studies of fatality at wind turbines in the CMHWRA. These data included 212 searcher-efficiency trials in which the same four observers who searched met towers at Hamilton Ranch (Kerlinger 2008a), Shiloh I (Kerlinger 2008b), and Shiloh II (Kerlinger 2008c) were tested without their knowledge during regular searches in similar habitats. Carcasses were placed randomly in search areas early in the morning before observers began searches. Because large birds were more easily found than smaller birds, trials encompassed carcasses of various sizes, namely, 41 trials with large, 51 with medium, and 111 with small carcasses, for a total of 203 trials. Scavengers removed some carcasses prior to searches, which explains why the sample size differed from the 212 given above.

Carcass-removal trials extended up to 14 days and were also stratified by size class, namely, 48 with large bird carcasses, 66 with medium bird carcasses, and 110 with small bird carcasses, for a total of 224 trials. These trials yielded an average persistence time based on 7-day search intervals.

Examples of large carcasses were the Turkey Vulture (*Cathartes aura*), Red-tailed Hawk (*Buteo jamaicensis*), and California Gull (*Larus californicus*). Examples of medium carcass were the American Kestrel (Falco sparverius), American Coot (*Fulica americana*), and Mourning Dove (*Zenaida macroura*). Small carcasses included such birds as the Horned Lark (*Eremophila alpestris*), European Starling (*Sturnus vulgaris*), and Red-winged Blackbird (*Agelaius phoeniceus*).

Because the habitat around the APWRA towers was similar to that in the CMHWRA, we used the searcher-efficiency and carcass-removal adjustments derived at the CMHWRA wind farms to adjust the APWRA tower data. The CMHWRA rates were also similar to those used by Smallwood (2007) for estimating bird mortality in the APWRA. Those rates were based on averages among reports of trials in grasslands across the United States.

STATISTICAL ANALYSES

We estimated the total number of tower-related fatalities on basis of the searchers' efficiency (Se) rate, the scavengers' removal (Sr) rate, and the number of carcasses found during standardized searches, calculating them with an estimator published by Arnett et al. (2009) and Huso (2011). To derive the average Se, Sr, adjusted fatalities, and corresponding standard error and 95% CI we used bootstrapping, in R, for birds of three size classes (large, medium, and small), as well as for birds of all size classes pooled (Canty and Ripley 2010, Davidson and Hinkley 1997, R Development Core Team 2010). For each statistic we used 5000 bootstrap iterations.

The Se rate, expressed as p, is the average probability that a searcher would find a carcass during a given search (ratio of carcasses found to the number planted). Sr, the rate of removal of carcasses by scavengers before they could be detected, was calculated from the mean carcass-removal time $\bar{t}$, that is, the average length of time (in days) that a carcass was expected to remain detectable in the search area, calculated from a maximum-likelihood estimator under the assumption that carcass-removal times followed an exponential distribution with right-censoring of data (Young et al. 2009). For most of this study, carcasses were collected once they had been in the field for 14 consecutive days, so data were censored at 14 days. The maximum-likelihood estimator is

$$\bar{t} = \frac{\sum_{i=1}^{s} t_i}{S - S_c}$$

where S is the number of carcasses placed in Sr trials and S_c is the number of carcasses censored.

The observed number of fatalities, $\bar{c}$, found per met tower, per year is

$$\bar{c} = \frac{\sum_{j=1}^{n} c_j}{n \cdot \left(\frac{\mu}{12}\right)}$$

where c_j is the number of fatalities found at the jth tower during weekly searches for the duration of the study period, n is the number of towers, and μ is the length of the study period in months. There were four sites searched for this study, and the duration of the search at each was different (Table 1). We calculated $\bar{c}$ for each site and summed the results to calculate fatalities for each size class and the pooled size classes.

The final fatality estimate, $\bar{m}$, is found by dividing the observed number of fatalities, $\bar{c}$, by $\hat{r}$, p, and $\hat{v}$; these are factors that account for the probability of carcass persistence, probability of detection given persistence (i.e., p, as above), and the effective search interval, respectively (Huso 2011). Thus,

$$\bar{m} = \frac{\sum_{j=1}^{n} c_j}{\hat{r} \cdot p \cdot \hat{v}}$$

where

$$\hat{r} = \frac{\bar{t}\{1 - \exp[-\min(\tilde{I}, I)/\bar{t}]\}}{\min(\tilde{I}, I)},$$

$$\hat{v} = \min[1, (\tilde{I}/I)],$$

$$\tilde{I} = -\log(0.01) \cdot \bar{t},$$

and $I = 7$ since towers were searched weekly. We calcuated $\bar{m}$, standard error, and the 95% CI by bootstrapping $\bar{c}$ 5000 times and applying the persistence, detection, and effective-interval-adjustment factors.

The values reported under Results are means ± SE.

RESULTS

In total, 1632 searches were made at the 18 towers (90.7 ± 5.4). When searches were pooled, their distribution through the 12 months of the year was fairly constant and the number of searches per month did not vary greatly (136.0 ± 2.8).

Searchers found 85 avian carcasses, not including three that were located outside search areas (Table 2). This was equal to 5.2 carcasses found (within designated search areas) per 100 searches of a tower. Monthly rates ranged from 1.3 carcasses per 100 searches in April to 8.6 carcasses per 100 searches in October.

At the four towers with bird flight diverters, 6.0 ± 3.5 carcasses were found per 100 searches, while at the 14 towers without the diverters, 5.1 ± 0.8 carcasses were found per 100 searches. This difference in a t-test was not statistically significant ($P = 0.7$).

Nineteen species were identified, not including the Red-tailed Hawk that was not within a designated search area. Of these species, 13 ($n = 62$ individuals) were passerines, which accounted for 73% of all carcasses. One diurnal raptor, an American Kestrel, and one nocturnal raptor, a Barn Owl (*Tyto alba*), were found during searches. A Common

TABLE 2. Species recorded in collisions with 18 meteorological towers studied in Solano and Contra Costa counties, California.[a]

Species	Hamilton Ranch	Shiloh I	Shiloh II	Altamont Pass	Total
Red-tailed Hawk			0 (1)		0 (1)
American Kestrel		1			1
Common Gallinule			1		1
Killdeer		1	1		2
Rock Pigeon		1	7		8
Mourning Dove	2	2	6		10
Barn Owl			1		1
Pacific-slope Flycatcher			1		1
Loggerhead Shrike	1				1
Horned Lark			6	1	7
Barn Swallow		1			1
Swallow sp.		1			1
European Starling			1	1	2
American Pipit		1	4		5
Savannah Sparrow			3		3
Lincoln's Sparrow		1			1
White-crowned Sparrow			1		1
Dark-eyed Junco			1		1
Sparrow sp.			1		1
Red-winged Blackbird	3	6	9		18
Western Meadowlark	2	4	5 (1)	1	12 (1)
Brewer's Blackbird			3 (1)		3 (1)
Blackbird sp.				1	1
Songbird sp.		1		2	3
Totals	8	20	51 (3)	6	85 (3)

[a]Parentheses indicate carcasses found outside of standardized searches.

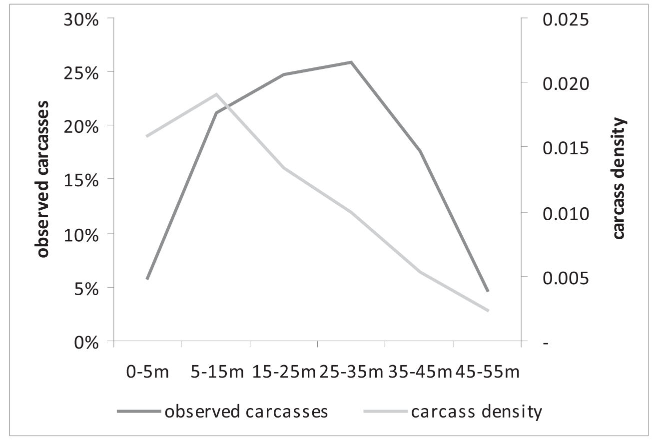

FIGURE 2. Distribution of avian carcasses (percentage and density [m^{-2}]) by distance from 18 meteorological towers studied in Solano and Contra Costa counties, California.

Gallinule (*Gallinula galeata*) was the only obligate waterbird found. The only shorebirds found were two Killdeer (*Charadrius vociferus*). Rock Pigeons (*Columba livia*) and Mourning Doves made up 21% (n = 18) of carcasses discovered in searches. The Horned Lark, American Pipit (*Anthus rubescens*), sparrows, and icterids accounted for 51 (60%) of the carcasses found.

Among the songbirds, five species—the Pacific-slope Flycatcher (*Empidonax difficilis*), Savannah Sparrow (*Passerculus sandwichensis*), Lincoln's Sparrow (*Melospiza lincolnii*), White-crowned Sparrow (*Zonotrichia leucophrys*), and Dark-eyed Junco (*Junco hyemalis*)—were night migrants that were found during migration seasons. These birds accounted for 7% of all fatalities identified.

The mean distance of carcasses from towers was 29.7 ± 1.3 m, but few carcasses were found at 0–15 m and at 45–55 m (Fig. 2). When adjusted for area searched, the number of carcasses found was greatest close to towers and diminished toward the edges of search plots (Fig. 2), demonstrating that search plots with a 55-m radius accounted for all but a tiny fraction of carcasses.

An average of 2.8 carcasses was found per tower per year (Table 3). When adjusted for searchers' efficiency and carcass removal by scavengers, fatalities per tower per year were 6.8 ± 1.1 for all birds. Thus, for every carcass found, about 2.5 were not found. Bootstrapping yielded a 95% confidence interval for the overall mortality rate from 4.9 to 9.0 fatalities per tower per year.

DISCUSSION

Systematically collected empirical information about collision fatalities at communication and meteorological towers is surprisingly limited. Although researchers and birders have searched beneath towers for more than 50 years, our study appears be the first published on (1) towers in North America west of the Rocky Mountains, (2) towers <61 m in height, and (3) with one exception (Stoddard 1962), towers studied throughout the year.

Although the towers we studied were meteorological towers, it is important to note that they were similar in structure to a large number of communication towers of approximately the same height. Meteorological towers have four sets of guy wires, whereas communication towers that are not self-supporting generally have three sets of guy wires. While it is reasonable to assume that a greater number of guy wires results in greater fatalities rates (Gehring et al. 2011), this has not been studied. Thus the towers we studied may serve as surrogates for short, guyed communication towers, for which no published studies are available.

Our findings also provide new insight into the species composition of fatalities at short, guyed towers in California, as well as fatalities year round. In a review of 47

TABLE 3. Observed and adjusted avian fatalities with 95% confidence intervals at 18 meteorological towers studied in Solano and Contra Costa counties, California.

	Observed fatalities	Searcher efficiency rate (fraction detected)		Scavenger carcass-removal time (days)		Adjusted fatalities	
All birds	2.76	0.67 ± 0.04	(0.56, 0.74)	13.02 ± 1.23	(10.82, 15.63)	6.78 ± 1.07	(4.85, 9.03)
Large birds	0.09	0.91 ± 0.04	(0.78, 0.97)	161.75 ± 2.07	(65.50, 673.00)	0.10 ± 0.05	(0.00, 0.23)
Medium birds	1.09	0.80 ± 0.08	(0.59, 0.91)	11.98 ± 2.11	(8.80, 17.10)	1.79 ± 0.42	(1.13, 2.85)
Small birds	1.57	0.51 ± 0.06	(0.39, 0.62)	7.13 ± 0.78	(5.82, 8.93)	4.86 ± 0.10	(3.18, 7.10)

studies of tall (mostly >153 m), guyed communication towers in eastern and central North America, Shire et al. (2000) reported that 53% of the 184 797 carcasses found were definitely of night migrants, whereas 21% were of migrants for which time of day was not known and 4% were of species migrating by both day and night. Thus as many as 78% of the carcasses in those studies may have been of night migrants. In Michigan, Gehring et al. (2009, 2011) found that about 92% of carcasses recovered under guyed and unguyed communication towers 116 m to >305 m in height were night-migrating songbirds. In contrast, we found that night-migrating songbirds found during the migration seasons accounted for only 7% of carcasses and were limited to five species. Also, we did not find warblers, which accounted for about 18% of carcasses at eastern and Midwestern towers (Shire et al. 2000).

Instead of night-migrating songbirds, we found mostly birds that were likely foraging or nesting in the tower areas. Five species, all daytime migrants or residents, accounted for 52 of 85 (61%) carcasses found. These included the Mourning Dove, Horned Lark, American Pipit, Red-winged Blackbird, and Western Meadowlark (*Sturnella neglecta*). They were also found in all seasons of the year, suggesting that some nested or wintered in the area, foraged in the area, or made migration stopovers in the area. In their review of Midwestern and eastern towers, Shire et al. (2000), reported that these species accounted for 0.4% of fatalities, although some of the meadowlarks were Eastern Meadowlarks (*S. magna*).

There are several explanations for the differences in species composition between towers we studied and those reviewed by Shire et al. (2000) and Gehring et al. (2009, 2011). These differences are related to differences in the seasonal timing of the studies, the height of the towers, difference in FAA lighting, and the geographic differences between these areas.

With respect to seasonal timing, we attempted to determine year-round fatality rates rather than rates for migrants, which were the focus of previous studies. Because so few year-round studies have been conducted at towers in eastern and central North America, we have little knowledge regarding how many birds are being killed at those towers outside the migration seasons.

That such a small percentage of species and carcasses were night migrants may be related to searching throughout the year, not just in migration seasons, but it is also likely that the height of the towers played a role. The towers we studied were roughly one-third to one-fifth the height of the guyed communication towers reviewed by Shire et al. (2000), which were more than 200 m greater in height. The towers were also shorter than the 116- to >305-m towers studied by Gehring et al. (2009, 2011). Taller towers, like those studied in the East and Midwest, are struck by greater numbers of night migrants than are shorter towers (Gehring et al. 2011) because they extend higher into the altitude zone of night migrants, whereas the 50- to 60-m towers we studied were much lower than the mean altitudes of migration (Kerlinger and Moore 1989).

Another important difference is that the towers we studied were not equipped with obstruction lighting, as the FAA requires on taller towers (FAA 2007). Nearly all of the studies summarized by Shire et al. (2000) and by Avery et al. (1980), as well as that of Gehring et al. (2009, 2011), addressed towers ranging from about 116 m to ~400 m in height and were, in all likelihood, equipped with two types of FAA-approved lighting (steady-burning red L-810 and flashing-red L-864). The absence of obstruction lighting, especially steady-burning red L-810 lights, may help to explain why so few night migrants were killed during our study. These lights have been demonstrated to account for roughly 50–70% of bird fatalities at guyed towers >116–146 m in height (Gehring et al. 2009), whereas L-864 flashing red lights did not influence collisions of night migrants at wind turbines in the 100- to 125-m height range (Kerlinger et al. 2010a).

Finally, it is possible that there are fewer night migrants in western than in central and eastern North America, as suggested by the continent-wide studies by Lowery and Newman (1966) and Gauthreaux et al. (2003). Without studies of taller towers in western North America and year-round studies in central and eastern North America, the reason for the differences in species composition between our study and others is speculation.

Fish remains were found under one of the APWRA met towers (Culver 2010), suggesting that raptors—in this case, an Osprey (*Pandion haliaetus*)—perched on towers or guy wires to consume prey. Thus it is possible that some of the partial carcasses we detected were left by raptors perched on cross arms with instrumentation, rather than killed by the towers. This may have inflated the mortality rate, although not likely to a great degree.

The guyed towers we examined were temporary structures that will be removed once the annual wind regime has been quantified. Most of these towers remain standing for 1 to 3 years and are replaced by permanent free-standing lattice or tubular towers, as mandated by California regulations for wind-power facilities. These permanent, unguyed towers pose much less risk to birds than do the temporary, guyed towers. Our basis for this statement is the research of Gehring et al. (2009, 2011), which has demonstrated that guyed towers 116–146 tall killed 16 times more birds than did unguyed towers of the same height. Studies at permanent meteorological towers and unguyed communication towers 50–60 m tall, appear to be lacking, but avian fatality rates would likely be minimal, as demonstrated by Gehring et al. (2011).

It would appear that the level of mortality we documented at the 18 towers studied was unlikely to result in population effects, because fatalities were spread among many, mostly common species and the towers were temporary structures.

With respect to the bird flight diverters that were installed on four of the 18 towers, our results suggest that they did not reduce collisions, but it should be emphasized that our study was not designed to test the effectiveness of such diverters.

The towers we studied may serve as surrogates for estimating the numbers of fatalities at guyed communication towers of similar height and structure in California, as well as elsewhere in the West where studies are not available. The FCC (2011) database indicates that 3555 of the 4186 (85%) towers in California were <61 m in height. However, the number supported by guy wires, or equipped with FAA obstruction lighting, is not provided, and such data are extremely difficult to acquire. With these uncertainties, it is not possible to estimate how many birds collide annually with short, guyed towers in California, or elsewhere. There is simply not enough data available to estimate how many birds collide with communication towers in western North America.

It is also interesting that the guyed towers we studied were only about half the height of wind turbines in the CMHWRA, but the adjusted fatality rate per structure was greater than or in the range of that calculated at nearby wind turbines. Kerlinger et al. (2006, 2009, 2010b) studied wind turbines in the 115–120-m range for more than 5 years in the CMHWRA and found adjusted fatality rates in the range of 2.5–10.4 birds per turbine per year. Thus, even though meteorological towers were shorter, the fatality rate at them comparable to that at wind turbines, likely because of the guy wires. Guy wires are known to be responsible for most fatalities at communication towers (Gehring et al. 2011).

What is surprising about the absence of information regarding fatalities of birds at western towers is that their FCC licensing is subject to the National Environmental Policy Act (NEPA) process. Thus their construction is open to review by the U.S. Fish and Wildlife Service or other agencies. Many towers are also subject to permitting at state, county, or local levels, as well as subject to scrutiny by some state wildlife agencies. Despite processes that would trigger environmental review, there is virtually no information currently available from California or other western states as to the actual effects on birds of these structures.

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