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Abstract. Wind energy development can negatively impact bird populations due to bird–turbine collisions. To accurately estimate bird mortality at wind farms, the number of dead birds found under turbines is commonly corrected for carcass removal by scavengers, which is quantified by measuring persistence of experimental carcasses through time. These studies often use domestic birds as surrogates because carcasses of wild birds (e.g., raptors) are difficult to obtain. We assessed scavenger removal of carcasses from five bird species at simulated turbines to determine whether domestic surrogates are scavenged at a different rate than raptors, species of interest for wind turbine mortality. The percentage of carcasses scavenged during 14-d rounds ranged from 34.6% for American kestrels (*Falco sparverius*) to 65.4% for chickens (*Gallus gallus*), and the percentage of carcasses completely removed ranged from 13.5% for red-tailed hawks (*Buteo jamaicensis*) to 67.3% for northern bobwhites (*Colinus virginianus*). Carcass type (i.e., species) was the only predictor included in the best-fit logistic regression model of complete carcass removal, and a survival analysis indicated carcass type influenced elapsed time to scavenging events. Our results suggest the use of surrogate species to quantify carcass removal at wind turbines could lead to inaccurate mortality estimates.

Key words: bird; carcass; collision; mortality; raptor; scavenger; wind turbine.

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Introduction

Collision with wind turbines is an important source of mortality for some bird populations (Loss et al. 2013, Smallwood 2013, Zimmerling et al. 2013, Erickson et al. 2014). In response to concerns about population-level effects of wind energy on birds and other wildlife, the U.S. Fish and Wildlife Service (USFWS 2012) developed a five-tiered approach to assist wind energy companies in identifying and avoiding development at sites with a high risk to wildlife. This effort recommends using mortality studies to detect sites with particularly high mortality and additional studies that can be used as part of an adaptive management process to reduce the risk to wildlife at operating wind energy sites. Because the guidance is voluntary, wind energy companies and their consultants have substantial freedom in terms of how they interpret and implement the guidelines (https://www.fws.gov/Midwest/endangered/permits/hcp/r3wind/DraftHCPandEIS.html).

To estimate the number of birds killed at a wind farm, trained observers search the area under turbines and record the number and species of bird (and other) carcasses found. This number is then corrected for the number of carcasses that are missed by observers, whether this error occurs as a result of observational bias or prior removal of carcasses by scavengers (Kunz et al. 2007, Smallwood 2007). Scavenger bias is evaluated on a site-specific basis by placing carcasses under turbines and assessing their fates at predetermined intervals (Smallwood et al. 2010). However, researchers often use easily obtained (e.g., domestic) carcasses, with chickens substituting for larger raptors, pigeons substituting for midsized birds, and quail substituting for smaller birds including passerines (Villegas-Patraca et al. 2012). Thus, experimental carcasses often do not match the species that are being killed (e.g., raptors), in large part because wild birds are legally protected and relatively difficult to obtain (Smallwood 2007, Urquhart et al. 2015).

When conducted, mortality studies are considered confidential business information and generally not publicly disseminated (Johnson et al. 2016), although references to several such studies are contained in USFWS wind energy guidance (USFWS 2012). Published, peer-reviewed studies that have investigated removal of raptor carcasses compared to domestic species include Smallwood et al. (2010), who used 17 raptor carcasses (including owls) from seven species and provided evidence indicating mortality rate calculations are sensitive to the number and frequency of carcasses used in the trials. Urquhart et al. (2015) monitored the fates of two bird species and found carcasses of pheasants (*Phasianus colchicus*) were more likely to be removed (by unknown scavengers) than were buzzards (*Buteo buteo*). These observations suggest mortality studies at wind energy sites could benefit from additional research comparing carcass persistence across bird species, especially studies including a more robust sample and informed by broader research in scavenging ecology.

There is mounting evidence indicating carcass removal by vertebrates is a complex process modulated by a multitude of biotic and abiotic factors (DeVault et al. 2003, Beasley et al. 2016), yet studies on scavenger removal of carcasses at wind farms rarely incorporate knowledge from the ecology literature regarding factors influencing carcass use by scavengers and decomposers (see Paula et al. 2014). In particular, the rate and proportion of carcasses consumed by vertebrates is inversely related to ambient temperature, due to increased invertebrate and microbial activity under warmer conditions (DeVault et al. 2004, Selva et al. 2005, Beasley et al. 2012). Carcass decomposition and acquisition by vertebrates are also strongly influenced by habitat, at both the microscale (Parmenter and MacMahon 2009) and macroscale (Selva et al. 2005, Huijbers et al. 2013, Turner et al. 2017), as well as the composition of local vertebrate and invertebrate communities (DeVault et al. 2011, Ogada et al. 2012, Olson et al. 2012). Furthermore, the properties of carcasses themselves can have a profound influence on vertebrate scavenging dynamics, although this remains an area of much-needed research (Robertson 1980). For example, both scavenging rates and the composition of vertebrate scavenging communities vary markedly as a function of carcass size (Moleón et al. 2015, Turner et al. 2017) and the cause of death of the carrion source (Selva et al. 2005). There is also recent evidence suggesting predators might be scavenged at a lower rate than other vertebrates (Abernethy et al. 2016, Olson et al. 2016, Moleón et al. 2017). Given the complexity of intrinsic and extrinsic factors influencing scavenging dynamics, careful planning of studies assessing carrion use, including the use of carcass surrogates, is essential to the broader application of research findings.

Our objective was to investigate factors influencing removal of bird carcasses by vertebrate scavengers at simulated wind turbine sites to determine whether the use of surrogate species accurately reflects carcass removal of species that are commonly killed by turbines. Our use of simulated wind turbines was necessary given the scarcity of published data from actual wind farms. We were especially interested in whether raptors (i.e., hawks and falcons) are removed at a different rate than domestic (often prey) species. Based on findings from recent studies (Urquhart et al. 2015, Moleón et al. 2017), we expected domestic species would be removed by scavengers more quickly than raptors.

Methods

We conducted our study at the 2200-ha National Aeronautics and Space Administration's Plum Brook Station (PBS; Erie County, Ohio, USA; 41°22′ N, 82°41′ W). The station has limited public access and is enclosed by a 2.4 m high chain-linked fence with barbed-wire outriggers. Habitat within PBS differs from the surrounding agricultural crops and exurban development, comprising canopy-dogwood (*Cornus* spp.), old field and grasslands, open woodlands, and mixed-hardwood forests interspersed by buildings and paved roads that circle and bisect the station. Scavengers commonly occurring at PBS include turkey vulture (*Cathartes aura*), red-tailed hawk (*Buteo jamaicensis*), bald eagle (*Haliaeetus leucocephalus*), raccoon (*Procyon lotor*), coyote (*Canis latrans*), and Virginia opossum (*Didelphis virginiana*). All experimental procedures were approved by the U.S. Department of Agriculture, National Wildlife Research Center, Institutional Animal Care and Use Committee (QA-2229).

We established 10 permanent, simulated wind turbine sites at PBS, five in forest and five in open field, with each plot ≥1 km from any other plot. We included forested sites because some operating wind turbines are located in or adjacent to forests (e.g., mountaintop turbines), and prior research suggests that removal of small carcasses can vary across habitat types (DeVault et al. 2004). Simulated wind turbine sites (hereafter, turbines) consisted of 40 m radius circular plots (Smallwood 2007); plot centers were marked with metal posts. We used 40 m radius plots because the vast majority of birds killed by collision with turbines are found within that distance from the turbine (Johnson et al. 2000). Forested turbine locations were chosen by finding comparable forested areas (i.e., similar plant communities) that allowed the center of the plot to be ≥50 m from the edge of the forest. Open-field locations were placed in established grasslands on PBS that allowed placement of a 40 m radius circular plot entirely within the grassy area.

Two bird carcasses were placed in random locations ≥30 m apart (as determined by a Geographic Information System) at each simulated turbine during each of 13 rounds of 14 d length each (DeVault et al. 2004, Paula et al. 2014). Nine rounds of trials were conducted from 2 July 2014 through 5 November 2014, and four rounds were conducted from 13 May 2015 through 8 July 2015, for a total of 260 carcasses (n = 20 per round). Carcasses were placed by walking (guided by a handheld Global Positioning System unit) to the predetermined, random carcass location, holding the carcass by the feet at head level, and dropping it to the ground. Because human scent might have been present on our experimental carcasses, the cues available to scavengers for finding carcasses might not accurately reflect those available for carcasses found at actual wind turbines. For that reason, comparing persistence rates of carcasses during our study to other studies investigating carcasses of birds killed by collisions with turbines might be inappropriate. However, because our primary research objective was concerned with relative persistence rates across carcass types and all carcasses were deployed using the same methods, presence of human scent should not influence our results.

Carcasses of five bird species were used (n = 52 of each): American kestrel (*Falco sparverius*), red-tailed hawk, northern bobwhite (*Colinus virginianus*), rock pigeon (*Columba livia*), and brown-feathered domestic chicken (*Gallus gallus*). Four carcasses from each species were used during each round and randomly distributed across turbines. American kestrel and red-tailed hawk carcasses were obtained from a local wildlife rehabilitator (i.e., birds euthanized because they were too injured to be rehabilitated and released). Pigeons were salvaged from control operations at a nearby airport where they were trapped and euthanized to reduce the likelihood of a collision with aircraft. Northern bobwhite and chicken carcasses were obtained frozen from a commercial supplier (RodentPro.com, Inglefield, Indiana, USA). All carcasses were stored in freezers until the evening before use, when they were thawed at room temperature. Each individual bird carcass was weighed (rounded to the nearest integer, in g) before storage; mean carcass masses (g) by species (mean ± SD) were as follows: American kestrel (101 ± 15), northern bobwhite (163 ± 10), rock pigeon (288 ± 42), red-tailed hawk (980 ± 276), and chicken (1623 ± 201).

Passive infrared, motion-detecting, remote cameras with infrared illumination (Reconyx models RC60 and PC900) were attached to metal posts and aimed at each carcass (approximately 2 m away). The cameras allowed us to determine which vertebrate species removed carcasses, and time stamps on each image allowed us to measure elapsed time from carcass placement until first investigation and scavenging by a vertebrate (Smallwood et al. 2010, Paula et al. 2014). The presence of such cameras has little influence on behavior of midsized species like raccoons and Virginia opossums (Gompper et al. 2006); therefore, we assumed that the cameras had no significant effects on our results. At the end of each round, we revisited carcass locations and searched for remains within 5 m of the initial location to determine the fate of carcasses (i.e., completely intact, 50–99% present, 1–49% present, feathers or bones only, completely missing), and all remains found were collected and incinerated at that time. We recorded weather conditions (e.g., mean ambient air temperature) during each round with an automated weather station located at PBS. At the end of each round, we moved cameras within the plot to the random carcass locations established for the next round and deployed new carcasses.

All images generated from scavenging trials were examined to determine the vertebrate species that investigated or scavenged carcasses. Carcasses were categorized as investigated when a vertebrate was photographed visually inspecting or directly smelling a carcass. Likewise, carcasses were deemed scavenged by a vertebrate when we observed the animal actively feeding on or moving the carcass. Thus, it was not necessary that the vertebrate completely consumed or removed the carcass for a scavenging event to be designated. Even so, we note the first species documented scavenging on a carcass was also primarily responsible for carcass removal for 93.3% of trials for which photographic evidence was sufficient for such a determination to be made.

Our inferential analyses were designed to elucidate results most relevant to managers investigating bird mortality at wind turbines. As such, we determined how carcass type and other factors influenced complete disappearance (no trace left) of carcasses after the trials ended (Ponce et al. 2010). We note that carcass disappearance could have resulted from the activities of scavengers or the combined effort of scavengers and decomposers; it was not dependent on whether we recorded a vertebrate feeding on the carcasses based on photographic data. Instead, carcass disappearance was determined based on our visual inspections of carcass locations at the end of each round. For this analysis, we conducted a logistic regression (logistic regression procedure in SPSS version 23.0; IBM Corporation 2014). The binary dependent variable was complete disappearance of the carcass or some remains left at the site of placement; the predictor variables were carcass type (American kestrel, northern bobwhite, rock pigeon, red-tailed hawk, or chicken), round number (i.e., season; 1–13), mean temperature during the round, and habitat type (grassland or forest). Carcass mass was not used as a potential predictor because it was not independent with carcass type. We evaluated all candidate models using Akaike's information criterion adjusted for small sample sizes (AIC_c) and considered models equally parsimonious with $\Delta AIC_c < 2$.

We subsequently used Kaplan–Meier survival analysis to investigate the effects of carcass type on elapsed time from carcass placement until (1) first investigation and (2) the first scavenging event as determined by photographic evidence. We included the analysis on first investigation to help determine whether some carcass types were more detectable to vertebrates than others. Carcasses that were not investigated or scavenged were assigned an elapsed time of 14 d (i.e., the entire round). For survival analysis examining elapsed time until scavenging, we censored trials for which the carcass was found completely missing at the end of the rounds by visual inspection but had no associated scavenging event recorded ($n = 40$), because we could not determine the removal time (i.e., when the scavenging event occurred) based on photographic evidence. Statistical significance for elapsed time until investigation and scavenging across carcass types was determined with a log-rank (Mantel–Cox) test, which calculates a chi-square value for observed and expected events at each time step and evaluates the null hypothesis of no difference across curves.

We investigated whether carcass type (i.e., species) influenced the vertebrate species that first investigated or scavenged carcasses using separate chi-square analyses. For these tests, we only considered carcasses that were investigated ($n = 208$) or scavenged ($n = 120$), respectively, at some point during the 14-d rounds. Statistical significance was set at $P \leq 0.05$. We used SPSS version 23.0 (IBM Corporation 2014) for all statistical analyses.

Results

We found substantial variation in the condition of carcasses across carcass types during visual inspection at the end of 14-d rounds (Table 1). For

Table 1. Carcass condition, as determined by visual inspection, at the end of 14-d rounds during an assessment of carcass persistence at simulated wind turbines in Ohio, USA, 2014–2015.

Carcass condition	American kestrel	Northern bobwhite	Rock pigeon	Red-tailed hawk	Chicken	Total
Completely intact	0	0	0	2	0	2
50–99% biomass present	6	2	2	6	2	18
1–49% biomass present	11	5	10	15	8	49
Feathers or bones only	13	10	21	22	21	87
Completely missing	22	35	19	7	21	104

example, the number of carcasses that were completely missing ranged from 7 (13.5%) for red-tailed hawks to 35 (67.3%) for northern bobwhites. The number of carcasses investigated by vertebrates during the rounds ranged from 38 (73.1%) for northern bobwhites to 47 (90.4%) for chickens (Table 2), and the number of carcasses scavenged by vertebrates ranged from 18 (34.6%) for American kestrels to 34 (65.4%) for chickens (Table 3).

The best-fit logistic regression model investigating factors influencing complete disappearance of carcasses included only a single-predictor variable, carcass type (Table 4). All other candidate models had ΔAIC_c values ≥14.06. The top model indicated northern bobwhites were more likely ($P = 0.007$) and red-tailed hawks less likely ($P = 0.003$) than chickens to be completely missing at the end of rounds (Table 4).

Across carcass types, mean persistence until first investigation was estimated at 4.76 d (SE = 0.32) and did not vary across carcass types (log-rank test, chi-square = 1.51, df = 4, $P = 0.825$; Table 5, Fig. 1). Conversely, overall mean carcass persistence until the first scavenging event was estimated at 8.70 d (SE = 0.37) and varied substantially across carcass types, ranging from 6.88 d (SE = 0.74) for chickens to 10.29 d (SE = 0.71) for red-tailed hawks (log-rank test, chi-square = 14.06, df = 4, $P = 0.007$; Table 5, Fig. 1). Finally, carcass type influenced the vertebrate species that first investigated (chi-square = 74.69, df = 52, $P = 0.021$; Table 2) and scavenged carcasses (chi-square = 47.12, df = 32, $P = 0.041$; Table 3).

Discussion

Our results clearly indicate that carcass type influenced the probability of scavenging and carcass persistence over the 14-d rounds. In particular, the two raptor species we tested (American kestrel and red-tailed hawk) persisted in the environment longer before they were scavenged and

Table 2. First investigators recorded by photographic evidence for carcasses of five bird species during an assessment of carcass persistence at simulated wind turbines in Ohio, USA, 2014–2015.

Investigator	American kestrel	Northern bobwhite	Rock pigeon	Red-tailed hawk	Chicken	Total
Eastern chipmunk *Tamias striatus*	0	0	0	0	1	1
Coyote *Canis latrans*	6	1	4	2	5	18
White-tailed deer *Odocoileus virginianus*	12	11	13	11	11	58
Southern flying squirrel *Glaucomys volans*	0	0	1	0	0	1
Fox squirrel *Sciurus niger*	0	1	1	0	3	5
American kestrel *Falco sparverius*	0	0	0	1	0	1
Deer mouse *Peromyscus* spp.	0	0	1	1	2	4
Virginia opossum *Didelphis virginiana*	3	1	3	1	2	10
Raccoon *Procyon lotor*	13	18	13	17	11	72
Red-tailed hawk *Buteo jamaicensis*	5	2	1	6	1	15
Turkey vulture *Cathartes aura*	0	4	1	0	11	16
Weasel *Mustela* spp.	2	0	2	0	0	4
Wild turkey *Meleagris gallopavo*	1	0	0	0	0	1
Unknown	1	0	0	1	0	2
Total	43	38	40	40	47	208

Table 3. First scavengers recorded by photographic evidence for carcasses of five bird species during an assessment of carcass persistence at simulated wind turbines in Ohio, USA, 2014–2015.

Scavenger	American kestrel	Northern bobwhite	Rock pigeon	Red-tailed hawk	Chicken	Total
Coyote *Canis latrans*	4	3	6	4	7	24
Domestic cat *Felis catus*	0	1	0	0	0	1
Great horned owl *Bubo virginianus*	0	0	0	0	1	1
Raccoon *Procyon lotor*	4	9	6	1	3	23
Red-tailed hawk *Buteo jamaicensis*	4	2	4	4	2	16
Turkey vulture *Cathartes aura*	0	2	1	1	12	16
Virginia opossum *Didelphis virginiana*	4	5	4	9	8	30
Weasel *Mustela* spp.	1	0	1	0	0	2
Unknown	1	1	2	2	1	7
Total	18	23	24	21	34	120

Table 4. Model coefficients (±SE) for parameters in the best-fit binary logistic regression model predicting complete carcass disappearance over a 14-d period at simulated wind turbines.

Parameter†	Estimate	SE	Wald statistic	*P*	Estimated odds ratio	Lower, upper 95% CI for estimated odds ratio
Carcass type (American kestrel)	−0.079	0.398	0.040	0.842	0.924	0.423, 2.017
Carcass type (northern bobwhite)	−1.112	0.409	7.387	0.007	0.329	0.148, 0.733
Carcass type (rock pigeon)	0.163	0.403	0.162	0.687	1.177	0.534, 2.595
Carcass type (red-tailed hawk)	1.471	0.495	8.837	0.003	4.355	1.651, 11.488
Intercept	0.478	0.141	11.564	0.001	1.613	

Notes: The single-predictor model reported here was significant at $P < 0.001$ as evaluated by the model chi-square, had a Nagelkerke R^2 value of 0.165, and was selected from all possible models using the predictor variables carcass type (American kestrel, northern bobwhite, rock pigeon, red-tailed hawk, or chicken), round number, mean temperature during the round, and habitat type (grassland or forest). The Wald statistic equals the ratio of the coefficient to its standard error, squared. All other candidate models had ΔAIC_c values ≥14.06.

† The reference category for carcass type was chicken; thus, the coefficients listed for all carcass types are relative to chickens.

Table 5. Mean persistence time (days), as determined by Kaplan–Meier survival estimates, until the first investigation and scavenging event for carcasses of five bird species during an assessment of carcass persistence at simulated wind turbines in Ohio, USA, 2014–2015.

	Investigation		Scavenging	
Carcass	Estimate	SE	Estimate	SE
American kestrel	4.69	0.70	10.22	0.80
Northern bobwhite	5.47	0.81	7.50	0.96
Rock pigeon	5.00	0.76	8.43	0.86
Red-tailed hawk	4.77	0.77	10.29	0.71
Chicken	3.87	0.54	6.88	0.74
Overall	4.76	0.32	8.70	0.37

were less likely to be completely removed by the end of trials than similarly sized, non-raptor species commonly used as surrogates in wind turbine carcass removal studies. For example, chickens were scavenged more often than red-tailed hawks (65.4% of carcasses scavenged for chickens vs. 40.4% for red-tailed hawks), and three times more chickens were completely removed by end of the 14-d rounds, even though chickens (mean mass = 1623 g) were substantially larger on average than red-tailed hawks (980 g). Furthermore, the best-fit logistic regression model for complete carcass disappearance included only carcass type as a predictor, suggesting the influence of carcass type on longevity overshadowed any effects of round number (i.e., season) and the environmental variables considered.

Our results strengthen inferences from previous studies documenting differences in persistence across carcass types with regard to wind turbine collisions (Smallwood 2007, Urquhart et al. 2015, but see Paula et al. 2014) and other direct causes of anthropic mortality (Ponce et al. 2010, Santos et al. 2011, Teixeira et al. 2013). Ecological studies investigating carcass use by vertebrates also have

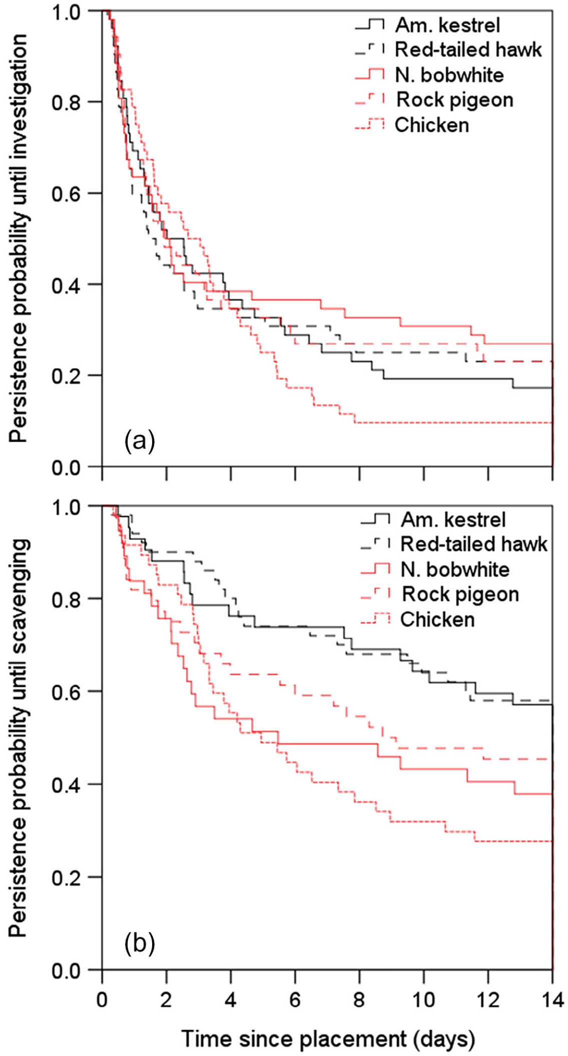

Fig. 1. Persistence of bird carcasses until (a) first investigation and (b) first scavenging event for carcasses of five bird species at simulated wind turbines in Ohio, USA, 2014–2015.

reported variability in scavenging rates across species (Parmenter and MacMahon 2009, Abernethy et al. 2016, Olson et al. 2016, Moleón et al. 2017, Turner et al. 2017). Clearly, all carcasses are not used equally by vertebrates.

We found strong evidence for differential use of various carcass types among vertebrate scavenger species, which could have driven the differences we found in persistence across carcass types (see also DeVault et al. 2011, Paula et al. 2014). In one notable example, turkey vultures scavenged 12 chicken carcasses but only four carcasses from all other species combined. Likewise, when baiting turkey vultures to roads during a previous study (DeVault et al. 2014), we found that turkey vultures strongly preferred raccoon to Canada goose (*Branta canadensis*) carcasses (T. L. DeVault, *unpublished data*). Given the abundance (Inzunza et al. 2010) and scavenging efficiency (Houston 1986, Turner et al. 2017) of turkey vultures across North and South America, a preference by turkey vultures for certain carcasses over others could strongly influence differences in persistence across carcass types.

The apparent preference shown by turkey vultures and other scavengers for certain carcass types could result from differences in palatability (Cott 1945, Weldon and Rappole 1997), carcass appearance (Robertson 1980), or odor (Weldon and Rappole 1997) and ultimately could reflect an evolutionary strategy for reducing disease transmission (Moleón et al. 2017). Furthermore, although we found that carcass type influenced the vertebrate species first investigating carcasses, we found no evidence supporting differences in overall detectability across carcass types, as indicated by the survival analysis. Similarly, Moleón et al. (2017) found the elapsed time needed for scavengers to detect carcasses did not vary between herbivore and carnivore carcasses, although the number of species observed feeding on carcasses and the percentage of carcass biomass consumed were much higher for herbivore than carnivore carcasses.

Although carcass type was clearly the most important predictor of carcass persistence in our study, the fate of carrion in various ecosystems can be strongly influenced by other biotic and abiotic factors (Beasley et al. 2016). In some cases, carcass size (DeVault et al. 2004, Parmenter and MacMahon 2009, Moleón et al. 2015, Turner et al. 2017) and air temperature (DeVault and Rhodes 2002, DeVault et al. 2004, 2011, Selva et al. 2005) contribute to differential carcass use by vertebrate scavengers and decomposers and therefore the persistence of carcasses in the landscape. Future assessments of carcass persistence at wind farms to elucidate collision mortality risk for birds and other wildlife would benefit from integrating knowledge from the broader ecological literature on scavenging ecology to adopt standardized criteria that account for key biotic and abiotic attributes known to influence carrion fate. For example, assessments of carcass persistence at wind farms could incorporate simple measurements of air temperature, carcass size, and when possible, the use of remote cameras to identify scavengers responsible for removing carcasses. These efforts could lead toward a more accurate understanding of carcass persistence across wind turbine sites that vary in habitat, climate, human disturbance, and resident vertebrate communities. Such data also would be particularly valuable if published in peer-reviewed journals or reports, which could allow for development of models that more accurately predict carcass removal and thus generate more accurate mortality estimates for birds and other wildlife at wind turbines.

The complex biological interaction by which scavengers select and remove carcasses is also complicated by a series of regulatory and business concerns. At present, wind energy sites that conduct mortality monitoring either recycle carcasses found during the study (resulting in a limited number of carcasses, many of which might be partially decomposed) or use domestic birds as surrogates. We have demonstrated that, based on common practices used at wind farms, the use of domestic birds is likely to result in an overestimate of scavenging rates and therefore lead to an inflated estimate of mortality in assessments of bird collision risks from wind turbines. Furthermore, given substantial variation reported across mortality studies, one must also be concerned with the quality of those studies that are maintained as confidential business data. We support the requirements contained in a draft habitat conservation plan from the midwestern USA that mortality monitoring be completed at all sites and that the resulting studies, their methods, and results be made public (https://www.fws.gov/Midwest/endangered/permits/hcp/r3wind/DraftHCPandEIS.html).

Humans cause a staggering amount of mortality, both directly and indirectly, to birds worldwide (Loss et al. 2015). Although overall bird mortality resulting from collisions with wind turbines is far surpassed by other anthropic causes (Calvert et al. 2013, DeVault 2015, Loss et al. 2015), these collisions are clearly detrimental for some bird populations and accurate mortality estimates are necessary to guide mitigation (Carrete et al. 2009, Loss et al. 2013, Erickson et al. 2014). Correction factors derived from carcass removal studies, designed to augment mortality estimates, can have a major effect on the accuracy of such estimates for wind turbines and other anthropic causes of mortality (Smallwood et al. 2010, Bernardino et al. 2011, Santos et al. 2011, Bispo et al. 2013, Teixeira et al. 2013). Our study suggests the use of surrogate species, particularly the substitution of domestic species for raptors, can bias carcass removal studies and therefore lead to inaccurate mortality estimates. We recommend mortality studies be completed with carcasses that are as similar to those detected on site as possible. This may require relaxation of regulatory requirements that allow animal control specialists, wildlife rehabilitators, and others with access to large numbers of bird carcasses to donate those for assessments of carcass persistence.

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