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WILD BIRD MORTALITY AND WEST NILE VIRUS SURVEILLANCE: BIASES ASSOCIATED WITH DETECTION, REPORTING, AND CARCASS PERSISTENCE

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ABSTRACT: Surveillance targeting dead wild birds, in particular American crows (*Corvus brachyrhynchos*), plays a critical role in West Nile virus (WNV) surveillance in the United States. Using crow decoy surrogates, detection and reporting of crow carcasses within urban and rural environments of DeKalb County, Georgia were assessed for potential biases that might occur in the county's WNV surveillance program. In each of two replicated trials, during July and September 2003, 400 decoys were labeled with reporting instructions and distributed along randomly chosen routes throughout designated urban and rural areas within DeKalb County. Information-theoretic methods were used to compare alternative models incorporating the effects of area and trial on probabilities of detection and reporting. The model with the best empirical support included the effects of area on both detection and reporting of decoys. The proportion of decoys detected in the urban area (0.605, SE=0.024) was approximately twice that of the rural area (0.293, SE=0.023), and the proportion of decoys reported in the urban area (0.273, SE=0.023) was approximately three times that of the rural area (0.103, SE=0.028). These results suggest that human density and associated factors can substantially influence dead crow detection and reporting and, thus, the perceived distribution of WNV. In a second and separate study, the persistence and fate of American crow and house sparrow (*Passer domesticus*) carcasses were assessed in urban and rural environments in Athens-Clarke, Madison, and Oconee counties, Georgia. Two replicated trials using 96 carcasses of each species were conducted during July and September 2004. For a portion of the carcasses, motion sensitive cameras were used to monitor scavenging species visits. Most carcasses (82%) disappeared or were decayed by the end of the 6-day study. Carcass persistence averaged 1.6 days in rural areas and 2.1 days in urban areas. We analyzed carcass persistence rates using a known-fate model framework in program MARK. Model selection based on Akaike's Information Criteria (AIC) indicated that the best model explaining carcass persistence rates included species and number of days of exposure; however, the model including area and number of days of exposure received approximately equal support. Model-averaged carcass persistence rates were higher for urban areas and for crow carcasses. Six mammalian and one avian species were documented scavenging upon carcasses. Dead wild birds could represent potential sources of oral WNV exposure to these scavenging species. Species composition of the scavenger assemblage was similar in urban and rural areas but "scavenging pressure" was greater in rural areas.

Key words: American crow, carcass, house sparrow, persistence, scavenging, surveillance, West Nile virus.

INTRODUCTION

Avian surveillance targeting dead wild birds can play a critical role in the early detection of West Nile virus (WNV, *Flavivirus*, *Flaviviridae*) in the United States (Eidson et al., 2001b; Guptill et al., 2003; Mostashari et al., 2003). Although WNV has been shown to infect at least 226 bird species in North America (Saito et al., 2004), American crows (*Corvus brachyrhynchos*) have been the focus of much surveillance targeting dead birds, in part because of their increased susceptibility to WNV disease (McLean et al., 2001; Caffrey et al., 2003; Komar et al., 2003; Yaremych et al., 2004). Crows also are large-bodied and ubiquitous in all land use environments, increasing their usefulness as a surveillance target. In many areas of the United States, dead crow reports have preceded human cases and have proven to be a valuable tool in predicting human cases (Eidson et al., 2001a; Eidson et al., 2001b; Watson et al., 2004). However, passive surveillance relies on the public for detecting and reporting dead birds and, thus, can be affected by human-related factors such as public awareness, public interest, media coverage, and human density (Eidson et al., 2001a; Mostashari et al, 2003; Theophilides et al., 2003).

Carcass counts can provide valuable information during wildlife mortality investigations; however, such counts can be influenced by the accuracy and precision of search methods, the time interval between mortality and the search, and the rate at which carcasses decompose or are removed by scavengers (Stutzenbaker et al., 1986; Tobin and Dolbeer, 1990; Linz et al., 1991; Wobeser and Wobeser, 1992). Carcass detection also can be affected by biological factors such as morphological characteristics of the species. Bird carcasses that are larger and more brightly colored often are more easily detected than smaller and less colorful species (Linz et al., 1991; Cliplef and Wobeser, 1993; Philibert et al., 1993). Factors such as density and visibility of carcasses, scavenger assemblages in the area, weather, and habitat characteristics may influence the duration of carcass persistence and cause variability in the rate at which carcasses disappear (Balcomb, 1986; Stutzenbaker et al., 1986; Tobin and Dolbeer, 1990; Linz et al., 1991; Wobeser and Wobeser, 1992). Furthermore, in several studies the majority of carcasses completely disappeared, demonstrating the need to investigate outbreaks as soon as possible (Balcomb, 1986; Tobin and Dolbeer, 1990; Wobeser and Wobeser, 1992). The specific cause of carcass removal is of interest when studying carcass persistence. A myriad of scavenging species, ranging from invertebrates to mammals, represent potential sources of avian carcass disappearance, and these scavengers are likely to differ across environmental settings. With WNV, such scavengers may actually become infected by consuming WNV-infected birds (McLean et al., 2001; Komar et al., 2003).

In DeKalb County, Georgia in 2002, extensive and specific data on dead wild bird surveillance were collected by the DeKalb County Board of Health as part of Georgia's WNV monitoring. The DeKalb County Board of Health recorded more reports of WNV-positive dead birds in urban areas versus rural areas (J. Willis, DeKalb County Board of Health, unpublished data). These results suggested that WNV was more prevalent in urban than in rural areas; however, because of potential biases in detection and reporting associated with human density and/or anthropogenic land use variations, such conclusions could not be confirmed.

The objectives of this project were to assess detection, reporting, persistence, and fate of avian carcasses in relation to WNV surveillance programs. The first objective was to assess detection and reporting of dead crows using decoy surrogates in urban and rural environments in DeKalb County, Georgia, which maintains an active organized dead bird surveillance system. Commercial crow decoy surrogates were used instead of actual crow carcasses because of the potential for public concerns and for monitoring abilities. The second objective was to assess temporal persistence and fate of American crow and house sparrow (*Passer domesticus*) carcasses in urban and rural environments near Athens-Clarke County, Georgia. Carcasses of both crows and sparrows were used to determine if morphological differences play a role in persistence and fate. Motion-sensitive cameras were used to identify scavenging species on a portion of the carcasses.

MATERIALS AND METHODS

Decoy detection and reporting

Detection and reporting of crow decoys (Flambeau Inc., Middlefield, Ohio, USA) within urban and rural environments was evaluated in DeKalb County, Georgia during July and September 2003. DeKalb County is located in the Piedmont physiographic region of Georgia and comprises approximately 694 km^2 (33°47′N, 84°15′W) (Fig. 1). This study area was selected based on the existence of detailed spatial information relating to the reporting of dead birds and an active organized dead bird surveillance system. Using major highways as boundaries, the highly urbanized and more rural portions of DeKalb County were delineated and were separated by a minimum of approximately 5 km by an equivalent-sized "buffer zone" (Fig. 1). DeKalb County is immediately east of metropolitan Atlanta, Georgia, and the urban area included that portion of the county within the Interstate 285 (I-285) perimeter of this major city. Specifically, the urban area in western DeKalb County was bounded on the north and east by I-285 and on the south by Interstate 20. The more rural area was the eastern portion of the county with Stone Mountain and Panola roads as the primary western boundaries. The buffer zone was the area bounded by I-285 on the west and Stone Mountain and Panola roads on the east.

The urban and rural areas were evaluated twice, once in July (trial 1) and again in September (trial 2). July and September were chosen because they are the start and peak of the WNV season in Georgia, respectively. For each trial, 200 decoys were placed in both urban and rural land use areas, totaling 400 decoy placements per trial, and 800 decoy placements after both trials had been completed.

Decoys were placed along 20 specified randomly selected routes in each area (Fig. 1). Using ArcView 3.2 (Environmental Systems Research Institute, Redlands, California, USA), 20 random points in each land use area were generated for each trial. From each random point, the nearest point on the nearest road was chosen as a starting location. Each route was driven, north–south or east–west, depending on road orientation, and 10 decoys were deposited, approximately one every 0.5 km, alternating between left and right sides of the road. Decoys were placed within approximately 2 to 20 m of roads because of logistical considerations when monitoring and collecting decoys when trials ended. At any point that a decoy could not be placed at the 0.5 km distance along the route, it was placed at the nearest available point. Routes usually encompassed multiple roads, depending on local road infrastructure. Routes for trials 1 and 2 were generated independently but there was minor overlap. For each decoy, the date, decoy number, description of placement location, GPS coordinates, and digital photographs were recorded.

Decoys were labeled with an individual identifying number and instructions for reporting, including the telephone number routinely used for dead bird reports by the DeKalb County Board of Health. DeKalb County Board of Health personnel recorded the date and decoy number as decoys were reported. Decoys were monitored at the end of 7 days and were categorized as detected and reported, missing but unreported, or still present but unreported. All decoys remaining at day 7 were removed. Reports received after 7 days were excluded from analysis because actual dead birds likely would not be suitable for diagnostic evaluation after this time.

We assumed that decoys still present had not been found and that decoys missing were found but not reported. Thus, the number of decoys detected was calculated by adding the number reported and the number missing but unreported. We investigated the effects of both area and trial on decoy detection and reporting. First, we constructed a global model in which both detection and reporting rates varied by area (urban or rural) and trial (July or September). The global model consisted of the following parameters:

π_{ij}=probability of detecting a decoy during trial i (i=1, 2) in area j (j=urban or rural).

λ_{ij}=probability of reporting a detected decoy during trial i (i=1, 2) in area j (j=urban or rural).

The expected values under this global model are shown in Table 1. The global and seven alternative models represent combinations of factors hypothesized as explaining variation in decoy detection and reporting rates as follows:

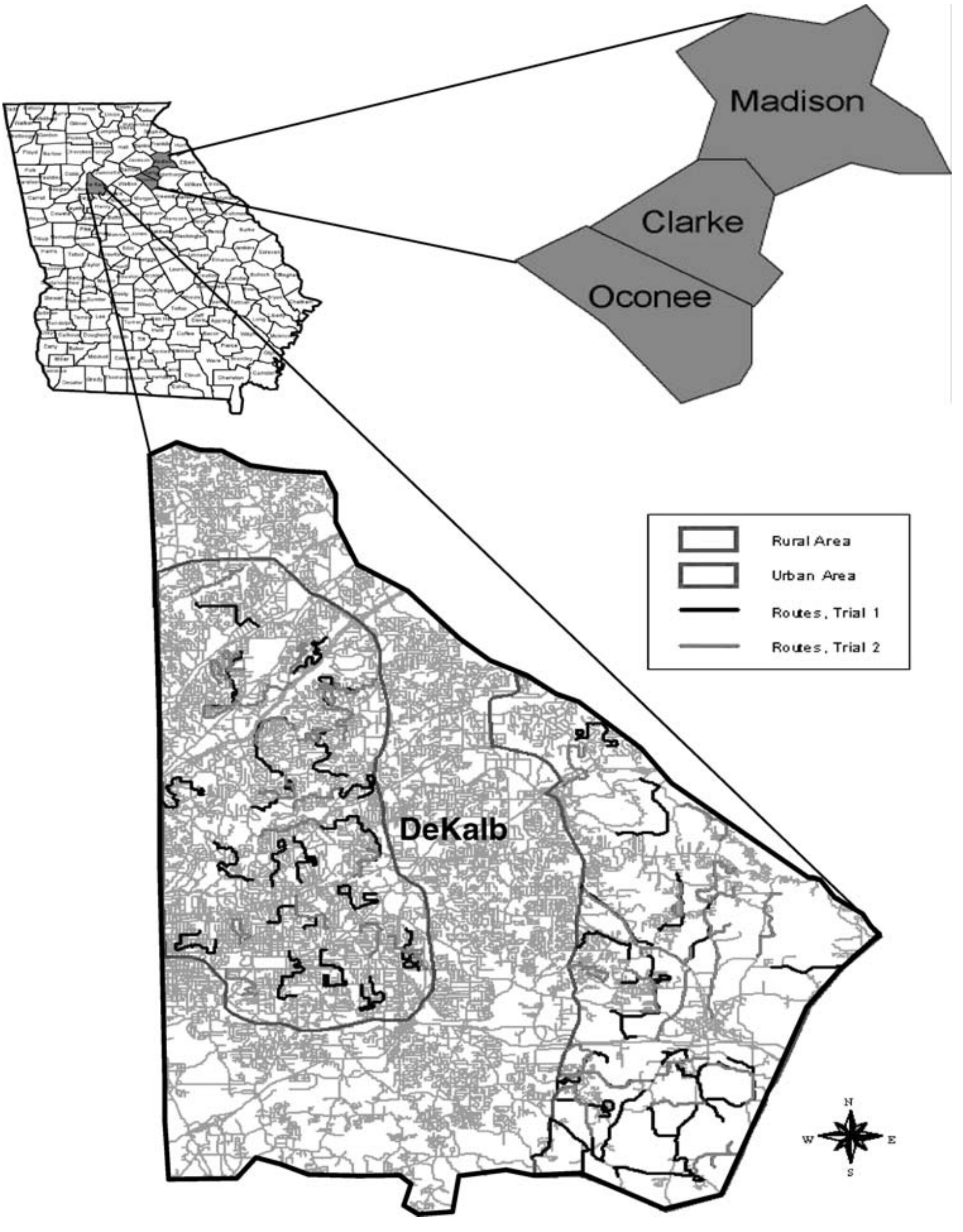


FIGURE 1. Routes for decoy placement during crow decoy study in urban and rural portions of DeKalb County, Georgia (2003) and location of crow and sparrow carcass persistence and fate study in Athens-Clarke, Madison, and Oconee counties, Georgia (2004).

$\pi(a*t)$ $\lambda(a*t)$, decoy detection and reporting vary by area (a) and trial (t).

$\pi(a)$ $\lambda(a)$, decoy detection and reporting vary by area, trial has no effect.

$\pi(a)$ $\lambda(.)$, decoy detection varies by area, decoy reporting is unaffected by area or trial.

$\pi(.)$ $\lambda(a)$, decoy detection is unaffected by area or trial, reporting varies by area.

$\pi(t)$ $\lambda(t)$, decoy detection and reporting vary by trial, area has no effect.

$\pi(t)$ $\lambda(a)$, decoy detection varies by trial, decoy reporting varies by area.

$\pi(a)$ $\lambda(t)$, decoy detection varies by area, decoy reporting varies by trial.

$\pi(.)$ $\lambda(.)$, decoy detection and reporting are unaffected by area or trial.

TABLE 1. Expected number of decoys reported, still present, and missing as predicted under the global model of detection and reporting varying by area (urban, rural) in Dekalb County, Georgia and by trial (July 2003 or September 2003).

	n Decoys	*n* Reported	*n* Present	*n* Missing/Unreported
Trial 1				
Urban	$_{1u}$[a]	$N_{1u}\ \pi_{1u}$[b] λ_{1u}[c]	$N_{1u}\ (1-\pi_{1u})$	$N_{1u}\ \pi_{1u}\ (1-\lambda\ _{1u})$
Rural	N_{1r}	$N_{1r}\ \pi_{1r}\ \lambda_{1r}$	$N_{1r}\ (1-\pi_{1r})$	$N_{1r}\ \pi_{1r}\ (1-\lambda\ _{1r})$
Trial 2				
Urban	N_{2u}	$N_{1u}\ \pi_{1u}\ \lambda_{1u}$	$N_{1u}\ (1-\pi_{1u})$	$N_{1u}\ \pi_{1u}\ (1-\lambda\ _{1u})$
Rural	N_{2r}	$N_{2r}\ \pi_{2r}\ \lambda_{2r}$	$N_{2r}\ (1-\pi_{2r})$	$N_{2r}\ \pi_{2r}\ (1-\lambda\ _{2r})$

[a] N_{ij} = number of decoys placed during trial i (i=1, 2) in area j (j=urban or rural).

[b] π_{ij} = probability of detecting a decoy during trial i (i=1, 2) in area j (j=urban or rural).

[c] λ_{ij} = probability of reporting a detected decoy during trial i (i=1, 2) in area j (j=urban or rural).

Analyses were conducted using the program SURVIV (White, 1983). We used the information-theoretic approach to model selection described in Burnham and Anderson (2002). Akaike's Information Criteria (AIC) values were calculated to evaluate and select the most parsimonious model (Burnham and Anderson, 2002). The AIC value is calculated as follows:

$$AIC_i = -2\log_e(L_i) + 2K$$

where L_i is the likelihood evaluated at the maximum likelihood estimates of the parameters for candidate model i. The AIC values were further adjusted for small sample sizes per Burnham and Anderson (2002) to form $AICc_i$. This statistic was computed for all i=1,…,7 competing models (including the global model), which were ranked by AICc from lowest to highest, with the lowest value representing the best approximating model. Akaike weights (w_i) were calculated as follows to determine the weight of evidence in favor of each model (Burnham and Anderson, 2002):

$$w_i = \frac{\exp(-\Delta \mathrm{AICc_i}/2)}{\sum_{j=1}^{7} \exp(-\Delta \mathrm{AICc_j}/2)}$$

where $\Delta\mathrm{AICc_i}$ is the difference between the AICc value for the candidate model i and the lowest-ranked AICc value; the denominator normalizes this quantity to sum to 1 over all the competing models. The model with the highest weight of evidence (range 0–1) was deemed the most plausible given the data and set of candidate models. The global model for this data structure exactly fit the data (zero degrees of freedom), and therefore no further adjustments (i.e., for overdispersion) were necessary.

Carcass persistence and fate

Persistence and fate of American crow and house sparrow carcasses were evaluated in the vicinity of Athens, Georgia (Athens-Clarke County) in July and September 2004 (33°57′N, 83°22′W). Athens-Clarke County is located in the Piedmont physiographic region of Georgia approximately 50 km east of DeKalb County (Fig. 1). The Athens vicinity, including Athens-Clarke and portions of adjacent Madison and Oconee counties, were divided into urban and rural areas. Urban and rural designations were based on the Georgia Land Use Trends Project, which used US satellite LANDSAT data to create land cover maps for each county in Georgia based on 11 land cover categories (Natural Resources Spatial Analysis Laboratory, Institute of Ecology, University of Georgia, unpublished data).

American crow carcasses were donated by a crow hunting guide located in Milledgeville, Georgia and were frozen within 24 hr after death. House sparrows were collected by Southeastern Cooperative Wildlife Disease Study (SCWDS) personnel, euthanized, and frozen within 24 hr after death. Because actual dead birds were used for this portion of the study, sites used for carcass placement were dependent on landowner permission and were not chosen randomly. Carcass placement sites included locations such as neighborhood residential lots, parks, farms, and forests. Each crow carcass was always paired with a house sparrow carcass. Smaller sites, such as neighborhood residential lots, were used for the placement of one pair of carcasses. Sites greater than 16.2 ha in size were allotted two pairs of carcasses; however, one 323.8-ha site was allotted three pairs of carcasses. The minimum of 16.2 ha for two carcass pairs was chosen arbitrarily but with the intention of ensuring spatial independence of the pairs. The crow and sparrow carcasses of each pair were also spatially separated as far as possible (at least 40 m apart). Often carcass placement on a particular site was dependent on landowner restrictions. When a second pair of carcasses was placed on a site, they were placed in a different area within that site, as far apart as size or landowner preference would allow (at least 100 m apart).

Carcass persistence and fate were evaluated twice, once in July (trial 1) and once in September (trial 2). For each trial, 48 carcasses of each species were placed in both urban and rural land use areas, totaling 96 carcass placements per trial, and 192 carcass placements after both trials had been completed. Carcass placement sites were used twice, once in July and once in September. Each trial consisted of three independent carcass placement sessions in which 16 crow and 16 sparrow carcasses were used and evaluated for a period of 6 days. Subdivision into the three sessions was done so that random events, such as extreme weather conditions, would not bias data collection and so that a larger number of photographic records of carcass fate could be obtained (see below).

For each carcass, the date, carcass number, site name and number, site category, and a general description of the carcass placement location were recorded. Carcasses were monitored daily for 6 days and the date and carcass status (present, absent, signs of insect activity) was recorded. Once a carcass was determined to be missing, monitoring ceased. Carcasses were considered missing if they were no longer present or if they were damaged by insects to the point that they would no longer be suitable for diagnostic evaluation. At the end of 6 days, carcasses were either removed or left in the environment, dependent on landowner requests.

Data analyses were conducted using the known fate model framework in program MARK (White and Burnham, 1999). The focus of known fate models is the estimation of survival probabilities, and it is assumed that the sampling probabilities are 1, that is, the status of all tagged animals is known at each sampling occasion. In our study, the tagged animals were carcasses, and each carcass was evaluated for persistence rates (survival) based on the classification as either present (alive) or missing (dead). We sought to investigate the effects of morphological differences between species, landscape differences, month (trial), and length of exposure on carcass persistence rates. We constructed a global model relating carcass persistence rates to species (crow and sparrow), area (urban and rural), day of exposure (0–6), and trial (July and September). The global model consisted of the following parameter:

S_i=the probability of surviving an interval between sampling occasions i and i+1 (i.e., persistence rates).

The global and seven alternative candidate models representing meaningful combinations of the variables explaining carcass persistence rates were as follows:

$S(s*a*t*e)$, persistence rates vary by species (s), area (a), trial (July or September) (t), and days of exposure (0–6) (e).

$S(s*a*t)$, persistence rates vary by species, area, and trial only.

$S(s*e)$, persistence rates vary by species and days of exposure.

$S(a*e)$, persistence rates vary by area and days of exposure.

$S(e)$, persistence rates vary by days of exposure only.

$S(s)$, persistence rates vary by species only.

$S(t)$, persistence rates vary by trial only.

$S(a)$, persistence rates vary by area only

$S(.)$, persistence rates are unaffected by species, area, trial, or days of exposure.

Persistence rates were calculated as proportions of dead birds remaining each day. Program MARK uses AICc model selection to rank each potential model (Burnham and Anderson, 2002). Akaike weights (w_i) were calculated to determine the weight of evidence in favor of each model (Burnham and Anderson, 2002). We used w_i values to weight the parameter estimates and sampling variances from each model and to compute model-averaged estimates and unconditional variances, accounting for model selection uncertainty, for parameters of interest (Burnham and Anderson, 2002). As with our previous analyses, the global model S($s*a*t*e$) fit the data exactly and there was no need for further adjustment of AIC scores (Burnham and Anderson 2002).

Sixteen motion-sensitive trail cameras, model DeerCam (NonTypical, Inc., Park Falls, Wisconsin, USA), were used to monitor a subsample of the carcasses to obtain photographic evidence of scavengers. Cameras were

TABLE 2. Detection and reporting of crow decoys within 7 days in urban and rural areas of DeKalb County, Georgia, in 2003.

	Decoys placed	Reported	Still present	Missing/unreported
Trial 1				
Urban	200	34 (17%)	74 (37%)	92 (46%)
Rural	200	5 (2%)	146 (73%)	49 (25%)
Trial 2				
Urban	200	32 (16%)	84 (42%)	84 (42%)
Rural	200	7 (3%)	137 (69%)	56 (28%)
Totals				
Urban	400	66 (17%)	158 (39%)	176 (44%)
Rural	400	12 (3%)	283 (71%)	105 (26%)

mounted vertically on a tree, approximately 0.3 m from the ground, set on automatic flash, and programmed to record date and time on each photograph and reset every 15 seconds. Carcasses were placed approximately 2 m away from the camera. Approximately half of the carcasses were monitored by camera each week. More crow carcasses than sparrow carcasses were monitored, approximately 12 crows and 4 sparrows per week, because most WNV monitoring using wild birds is focused on crows. Cameras were collected either at the point the carcass was determined to be missing or at the end of the 6-day monitoring period.

Photographs were reviewed and all visits by both scavenging and nonscavenging species to each carcass were recorded in chronological order. Nonscavenging species were excluded from analysis. The last known scavenging species visiting a carcass before it was missing was noted. The fate of the carcass was determined to be "known" if photographs depicted either of two scenarios: 1) a scavenger removing or scavenging upon the carcass or 2) a scavenger as the last known species visiting the carcass before it was missing. "Scavenging pressure" for urban and rural environments was estimated based on the combined number of visits of scavenging species per camera night.

RESULTS

Decoy detection and reporting

The proportion of decoys categorized as reported, still present and unreported, or missing but unreported are presented in Table 2. The statistical models indicated no difference between trials, so the results of both trials were combined (Table 3). The model containing only the area variable best approximated (w_i =0.95) decoy detection and reporting and indicated that both detection and reporting were lower in the rural area than in the urban area. This model was 19 times more likely than the next approximating model, and 100 times more likely than the remaining six models, which received no empirical support ($\Delta AICc_i > 7$, $w_i \leq 0.01$). The estimates from the best approximating model indicated that the proportion of decoys detected in the urban area (0.605, SE=0.024, 95% CI: 0.557 to 0.653) was approximately twice that of the rural area (0.293 SE=0.023, 95% CI: 0.248 to 0.337). The estimates from the best approximating model indicated that the proportion of decoys reported in the urban area (0.273, SE=0.029, 95% CI: 0.217 to 0.329) was approximately three times that of the rural area (0.103, SE=0.028, 95% CI: 0.048 to 0.158).

Twelve decoys that were reported after 7 days were excluded from analysis. Most (11 of 12) of these reports were from the urban area. A total of 16 decoys categorized as missing but unreported were found moved from their original location. Examples of these "moved" decoys included placement on shrubs near houses, on a stick in a garden, and on a stick in a back yard. In all cases, movements were attributable to human involvement; however, none of these "moved" decoys were

TABLE 3. Model selection results for models explaining influences of area and trial on decoy detection and reporting in DeKalb County, Georgia, in 2003.

Model[a]	K[b]	$AICc_i$	$\Delta AICc_i$	w_i[c]
$\pi(a)\ \lambda(a)$	4	49.8	0.0	0.95
$\pi(a{*}t)\ \lambda(a{*}t)$	8	55.8	6.0	0.05
$\pi(a)\ \lambda(.)$	3	62.7	12.9	0.00
$\pi(a)\ \lambda(t)$	4	64.7	14.9	0.00
$\pi(.)\ \lambda(a)$	2	128.2	78.4	0.00
$\pi(t)\ \lambda(a)$	4	130.2	80.4	0.00
$\pi(.)\ \lambda(.)$	2	141.0	91.2	0.00
$\pi(t)\ \lambda(t)$	4	145.0	95.2	0.00

[a] Models correspond to the following: π = probability of detecting a decoy, λ = probability of reporting a decoy, a = area, t = trial.

[b] Number of estimating parameters in approximating model.

[c] Akaike weight.

reported. Overall, 14 decoys in the urban area and 2 decoys in the rural area were considered "moved".

Carcass persistence and fate

Overall, by the end of both trials, 71 of 96 (74%) of all crow carcasses disappeared and 87 of 96 (91%) of all sparrow carcasses disappeared (Tables 4 and 5). Crow carcass losses were 52% and 29% after day 1 and 65% and 48% after day 2, in rural and urban areas, respectively. Sparrow carcass losses were 54% and 23% after day 1 and 75% and 67% after day 2, in rural and urban areas, respectively.

The statistical models indicated no difference between trials (Table 6), so the results of both trials were combined (Fig. 2). The best approximating model (w_i =0.54) indicated that species and days of exposure were important factors explaining carcass persistence rates. Weight of evidence in favor of this model was only 1.2 greater than that of the next approximating model, indicating some uncertainty in selection of the best candidate model. The second best model (w_i=0.44) indicated that area and days of exposure were important factors explaining carcass persistence rates. The third best model received only marginal support and the remaining six models received no empirical support ($\Delta AICc_i$>7, w_i≤0.01).

Carcass losses were greatest over the first day of exposure and thereafter carcass persistence increased over time (Fig. 2). In the first day of exposure, persistence rates were lower in rural areas than urban areas. Over the second through fourth days of exposure, sparrow carcasses persisted at lower rates than crow carcasses and persistence did not appear to be greatly affected by area. Few changes in persistence were noted over the final 2 days of exposure.

There were a total of 96 and 101 camera nights compiled monitoring crow carcasses for rural and urban areas, respectively, and these captured photographic evidence of seven vertebrate scavenging species (Table 7). Virginia opossums (*Didelphis virginiana*) accounted for most of the visits

TABLE 4. Number of crow carcasses remaining at daily checks in Athens-Clarke, Madison, and Oconee counties, Georgia, in 2004.

			Day					
Trial	Area	No. Monitored	1	2	3	4	5	6
1	Rural	24	14 (58%)	10 (42%)	8 (33%)	7 (29%)	7 (29%)	7 (29%)
	Urban	24	20 (83%)	14 (58%)	10 (42%)	10 (42%)	10 (42%)	8 (33%)
2	Rural	24	9 (38%)	7 (29%)	5 (21%)	4 (17%)	4 (17%)	4 (17%)
	Urban	24	14 (58%)	11 (46%)	7 (29%)	6 (25%)	6 (25%)	6 (25%)
Total								
	Rural	48	23 (48%)	17 (35%)	13 (27%)	11 (23%)	11 (23%)	11 (23%)
	Urban	48	34 (71%)	25 (52%)	17 (35%)	16 (33%)	16 (33%)	14 (29%)

TABLE 5. Number of sparrow carcasses remaining at daily checks in Athens-Clarke, Madison, and Oconee counties, Georgia, in 2004.

Trial	Area	No. monitored	Day 1	2	3	4	5	6
1	Rural	24	9 (38%)	6 (25%)	6 (25%)	4 (17%)	4 (17%)	4 (17%)
	Urban	24	20 (83%)	11 (46%)	8 (33%)	4 (17%)	4 (17%)	4 (17%)
2	Rural	24	13 (54%)	6 (25%)	2 (8%)	0 (0%)	0 (0%)	0 (0%)
	Urban	24	17 (71%)	5 (21%)	1 (4%)	1 (4%)	1 (4%)	1 (4%)
Total								
	Rural	48	22 (46%)	12 (25%)	8 (17%)	4 (8%)	4 (8%)	4 (8%)
	Urban	48	37 (77%)	16 (33%)	9 (19%)	5 (10%)	5 (10%)	5 (10%)

in both rural (42%) and urban (52%) areas, followed by domestic cats (*Felis catus*) and raccoons (*Procyon lotor*) for both areas. Of the opossum visits, 50% of the rural visits and 43% of the urban visits resulted in the removal of the carcass, accounting for 64% of all documented crow carcass removals. Raccoons accounted for 23% of all documented crow carcass removals. Although insect damage (predominantly ants) was observed, none of the crow carcasses were completely destroyed by insects. Overall, "scavenging pressure" for crow carcasses was 40% (38 scavenger visits/96 camera nights) in the rural area and 27% (27 scavenger visits/101 camera nights) in the urban area. Multiple scavengers were recorded visiting an individual crow carcass 11 times in the rural area and 6 times in the urban area.

TABLE 6. Comparison of models explaining influences of species, area, trial, and days of exposure on carcass persistence rates in Athens-Clarke, Madison, and Oconee counties, Georgia, in 2004.

Model[a]	K[b]	AICc	$\Delta AICc_i$	w_i[c]
$S(s*e)$	12	574.72	0.00	0.54
$S(a*e)$	12	575.11	0.39	0.44
$S(e)$	6	581.32	6.60	0.02
$S(s*a*t*e)$	46	598.98	24.26	0.00
$S(s*a*t)$	8	614.45	39.73	0.00
$S(s)$	2	616.82	42.10	0.00
$S(t)$	2	618.11	43.40	0.00
$S(a)$	2	623.18	48.46	0.00
$S(.)$	1	625.83	51.11	0.00

[a] Models correspond to : S = carcass persistence rates, s = species, e = days of exposure, a = area, t = trial.

[b] Number of estimated parameters in approximating model.

[c] Akaike weight.

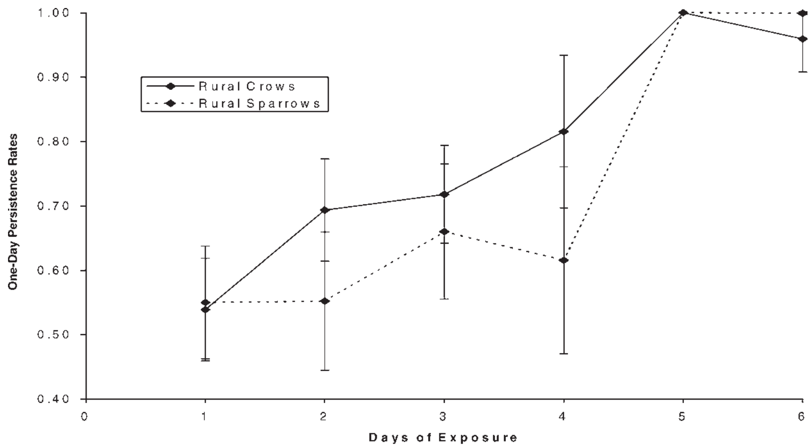
There were a total of 23 and 22 camera nights compiled monitoring sparrow carcasses for rural and urban areas, respectively, which captured photographic evidence of two vertebrate scavenging species (Table 7). Insect activity (ants) destroyed 27% of the sparrow carcasses, including 21% and 33% in rural and urban areas, respectively. Overall, "scavenging pressure" for sparrow carcasses was 17% (4 scavenger visits/23 camera nights) in the rural area and 14% (3 scavenger visits/22 camera nights) in the urban area. Multiple scavengers were recorded visiting an individual sparrow carcass once each in the rural and urban areas.

Twenty-six of the 72 (36%) visits resulted in the removal of a carcass. Incidental visits recorded to carcasses included one American robin (*Turdus migratorius*), one ovenbird (*Seiurus aurocapillus*), one armadillo (*Dasypus novemcinctus*), two eastern chipmunks (*Tamias striatus*), two eastern cottontail rabbits (*Sylvilagus floridanus*), 11 eastern gray squirrels (*Sciurus carolinensis*), 33 white-tailed deer (*Odocoileus virginianus*), and two unknown species where photographs were too blurred for identification.

DISCUSSION

Decoy detection and reporting

Surveillance of dead wild birds has proven to be a valuable tool for monitoring



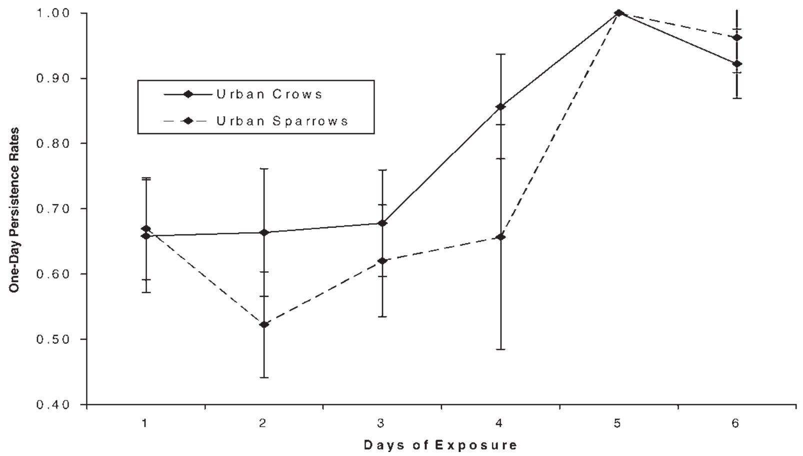


FIGURE 2. Model-averaged parameter estimates for crow and sparrow carcass 1-day persistence rates in urban and rural areas in the vicinity of Athens-Clarke County, Georgia, 2004. Persistence rates are based on the proportion of carcasses remaining from the preceding day. Error bars represent one standard error.

WNV activity and subsequently for assessing the potential for human risk, as well as for guiding public education and mosquito control programs (Eidson et al., 2001a, b; Guptill et al., 2003; Watson et al., 2004). However, our study demonstrates that passive surveillance markedly underestimates the extent of total mortality of dead birds and, thus, the extent and intensity of WNV activity. In this study, 43% of known "dead crows" were detected but only 10% were reported to the local public health agency. These results are generally in accord with findings of prior studies evaluating active searches for bird carcasses. Searchers in a Texas marsh located 6% of duck carcasses and 32% of dummy waterfowl carcasses in a Saskatchewan, Canada, wetland (Stutzenbaker et al., 1986; Cliplef and Wobeser, 1993). However, Linz et al. (1991) reported a finding rate of 81% for red-winged blackbird (*Agelaius phoeniceus*) carcasses in cattail (*Typha* spp.) marshes, and Tobin and Dolbeer (1990) reported that 75% of songbird carcasses placed beneath orchard trees were found. Although 43% of our decoys were found, only a small percentage was reported. Thus, the success of a dead bird surveillance system depends not only on people detecting dead birds, but also on their knowledge

TABLE 7. Documented vertebrate scavenger visits to crow and sparrow carcasses in Athens-Clarke, Madison, and Oconee counties, Georgia, in 2004.[a]

	Rural visits[b]	Removed[c]	Urban visits[b]	Removed[c]
Crow				
Coyote (*Canis latrans*)	1 (3%)	0	0	0
Domestic cat (*Felis catus*)	10 (26%)	1	9 (33%)	1
Domestic dog (*Canis familiaris*)	3 (8%)	0	1 (4%)	0
Gray fox (*Urocyon cinereoargenteus*)	0	0	1 (4%)	1
Raccoon (*Procyon lotor*)	7 (18%)	2	4 (15%)	3
Red-tailed hawk (*Buteo jamaicensis*)	1 (3%)	0	0	0
Virginia opossum (*Didelphis virginiana*)	16 (42%)	8	14 (52%)	6
Total	38	11	27	11
Sparrow				
Domestic cat (*F. catus*)	3 (75%)	1	3 (33%)	2
Virginia opossum (*D. virginiana*)	1 (25%)	1	0	0
Tota	4	2	3	2

[a] Data based on 96 and 101 crow carcass camera nights and 23 and 22 sparrow carcass camera nights for rural and urban areas, respectively.

[b] Numbers in column represent number of visits (percent of total visits).

[c] Removed columns represent number of carcasses removed by corresponding scavenger.

and interest in reporting them (Eidson et al., 2001b; Mostashari et al., 2003).

Based on prior dead bird surveillance in DeKalb County, the perceived distribution of WNV was that more virus activity occurred in urban areas than in rural areas. In our study, the model receiving the most support indicated that decoys were more likely to be both detected and reported in urban areas. The model indicated that urban detection was approximately twice and reporting was approximately three times that of the rural area when both areas had the same number of distributed "dead crows". Therefore, the same level of WNV activity is far more likely to be detected in urban areas than in rural areas. This strongly suggests that human density and associated factors should be considered when interpreting dead wild bird surveillance for WNV.

In this study, the decoys categorized as still present but unreported were the best measure of dead birds that were undiscovered. In the rural area, the majority of unreported decoys were in this category, which is consistent with the assumption that rural areas are less frequented by humans and, thus, dead birds are less likely to be found (Eidson et al., 2001b, Guptill et al., 2003; Mostashari et al., 2003). The proportion of decoys detected but not reported was the best measure of nonreporting bias. A higher nonreporting bias occurred in the rural landscape, where 10% (12 of 117) of detected decoys were reported compared to 27% (66 of 242) for the urban area. Thus, rural residents were less likely to report a detected decoy than were urban residents; however, the reasons for this differing behavioral response are unknown.

There are several considerations with the interpretation and application of findings from the present study. First, crow decoys were used instead of actual crow carcasses. Decoys may be more or less likely to be picked up and investigated than an actual carcass and this may have influenced study results. The movement of some decoys suggests human involvement and indicates that decoys were not treated as real dead birds. The fact that none of these decoys were reported may demonstrate a lack of concern or knowledge regarding WNV surveillance. Second, varied socioeconomic characteristics within the study area also may have influenced results by creating a reporting bias. A paired comparison of decoys with actual dead crows during this study could have provided information related to differing responses to simulated versus real crows; however, the use of actual dead crow carcasses was not feasible in DeKalb county. Finally, our data are restricted to detection of decoys <20 m from a road, and it is possible that decoys at >20 m would be detected at rates different than those estimated. This effect, if present, could cause our estimates of absolute detection to be biased, but likely would not affect our inferences about relative detection differing by location, nor would it affect reporting estimates (by definition conditional on detection).

The impacts of WNV on crow populations are not completely understood. Field studies have demonstrated that WNV can severely affect local crow populations, reducing them by as much as 40 to 68% (Caffrey et al., 2003; Yaremych et al., 2004). In an analysis of Christmas Bird Count data from 1989 through 2002 that focused on 10 resident species in areas of documented WNV activity, American crows and great horned owls (*Bubo virginianus*) showed weak region-wide declines whereas most other species showed only local declines (Caffrey and Peterson, 2003). Caffrey and Peterson (2003) were unable to demonstrate population level conservation concerns for any of the species examined. Because the number of decoys was known, the present study provided a unique opportunity to calculate how many unreported crow decoys each reported decoy represented. Within the urban area, each decoy report represented four unreported decoys whereas in the rural area, each decoy report represented 30 unreported decoys. Using these ratios as guidelines, it would be possible to calculate crude estimates for the total number of dead crows based on the number of dead crows that are reported. However, estimation of mortality and determining the actual long-term impacts of WNV on crow populations or other avian communities will require additional study.

Carcass persistence and fate

In our study, most carcasses (82%) disappeared or were decayed within 6 days. Balcomb (1986) reported that 92% of songbird carcasses were removed by scavengers within 5 days and, of these, 58% were without observable remains. Tobin and Dolbeer (1990) found that 75% of songbird carcasses were completely removed within 12 days, and an additional 12% had only feathers remaining. Of 275 chick carcasses, only two carcasses that had been in place for over 24 hr were found (Wobeser and Wobeser, 1992). Intact carcasses are important for diagnostic evaluation and, thus, mortality estimates may be limited by the fact that few persist past a few days (Wobeser and Wobeser, 1992). Furthermore, this emphasizes the need to investigate outbreaks quickly if a large proportion of birds are to be detected (Balcomb, 1986; Tobin and Dolbeer, 1990; Wobeser and Wobeser, 1992).

Rural carcasses persisted approximately 1.6 days and urban carcasses persisted an average of 2.1 days. Sixty-four percent of all carcasses were removed by day 2. These findings support the conclusion of Stutzenbaker et al. (1986) that carcasses are quickly incorporated into the environment. In their study of 47 duck carcasses in a Texas wetland, 62% of the carcasses were gone in 3 days. Similarly, Balcomb (1986) found rapid initial disappearance of songbird carcasses in agricultural fields in Maryland. At 1 day after placement, 75% of all carcasses were gone. In contrast, Tobin and Dolbeer (1990) examined songbird carcass survival in cherry and apple orchards and found mean survival times for carcasses were 8.2 days and 10.4 days, respectively. However, none of the 25 carcasses placed in one of the study orchards were found the next day, implying variable rates of persistence even within a single study. The rate of carcass removal can be highly variable and site specific; therefore, it should be measured in an area before mortality estimates are made (Wobeser and Wobeser, 1992).

Two of our models received approximately equal support and indicated that carcass persistence rates were affected by species and number of days of exposure or by area and number of days of exposure, respectively. To incorporate model selection uncertainty and the uncertainty associated with parameter estimates within each model, we used model-averaged parameter estimates to examine carcass persistence rates. The estimates indicated that initial carcass losses were greatest over the first day of exposure and that persistence of the remaining carcasses increased over time. Similar results were reported by Balcomb (1986), who found that songbird carcass losses were markedly greater during the first 24-hr period and that the rate of carcass disappearance was not uniform over a 5-day study period. Balcomb (1986) suggested that high initial losses might be best explained by scavenger foraging behaviors. If scavengers maintain regular hunting territories or search routes, then carcasses would be likely to be detected and removed within those areas; however, carcasses located outside of these territories probably would disappear at slower rates (Balcomb, 1986). Our estimates also indicated that, initially, rural areas had higher disappearance rates than did urban areas. This pattern might occur in areas with higher scavenger density and, in our study, "scavenging pressure" was higher in rural areas. After the initial 24-hr period, sparrow carcass persistence rates were lower than persistence rates of crow carcasses. Small carcasses, such as sparrows, may have a wider range of potential scavengers than do larger species. Furthermore, because of their smaller mass, sparrow carcasses may be more rapidly destroyed by invertebrates.

There was little variation in the composition of scavenging species or their visits between urban and rural areas for crow carcasses. Because opossums and raccoons are common species and are well adapted to human environments, it was not surprising that they accounted for most of the crow carcass removals. Domestic cats and insects were the major causes of sparrow carcass removals; neither were major causes of crow carcass removals. The use of cameras may have affected study results, and in particular may explain the high percentage of scavenger visits (64%) that did not result in the removal of a carcass and the multiple scavenger visits to individual carcasses. Camera flash and/or noise at the time of the photograph may have startled scavengers. Wary species presumably would be less likely to remain with or return to carcasses after being startled. For example, the coyote (*Canis latrans*) and red-tailed hawk (*Buteo jamaicensis*) visits did not result in carcass removal. However, less-cautious species such as opossums, raccoons, and domestic cats may not be deterred by unusual events.

The entire host range of WNV, as well as all means of transmission of the virus in the wild, remains to be completely understood. Under laboratory conditions, crows were experimentally infected with WNV by oral and contact transmission routes (McLean et al., 2001; Komar et al., 2003). Infected crows were shown to have high viral loads in numerous organs, which may increase the likelihood for oral transmission of WNV to scavengers (Komar et al., 2003). In our study, we documented six mammalian and one avian species scavenging carcasses over a 6-day observation period. Freshly dead wild birds could represent potential sources of oral WNV exposure to scavenging species, and this route of exposure could possibly increase the prevalence of infection among scavengers in the wild.

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