ABSTRACT

Surveillance of dead wild birds is useful for early detection of West Nile virus (WNV) activity. Objectives of this project were to assess detection, reporting, persistence, and fate of dead birds in relation to WNV surveillance programs in Georgia. The project assessed detection and reporting of dead crows (decoy surrogates) within urban and rural environments of DeKalb County, a location with an intensive dead bird surveillance system. Both detection and reporting were higher in the urban area. The project also assessed persistence and fate of American crow (Corvus brachyrhynchos) and house sparrow (Passer domesticus) carcasses within similar urban and rural environments. Carcass species, environmental category, and exposure duration affected carcass persistence. Species composition of scavengers was similar in urban and rural areas but “scavenging pressure” was greater in rural areas. This information was related to interpretation of wild bird WNV surveillance data and the potential for WNV exposure among scavengers.

INDEX WORDS: American crow, Carcass, Corvus brachyrhynchos, Detection, Fate, House sparrow, Passer domesticus, Reporting, Scavenging, Persistence, West Nile virus
WILD BIRD MORTALITY AND WEST NILE VIRUS SURVEILLANCE: BIASES
ASSOCIATED WITH DETECTION, REPORTING, AND CARCASS PERSISTENCE

by

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INTRODUCTION

West Nile virus (WNV), a member of the family Flaviviridae, is a human, equine, and avian pathogen (Fields et al. 2001). The virus is indigenous to Africa, Asia, Europe, and Australia (Campbell et al. 2002). It was first described in Uganda in 1937 (Smithburn et al. 1940) and was first recognized in North America in 1999 (CDC 2004a). Since 1999, WNV has been documented across all of North America, resulting in the deaths of over 600 people and tens of thousands of birds, horses, and other animals (Eidson et al. 2001a, CDC 2004a).

West Nile virus is maintained in nature in a mosquito-bird-mosquito transmission cycle (Work et al. 1955, Taylor et al. 1956). Mosquitoes in the genus *Culex* are thought to be the main WNV vectors (Bernard et al. 2001, Campbell et al. 2002). Birds have long been recognized as amplifying hosts of WNV and are a critical component in the epidemiology of the virus (Work et al. 1955). Other vertebrate hosts, such as humans and horses, are considered dead-end hosts for WNV because they do not typically develop sufficient viremia to infect mosquitoes and maintain the WNV transmission cycle (Peiris and Amerasinghe 1994, Bunning et al. 2002). Since WNV depends on mosquitoes for transmission among its hosts, temperate epidemics often occur during seasons of high temperature (i.e. summer and fall) when mosquito vector density is highest (Marra et al. 2004).

West Nile virus and crows

Since 1999, published records have documented the occurrence of WNV in 226 avian species in North America (Saito et al. 2004); however, according to the Centers for Disease
Control, WNV infects at least 280 species of birds, of which at least 190 are native North American species (CDC 2004a). In indigenous countries, WNV infections in birds are generally asymptomatic with high-level viremias (Peiris and Amerasinghe 1994). In contrast, the strain of WNV introduced into the United States is highly pathogenic to certain birds, most notably species in the family Corvidae, which includes crows, jays, and magpies. Under laboratory conditions, almost 100% of American crows (*Corvus brachyrhynchos*) experimentally infected with WNV have died (McLean et al. 2001, Komar et al. 2003). High rates of mortality associated with WNV also have been described in black-billed magpies (*Pica hudsonia*), blue jays (*Cyanocitta cristata*), and fish crows (*Corvus ossifragus*) (Komar et al. 2003). Crows also have been shown to be susceptible in field studies. In Illinois in 2002, 19 of 28 crows (68%) tracked with radio-transmitters died of WNV (Yaremych et al. 2004). Crows also experienced high death rates (estimated 40%) in Oklahoma within two months after the arrival of WNV (Caffrey et al. 2003).

As crows are large-bodied, ubiquitous in all land use environments, and highly susceptibility to disease, they are important indicators of WNV activity. In the United States in 2001, dead crows were the first indicators of WNV in 66% of the 359 counties reporting WNV activity (CDC 2002b). Monitoring dead crows is advocated as a key component of WNV surveillance systems (Eidson et al. 2001a, Eidson et al. 2001b, Watson et al. 2004).

West Nile virus surveillance using avian sentinels

As human and equine cases of WNV encephalitis generally are preceded by the observance of bird morbidity and mortality, dead wild bird surveillance can play a critical role in the early detection and, therefore, potential prevention of WNV transmission to humans (Guptill
et al. 2003, Mostashari et al. 2003). Of the 359 counties in the United States reporting WNV activity in 2001, 92% of the first cases were preceded by at least one report of a WNV-infected bird (CDC 2002b). Because bird mortality was shown to be a sensitive method for WNV surveillance in 2001, much WNV surveillance effort has focused on dead wild bird surveillance. However, limitations exist to the extent of the usefulness of dead bird surveillance data. For example, the number of dead birds reported in an area is a function of human density (Theophilides et al. 2003). Dead bird reports also can be influenced by other associated human factors, such as public awareness of the surveillance system, public interest, and current media coverage (Eidson et al. 2001b). Also, due to the focus on human health and restricted budgets, many public health departments quit monitoring dead birds after only a few local birds test positive.

Carcass detection during wild bird mortality events

Although a count of carcasses often is the only information available to estimate disease impacts in wild animals, 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 (Wobeser and Wobeser 1992). Search methods for carcasses have reported variable results. Linz et al. (1991) found that 81% of red-winged blackbird (Agelaius phoeniceus) carcasses placed in cattail (Typha spp.) marsh plots were found by organized searches. Similarly, in a study by Tobin and Dolbeer (1990), 75% of songbird carcasses placed beneath orchard trees were found. In contrast, Stuzenbacher et al. (1986) studied the effectiveness of search crews in locating dead ducks in a shallow Texas wetland and found none of the birds placed in cover and only six (12%) of the highly visible carcasses. The authors concluded that lack of carcasses recovered during intensive searches does not rule out
extensive waterfowl mortality. Similarly, in a study by Cliplef and Wobeser (1993), only 32% of marked dummy waterfowl carcasses in a wetland were recovered during searches. Three different search methods for estimating the density of dead birds in an epizootic were evaluated by Philibert et al. (1993). Birds were found during every search; however, they concluded that the number of birds found during most searches was less than needed to estimate density accurately.

Morphological characteristics of carcasses can affect carcass search methods. For example, Philibert et al. (1993) used clay models resembling western meadowlarks (*Sturnella neglecta*) and Savannah sparrows (*Passerculus sandwichensis*) to study carcass detection methods. Meadowlarks are larger and more brightly colored than sparrows, and as expected, more meadowlarks (90%) were detected than sparrows (62%). Similarly, in a study by Linz et al. (1991), fewer female red-wing blackbirds (78%) were found than males (83%), which are larger and more brightly colored than females. Additionally, carcass searchers in a study by Cliplef and Wobeser (1993) on waterfowl carcasses found more mallards (53%) than smaller species of waterfowl (25%).

Estimation of carcass disappearance rates

The rate at which carcasses decompose or are removed by scavengers may bias mortality estimates in wild bird populations. Factors such as the density and visibility of carcasses, scavenger assemblages in the area, weather, and habitat characteristics may influence the duration of carcass persistence (Wobeser and Wobeser 1992). Wobeser (1994) suggests that approximately 50% of duck-sized carcasses disappear within four days and that approximately 75% of passerine bird carcasses may be removed within the first day.
Stuzenbacher et al. (1986) suggests that wild animal carcasses are quickly assimilated into the environment. In a study of 47 duck carcasses in a Texas wetland, all carcasses were eventually consumed by predators and scavengers. Sixty-two percent of the carcasses were gone in three days. Balcomb (1986) found rapid initial disappearance of songbird carcasses in agricultural fields in Maryland. At one day after placement, 75% of all carcasses were gone. Carcass losses were markedly greater during this first 24-hour period, demonstrating that the rate of carcass disappearance was not uniform over the 5-day study period. Similarly, Wobeser and Wobeser (1992) found that only 20% of chick carcasses in mixed-grass pasture remained after one day. 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.

Differences in carcass location within a particular environment can affect persistence. Pain (1991) found that exposed duck carcasses on land persisted an average of 1.5 days, whereas carcasses concealed by vegetation on land, and those in water, persisted and average of 3.3 and 7.6 days, respectively. Similarly, Stuzenbacher et al. (1986) found that duck carcasses in open water persisted an average of 11.2 days, whereas carcasses with overhead cover or completely exposed persisted an average of 2.6 days and 3.8 days, respectively. Linz et al. (1991) studied red-winged blackbird carcasses in cattail marshes and found that scavenging activity differed among marshes and was influenced by carcass density and depth of water.

Balcomb (1986) reported that 58% of songbird carcasses disappeared without leaving observable remains and Tobin and Dolbeer (1990) found that 75% of bird carcasses were removed completely. Of the 275 chick carcasses observed by Wobeser and Wobeser (1992),
only two carcasses that had been in place for over 24 hours were found. These studies
demonstrate the need to investigate outbreaks quickly if a large proportion of birds are to be
detected.

An exception to a rapid rate of carcass disappearance may occur when a large number of
animals die within a short period of time in a small area, presumably by overloading existent
scavenging populations. For example, only one of 42 duck carcasses marked and observed
during a botulism outbreak was disturbed by scavengers during the four days after death (Cliplef
and Wobeser 1993).

The specific cause of the carcass removal is also 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

West Nile virus surveillance in Georgia

The Southeastern Cooperative Wildlife Disease Study (SCWDS) has conducted WNV
surveillance among wild birds in Georgia since 2000. West Nile virus was first detected in
Georgia in an American crow carcass submitted to SCWDS from Lowndes County on July 11,
2001. From January 1, 2001 to January 1, 2004, a total of 6,114 dead birds were submitted to
SCWDS for WNV testing (D. G. Mead, SCWDS, personal communication). Corvids made up
46% of all dead birds submitted. Eighteen percent of all dead birds submitted were crows, and
of these, 64% (700 of 1,087) were positive for WNV.
Currently, interpretation of dead bird surveillance is unclear because there is little information relative to detection and reporting of dead birds. For example, in DeKalb County, Georgia in 2002, extensive and specific data on dead wild bird surveillance was collected by the DeKalb County Board of Health as part of Georgia’s WNV monitoring. DeKalb County Board of Health found more reported WNV positive dead birds in urban areas versus rural areas (J. Willis, DeKalb County Board of Health, personal communication). 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.

Objectives

The objectives of this research were to assess detection, reporting, and carcass persistence and fate in relation to WNV surveillance programs. First, I assessed the detection and reporting of dead crows (decoy surrogates) in urban and rural environments in a location with an intensive and organized dead bird surveillance system. Second, I assessed the temporal persistence and fate of American crow and house sparrow (Passer domesticus) carcasses in urban and rural environments. Carcasses of both crows and sparrows were used to determine if morphological differences play a role in persistence and fate. The data from this study will provide important information related to the interpretation of dead bird surveillance data and on the potential for oral exposure to WNV among both avian and mammalian scavengers.
CHAPTER 1

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

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 reporting biases that might occur in the county’s WNV surveillance program. In each of two trials, 400 decoys were labeled with reporting instructions and distributed along randomly chosen routes throughout designated urban and rural areas within DeKalb County. Akaike’s Information Criterion (AIC) model selection indicated that the model containing area best explained decoy detection and reporting. The proportion of decoys detected in the urban area (0.6, SE=0.024) was approximately twice that of the rural area (0.3, SE=0.023), and the proportion of decoys reported in the urban area (0.3, SE=0.023) was approximately three times that of the rural area (0.1, 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 study, the persistence and fate of American crow and house sparrow (*Passer domesticus*) carcasses were assessed in similar urban and rural environments in Clarke, Madison, and Oconee counties, Georgia. Two separate trials using 96 carcasses of each species were conducted. For a portion of the carcasses, motion and heat 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. Model selection based on 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. Carcass disappearance rates were higher for rural areas and for sparrow 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 scavengers was similar in urban and rural areas but “scavenging pressure” was greater in rural areas.

**Key words:** American crow, carcass, *Corvus brachyrhynchos*, detection, fate, house sparrow, *Passer domesticus*, persistence, reporting, scavenging, West Nile virus

**INTRODUCTION**

Avian surveillance targeting dead wild birds can play a critical role in the early detection of West Nile virus (WNV) in the United States (Eidson et al., 2001a; Guptill et al., 2003; Mostashari et al., 2003). Although West Nile virus 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 due to 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., 2001b; Mostashari et al, 2003; Theophilides et al., 2003).
Carcass counts can provide valuable information; 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 drabber species (Linz et al., 1991; Cliplef and Wobeser, 1993; Philibert et al., 1993). Factors such as the density and visibility of the 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). However, even with variable rates of persistence, 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 the carcass removal also 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 was collected by the DeKalb County Board of Health as part of Georgia’s WNV monitoring. The DeKalb County Board of Health found more reported WNV positive dead birds in urban areas versus rural areas (J. Willis, DeKalb County Board of Health, personal...
communication). 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, and carcass persistence and fate in relation to WNV surveillance programs. The first objective was to assess the detection and reporting of dead crows using decoy surrogates in urban and rural environments in DeKalb County, Georgia, which possesses an active organized dead bird surveillance system. Commercial crow decoy surrogates were used instead of actual crow carcasses due to the potential for public concerns and for monitoring abilities. The second objective was to assess the temporal persistence and fate of American crow and house sparrow (*Passer domesticus*) carcasses in similar 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 and heat 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 within urban and rural environments was evaluated in DeKalb County, Georgia during July and September 2003. DeKalb County is located in the Piedmont physiographic province of Georgia, has a population of approximately 674,000 people, and comprises approximately 694 km² (Figure 1-1) (U.S. Census Bureau, 2004). 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” (Figure 1-1). 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 (Figure 1-1). Using ArcView, 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 the 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 the decoys were reported. Decoys were monitored at the end of seven days and were
categorized as detected and reported, missing but unreported, or still present but unreported. All
remaining decoys were removed at day seven. Reports received after seven days were excluded
from analysis because actual dead birds would not be suitable for diagnostic evaluation after this
time.

Analyses were conducted using the program SURVIV (White, 1983). We constructed a
global and four candidate models to determine the best approximating model relating decoy
detection and reporting to area type (urban or rural) and time (July or September) (Table 1-1).
Our global model included both variables and each candidate model included either area or
neither variable. Assumptions associated with these models included decoys still present had not
been found and decoys missing were found but not reported. Thus, the “detection” of decoys
was calculated by adding the number reported and the number missing but unreported. 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). We ranked all models according to
AIC values, with the lowest value representing the best approximating model. Akaike weights
($w_i$) were calculated to determine the weight of evidence in favor of each model (Burnham and
Anderson, 2002). The model with the highest weight of evidence (range 0-1) is deemed the most plausible given the data and set of candidate models.

**Carcass persistence and fate**

Persistence and fate of American crow and house sparrow carcasses were evaluated in the vicinity of Athens, Georgia (Clarke County) in July and September 2004. Clarke, Madison, and Oconee counties are located in the Piedmont province of Georgia approximately 50 km east of DeKalb County (Figure 1-1). The Athens vicinity, including Clarke and portions of Madison and Oconee counties, were divided into urban and rural areas designed to be similar to those used in the decoy detection and reporting portion of this study. Urban and rural designations were based on land uses derived from LANDSAT data (NRSAL IOE UGA, 2004).

American crow carcasses were donated by a crow hunting guide located in Milledgeville, Georgia and were frozen within 24 hours after death. House sparrow carcasses were collected by Southeastern Cooperative Wildlife Disease Study personnel and frozen within 24 hours 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) for each site. 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 was 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 six 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, carcass number, site name, site category, and carcass presence or
absence 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 of program MARK (White
and Burnham, 1999). We constructed a global and seven candidate models to determine the best
approximating model relating carcass persistence rates to species (crow and sparrow), area
(urban and rural), day of exposure (0-6), and time (July and September) (Table 1-2). Our global model included all four variables and each candidate model was a variation on the global model. Persistence rates were calculated as proportions of dead birds remaining each day. We used the information-theoretic approach to model selection described in Burnham and Anderson (2002). Akaike’s Information Criteria (AIC$_c$) values for small samples were calculated to evaluate and select the most parsimonious model (Burnham and Anderson, 2002). We ranked all models according to AIC$_c$ values, with the lowest value representing the best approximating model. Akaike weights ($w_i$) were calculated to determine the weight of evidence in favor of each model (Burnham and Anderson, 2002). The model with the highest weight of evidence (range 0-1) is deemed the most plausible given the data and set of candidate models. Model averaging was used to incorporate model selection uncertainty directly into the parameter estimates using the Akaike weights (Burnham and Anderson, 2002). We used $w_i$ values to weight the parameter estimates and variances from each model.

Sixteen motion and heat sensitive trail cameras, model DeerCam (NonTypical, Inc., Park Falls, WI), were used to monitor a subsample of the carcasses to obtain photographic evidence of scavengers. Cameras were mounted vertically on a tree, approximately 0.3 m from the ground, and were programmed to record date and time on each photograph and to 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 for each carcass and all species visiting each carcass were recorded in chronological order and determined to be investigative or incidental (i.e. walking by). The last known scavenging species visiting each carcass before it was missing also 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 detected and reported, missing but unreported, or still present but unreported are presented in Table 1-3. The models indicated no difference between trials, so the results of both trials were combined. The model containing only the area variable best approximated (95% probability) decoy detection and reporting (Table 1-4) 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 three models which received no empirical support ($\Lambda_i > 7, w_i \leq 0.01$). The estimates from the best approximating model indicated that the proportion of decoys detected in the urban area (0.6, SE=0.024, 95% CI: 0.557 to 0.653) was approximately twice that of the rural area (0.3, 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 (0.3,
SE=0.029, 95% CI: 0.217 to 0.329) was approximately three times that of the rural area (0.1,
SE=0.028, 95% CI: 0.048 to 0.158).

There were 12 decoys reported after seven days that were excluded from analysis.  
Almost all (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 noted as most likely due to human involvement; 
however, none of the “moved” decoys were 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 were removed and 
87 of 96 (91%) of all sparrow carcasses had been removed (Tables 1-5 and 1-6). Crow carcass 
losses were 52% and 29% after day one and 65% and 48% after day two, in rural and urban 
areas, respectively (Table 1-5). Sparrow carcass losses were 54% and 23% after day one and 
75% and 67% after day two, in rural and urban areas, respectively (Table 1-6). Crow carcasses 
persisted an average of 1.5 days in the rural area and 2.1 days in the urban area. Sparrow 
carcasses persisted an average of 1.7 and 2.1 days in rural and urban areas, respectively.

The models indicated no difference between trials, so the results of both trials were 
combined. The best approximating model (54% probability) estimating carcass persistence rates 
contained species and days of exposure variables (Table 1-7) and indicated that crow and 
sparrow carcasses differed in their persistence rates and that persistence rates were not consistent 
over the days of exposure. Weight of evidence in favor of this model was only 1.2 times greater 
than that of the next approximating model, indicating some uncertainty in selection of the best
candidate model. The second best model (44% probability) contained area and days of exposure variables (Table 1-7) and indicated that urban and rural areas differed in their persistence rates and that persistence rates were not consistent over the days of exposure. The third best model received only marginal support and the remaining five models received no empirical support ($\Delta_i > 7, w_i \leq 0.01$).

Figure 1-2 shows the model-averaged estimates for the parameters used to model carcass persistence rates over each day of exposure. Parameter estimates indicated that carcass losses were greatest over the first day of exposure and that thereafter carcass persistence increased over time. 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 two days of exposure.

There were a total of 96 and 101 camera nights compiled monitoring crow carcasses for rural and urban areas, respectively, which captured photographic evidence of seven scavenging species (Table 1-8). Virginia opossums (*Didelphis virginiana*) accounted for most of the visits in both rural (42%) and urban (52%) areas, followed by domestic cats (*Felis catus*) and raccoons (*Procyon lotor*) for both areas (Table 1-8). 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 carcass 11 times in the rural area and 6 times in the urban area.

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 scavenging species (Table 1-8). 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 carcass one time in the rural area and one time in the urban area.

Forty-six of the 72 (64%) total recorded scavenger visits did not result in the removal of a carcass. Examples of photographic evidence of scavenger visits are shown in Figure 1-3. 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**

The reporting of dead wild birds has proven to be a valuable tool for monitoring WNV activity and subsequently assessing the potential for human risk, as well as for guiding public education and mosquito control programs (Eidson et al., 2001a; Eidson et al., 2001b; 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 while 32% of dummy waterfowl carcasses were found in a Saskatchewan, Canada wetland (Stutzenbacher 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 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 and interest in reporting them (Eidson et al., 2001a; 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 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 that 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., 2001a, Guptill et al., 2003; Mostashari et al., 2003). In contrast, unreported decoys in the urban area were approximately evenly distributed between the still present and the missing but unreported categories. The proportion of decoys detected but not reported was the best measure of non-reporting bias; and a higher non-reporting bias occurred in the rural landscape. Thus, rural residents were less likely to report a detected decoy than urban residents; however, the reasons for this differing behavioral response are unknown.

There are several concerns 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 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 during this research.

The impacts of WNV on crow populations are not completely understood. Field studies have demonstrated that WNV can severely impact 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 ten 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 hours 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).
In our study, 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 two. These findings support the conclusions of Stuzenbacher et al. (1986), who stated 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 one 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 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).

In our study, two models received approximately equal support and these models indicated that carcass persistence rates were affected by species and number of days of exposure and 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. Parameter estimates indicated that carcass losses were greatest over the first day of exposure and that thereafter carcass persistence increased over time. Similar results were reported by Balcomb (1986), who found that songbird carcass losses were markedly greater during the first 24-hour 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 will be quickly
detected within those areas; however, carcasses located outside of these territories will probably
disappear at slower rates (Balcomb, 1986). Our estimates also indicated that initially, rural areas
had higher disappearance rates than 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-hour 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 larger species. Furthermore, because of their smaller mass, sparrow carcasses
may be more rapidly destroyed by insects and bacteria.

There was little variation in the composition of scavenging species or their visits between
urban and rural areas for crow carcasses. Since opossums and raccoons are common species and
also 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, of which 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.

ACKNOWLEDGEMENTS

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North Carolina, Ohio, Puerto Rico, South Carolina, Tennessee, Virginia, and West Virginia. Funds were provided to SCWDS by the Federal Aid to Wildlife Restoration Act (50 Stat. 917).

REFERENCES


_____, N. KOMAR, F. SORHAGE, R. NELSON, T. TALBOT, F. MOSTASHARI, R. MCLEAN, AND THE WEST NILE VIRUS AVIAN MORTALITY SURVEILLANCE


Table 1-1. Alternative models for predicting decoy detection and reporting in urban and rural areas of DeKalb County, Georgia in 2003.

Decoy detection (D) and reporting (R) vary by area (a) and by time (July or September) (t).

\{D(a^t) \ R(a^t)\}

Decoy detection and reporting vary by area only, time has no effect.

\{D(a) \ R(a)\}

Decoy detection varies by area only, decoy reporting is unaffected by area or time.

\{D(a) \ R(.)\}

Decoy detection is unaffected by area or time, decoy reporting varies by area only.

\{D(.) \ R(a)\}

Decoy detection and reporting are unaffected either by area or time.

\{D(.) \ R(.)\}
Table 1-2. Alternative models for predicting crow and sparrow carcass persistence rates in urban and rural areas of Clarke, Madison, and Oconee counties, Georgia in 2004.

Carcass persistence varies by species (spp), area (a), time (July or September) (t), and days of exposure (0-6) (e).

\{S(spp*a*t*e)\}

Carcass persistence varies by species, area, and time only.

\{S(spp*a*t)\}

Carcass persistence varies by species (spp) and days of exposure.

\{S(spp*e)\}

Carcass persistence varies by area (a) and days of exposure.

\{S(a*e)\}

Carcass persistence varies by days of exposure only.

\{S(e)\}

Carcass persistence varies by species only.

\{S(spp)\}

Carcass persistence varies by area only.

\{S(a)\}

Carcass persistence is unaffected by species, area, time, or days of exposure.

\{S(.)\}
Table 1-3. Detection and reporting of crow decoys within 7 days in urban and rural areas of DeKalb County, Georgia in 2003.

<table>
<thead>
<tr>
<th></th>
<th>Decoys Placed</th>
<th>Reported</th>
<th>Still Present</th>
<th>Missing/Unreported</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trial 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>200</td>
<td>34 (17%)</td>
<td>74 (37%)</td>
<td>92 (46%)</td>
</tr>
<tr>
<td>Rural</td>
<td>200</td>
<td>5 (2%)</td>
<td>146 (73%)</td>
<td>49 (25%)</td>
</tr>
<tr>
<td><strong>Trial 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>200</td>
<td>32 (16%)</td>
<td>84 (42%)</td>
<td>84 (42%)</td>
</tr>
<tr>
<td>Rural</td>
<td>200</td>
<td>7 (3%)</td>
<td>137 (69%)</td>
<td>56 (28%)</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>400</td>
<td>66 (17%)</td>
<td>158 (39%)</td>
<td>176 (44%)</td>
</tr>
<tr>
<td>Rural</td>
<td>400</td>
<td>12 (3%)</td>
<td>283 (71%)</td>
<td>105 (26%)</td>
</tr>
</tbody>
</table>
Table 1-4. Model selection results for models explaining influences of area and time on decoy
detection and reporting in DeKalb County, Georgia in 2003.

<table>
<thead>
<tr>
<th>Model</th>
<th>K^b</th>
<th>ln(likelihood)</th>
<th>AIC</th>
<th>Δ_i</th>
<th>w_i^c</th>
</tr>
</thead>
<tbody>
<tr>
<td>{D(a) R(a)}</td>
<td>4</td>
<td>-20.90</td>
<td>49.8</td>
<td>0.00</td>
<td>0.95</td>
</tr>
<tr>
<td>{D(a<em>t) R(a</em>t)}</td>
<td>8</td>
<td>-19.82</td>
<td>55.6</td>
<td>5.80</td>
<td>0.05</td>
</tr>
<tr>
<td>{D(a) R(.)}</td>
<td>3</td>
<td>-28.32</td>
<td>62.6</td>
<td>12.80</td>
<td>0.00</td>
</tr>
<tr>
<td>{D(.) R(a)}</td>
<td>3</td>
<td>-61.08</td>
<td>128.2</td>
<td>78.40</td>
<td>0.00</td>
</tr>
<tr>
<td>{D(.) R(.)}</td>
<td>2</td>
<td>-68.50</td>
<td>141.0</td>
<td>91.20</td>
<td>0.00</td>
</tr>
</tbody>
</table>

^a Abbreviations correspond to model candidates in Table 1-1.
^b Number of estimating parameters in approximating model.
^c Akaike weight.
Table 1-5. Results of crow carcass persistence trials in Clarke, Madison, and Oconee counties, Georgia in 2004.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Area</th>
<th>#Monitored</th>
<th>1 (58%)</th>
<th>2 (42%)</th>
<th>3 (33%)</th>
<th>4 (29%)</th>
<th>5 (29%)</th>
<th>6 (29%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rural</td>
<td>24</td>
<td>14</td>
<td>10</td>
<td>8</td>
<td>7</td>
<td>7</td>
<td>7</td>
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<tr>
<td></td>
<td>Urban</td>
<td>24</td>
<td>20</td>
<td>14</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>8</td>
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<tr>
<td>2</td>
<td>Rural</td>
<td>24</td>
<td>9</td>
<td>7</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Urban</td>
<td>24</td>
<td>14</td>
<td>11</td>
<td>7</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>Rural</td>
<td>48</td>
<td>23</td>
<td>17</td>
<td>13</td>
<td>11</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Urban</td>
<td>48</td>
<td>34</td>
<td>25</td>
<td>17</td>
<td>16</td>
<td>16</td>
<td>14</td>
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</tbody>
</table>
Table 1-6. Results of sparrow carcass persistence trials in Clarke, Madison, and Oconee counties, Georgia in 2004.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Area</th>
<th>#Monitored</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rural</td>
<td>24</td>
<td>9 (38%)</td>
<td>6 (25%)</td>
<td>6 (25%)</td>
<td>4 (17%)</td>
<td>4 (17%)</td>
<td>4 (17%)</td>
</tr>
<tr>
<td></td>
<td>Urban</td>
<td>24</td>
<td>20 (83%)</td>
<td>11 (46%)</td>
<td>8 (33%)</td>
<td>4 (17%)</td>
<td>4 (17%)</td>
<td>4 (17%)</td>
</tr>
<tr>
<td>2</td>
<td>Rural</td>
<td>24</td>
<td>13 (54%)</td>
<td>6 (25%)</td>
<td>2 (8%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td></td>
<td>Urban</td>
<td>24</td>
<td>17 (71%)</td>
<td>5 (21%)</td>
<td>1 (4%)</td>
<td>1 (4%)</td>
<td>1 (4%)</td>
<td>1 (4%)</td>
</tr>
<tr>
<td>Total</td>
<td>Rural</td>
<td>48</td>
<td>22 (46%)</td>
<td>12 (25%)</td>
<td>8 (17%)</td>
<td>4 (8%)</td>
<td>4 (8%)</td>
<td>4 (8%)</td>
</tr>
<tr>
<td></td>
<td>Urban</td>
<td>48</td>
<td>37 (77%)</td>
<td>16 (33%)</td>
<td>9 (19%)</td>
<td>5 (10%)</td>
<td>5 (10%)</td>
<td>5 (10%)</td>
</tr>
</tbody>
</table>
Table 1-7. Model selection results for models explaining influences of species, area, time, and days of exposure on carcass persistence rates in Clarke, Madison, and Oconee counties, Georgia in 2004.

<table>
<thead>
<tr>
<th>Model</th>
<th>K^b</th>
<th>AICc</th>
<th>Δi</th>
<th>wi^c</th>
</tr>
</thead>
<tbody>
<tr>
<td>{S(spp*e)}</td>
<td>12</td>
<td>574.72</td>
<td>0.00</td>
<td>0.54</td>
</tr>
<tr>
<td>{S(a*e)}</td>
<td>12</td>
<td>575.11</td>
<td>0.39</td>
<td>0.44</td>
</tr>
<tr>
<td>{S(e)}</td>
<td>6</td>
<td>581.32</td>
<td>6.60</td>
<td>0.02</td>
</tr>
<tr>
<td>{S(spp<em>a</em>t*e)}</td>
<td>46</td>
<td>598.98</td>
<td>24.26</td>
<td>0.00</td>
</tr>
<tr>
<td>{S(spp<em>a</em>t)}</td>
<td>8</td>
<td>614.45</td>
<td>39.73</td>
<td>0.00</td>
</tr>
<tr>
<td>{S(spp)}</td>
<td>2</td>
<td>616.82</td>
<td>42.10</td>
<td>0.00</td>
</tr>
<tr>
<td>{S(a)}</td>
<td>2</td>
<td>623.18</td>
<td>48.46</td>
<td>0.00</td>
</tr>
<tr>
<td>{S(.)}</td>
<td>1</td>
<td>625.83</td>
<td>51.11</td>
<td>0.00</td>
</tr>
</tbody>
</table>

^a Abbreviations correspond to model candidates in Table 1-2.

^b Number of estimating parameters in approximating model.

^c Akaike weight.
Table 1-8. Documented scavenger visits to crow and sparrow carcasses in Clarke, Madison, and Oconee counties, Georgia in 2004.a

<table>
<thead>
<tr>
<th></th>
<th>Rural visits(^b)</th>
<th>Consumed(^c)</th>
<th>Urban visits(^b)</th>
<th>Consumed(^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Crow</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coyote (Canis latrans)</td>
<td>1 (3%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Domestic cat (Felis catus)</td>
<td>10 (26%)</td>
<td>1</td>
<td>9 (33%)</td>
<td>1</td>
</tr>
<tr>
<td>Domestic dog (Canis familiaris)</td>
<td>3 (8%)</td>
<td>0</td>
<td>1 (4%)</td>
<td>0</td>
</tr>
<tr>
<td>Gray fox (Urocyon cinereoargenteus)</td>
<td>0</td>
<td>0</td>
<td>1 (4%)</td>
<td>1</td>
</tr>
<tr>
<td>Raccoon (Procyon lotor)</td>
<td>7 (18%)</td>
<td>2</td>
<td>4 (15%)</td>
<td>3</td>
</tr>
<tr>
<td>Red-tailed hawk (Buteo jamaicensis)</td>
<td>1 (3%)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Virginia opossum (Didelphis virginiana)</td>
<td>16 (42%)</td>
<td>8</td>
<td>14 (52%)</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>38</td>
<td>11</td>
<td>27</td>
</tr>
<tr>
<td><strong>Sparrow</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Domestic cat (F. catus)</td>
<td>3 (75%)</td>
<td>1</td>
<td>3 (33%)</td>
<td>2</td>
</tr>
<tr>
<td>Virginia opossum (D. virginiana)</td>
<td>1 (25%)</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>4</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

\(^a\) 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).

\(^c\) Represent number of carcasses removed by corresponding scavenger.
Figure 1-1. Land use areas and routes for decoy placement during crow decoy study in DeKalb County, Georgia in July and September 2003 and location for crow and sparrow carcass persistence and fate study in Clarke, Madison, and Oconee counties, Georgia in July and September 2004.
Figure 1-2. Model-averaged parameter estimates for crow and sparrow carcass persistence rates in urban and rural areas in Clarke, Madison, and Oconee counties, Georgia in 2004. Persistence rates are based on the proportion of carcasses remaining from the preceding day. Error bars represent one standard error.
Figure 1-3. Exemplar photographs of scavenging species obtained during carcass persistence and fate study in Clarke, Madison, and Oconee counties, Georgia in 2004. (a) Gray fox (*Urocyon cinereoargenteus*). (b) Domestic cat (*Felis catus*). (c) Red-tailed hawk (*Buteo jamaicensis*). (d) Coyote (*Canis latrans*). (e) Raccoon (*Procyon lotor*). (g) Virginia opossum (*Didelphis virginiana*).
SUMMARY AND CONCLUSIONS

Surveillance of dead wild birds can be a valuable tool for monitoring WNV activity and subsequently assessing the potential for human risk, as well as for guiding public education and mosquito control programs (Eidson et al. 2001a, Eidson et al. 2001b, Guptill et al. 2003, Watson et al. 2004). The success of a dead bird surveillance system depends not only on people detecting dead birds, but also on their knowledge and interest in reporting them (Eidson et al. 2001a, Mostashari et al. 2003). 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. Our findings also illustrate the need for active communication with the public to optimize the use of dead wild birds as a surveillance tool.

Our study indicated that detection and reporting biases existed between urban and rural landscapes in DeKalb County, Georgia in 2003. We found that urban areas were more likely to detect as well as report crow decoys and presumably dead crows as well. Therefore, the same level of WNV activity is far more likely to be detected in urban areas than in rural areas. The observed biases strongly suggest that human density and associated factors should be considered when interpreting dead wild bird surveillance for WNV.

In our study, most carcasses (82%) disappeared or were decayed by the end of the 6-day study period. Intact carcasses are important for diagnostic evaluation and, thus, mortality estimates may be limited by the fact that few persist (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).
Our study supported previous conclusions that carcasses are quickly incorporated into the environment (Balcomb 1986, Stuzenbacher et al. 1986, Wobeser and Wobeser 1992). We found that carcass species, environmental category, and exposure duration affected carcass persistence rates. We found that crow and sparrow carcasses differed in persistence rates; specifically, sparrows disappeared more rapidly than crows. Smaller carcasses may have a wider range of potential scavengers than larger species and because of their smaller mass, may be more rapidly destroyed by insects. We also found that rural areas had higher carcass disappearance rates than urban areas; this appeared to be explained by higher “scavenging pressure” in our rural study area. Last, we found that initial carcass losses were greatest over the first day of exposure but thereafter persistence of remaining carcasses increased over time.

The entire host range of WNV, as well as all means of transmission of the virus in the wild, remains to be completely understood. In our study, we documented six mammalian and one avian species scavenging carcasses over a 6-day observation period. Dead wild birds, for example crows, which develop high viral loads in numerous organs, could represent potential sources of oral WNV infection to scavenging species (Komar et al. 2003).

This research demonstrated that landscape differences can affect detection and reporting of dead birds. Carcass persistence can be affected by these same landscape differences, as well as interspecific morphology and length of exposure. These variations are important concerns relative to WNV surveillance and should be considered in interpretation of dead bird surveillance data. It may be beneficial to assess areas for detection and reporting, as well as site-specific rates of carcass removal, in order to more accurately estimate avian mortality or the extent of disease occurrence.
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