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# Rock pigeon use of livestock facilities in northern Colorado: implications for improving farm bio-security

**James C. Carlson**, USDA/APHIS/Wildlife Services' National Wildlife Research Center, 4101 LaPorte Avenue, Fort Collins, CO 80521, USA *James.C.Carlson@aphis.usda.gov*

**Larry Clark**, USDA/APHIS/Wildlife Services' National Wildlife Research Center, 4101 LaPorte Avenue, Fort Collins, CO 80521, USA

**Michael F. Antolin**, Department of Biology, Colorado State University, Fort Collins, CO 80523, USA

**Mo D. Salman**, Department of Clinical Sciences, Colorado State University, Fort Collins, CO 80523, USA

***Abstract*:** Rock pigeons (*Columba livia*) have been implicated in the spread of pathogens within commercial livestock facilities. Currently, there is no data characterizing pigeon habitat use and movement patterns within and among commercial livestock facilities. To better understand the capacity for pigeons to spread pathogens, we used radio-telemetry techniques to estimate the home-range, travel distance, activity, and habitat use of pigeons roosting on and off dairies and feedlots in western Weld County, Colorado. Our observations suggest that pigeons roosting on (resident) and off (nonresident) livestock facilities use habitat differently. Nonresident pigeons used larger home-range areas than did resident pigeons. Nonresident pigeons traveled farther and frequented more livestock facilities than did resident pigeons. Both resident and nonresident pigeons disproportionally selected livestock facilities over other available foraging sites. We detected no difference in pigeon activities (i.e. loafing, feeding, drinking, flying) between resident and nonresident pigeons. Data suggest that nonresident pigeons may vector livestock pathogens among livestock facilities and resident pigeons may aid in the amplification and maintenance of pathogens within livestock facilities. Thus, targeted management of pigeons may help mitigate the introduction and maintenance of pathogens that cause disease and economic loss within livestock facilities.

***Key Words*:** birds, *Bos taurus*, *Columba livia,* home range, human–wildlife conflicts, invasive species, peridomestic wildlife, telemetry, wildlife disease, zoonotic disease

Domestic cattle (*Bos taurus*) are the primary reservoir for many bacterial pathogens that affect human and livestock health (e.g., *Escherichia coli* O157:H7 and *Salmonella enterica*; Montenegro et al. 1990, Kobayashi et al. 2001, Wells et al. 2001). Infection in livestock usually occurs as a result of fecal shedding from other infected livestock that spread pathogens throughout the herd via contaminated cattle feces (Wells et al. 2001), cattle feed (Daniels et al. 2003), and water (Kirk et al. 2002*a*). Thus, limiting shedding of pathogenic bacteria by cattle is essential to prevent dissemination. However, once a herd has become infected, the environment can become contaminated. In the absence of effective farm bio-security, the risk of pathogen transport from the farm to other locations increases (Gilchrist et al. 2007).

Wild birds can be infected by and carry a large number of pathogens that are a health risk to humans and livestock (Sambyal and Sharma 1972, McLean et al. 2001, Gaukler et al. 2009). For example, serotypes of *Salmonella enterica*, known to cause infection in humans and livestock, have been isolated from asymptomatic house sparrows (*Passer domesticus*), brown-headed cowbirds (*Molothrus ater*), Brewers blackbirds (*Euphagus cyanocephalus*), European starlings (*Sturnus vulgaris*), house finches (*Carpodacus mexicanus*), red-winged blackbirds (*Agelaius phoeniceus*), and rock pigeons (*Columba livia*) captured within dairies, suggesting that transmission across species is possible (Kirk et al. 2002*b*). Moreover, because birds can traverse large distances in short periods of time, they have the potential to transport and disseminate microbes over large distances (Palmgren et al. 1997, Hubálek 2004).

Rock pigeons in particular have been implicated in causing economic losses at livestock facilities because of pathogen dissemination and feed consumption (Williams and Corrigan 1994, Pedersen and Clark 2007). Pigeons are known carriers of *Histoplasma capsulatum*, *Listeria monocytogenes*, western equine encephalitis, West Nile virus,

Newcastle disease, *Cryptococcus neoformans*, *Toxoplasma gondii*, and *Salmonella enterica* (Haag-Wackernagel and Moch 2004). Between 1941 and 2003, there have been 176 documented transmissions of disease-causing pathogens from pigeons. These include, but are not limited to, *Salmonella enterica kiambu*, *Chlamydophila psittaci*, and *Cryptococcus neoformans* (Haag-Wackernagel and Moch 2004).

Previous studies have demonstrated that pigeons can be carriers of *S. enterica* within dairies (Kirk et al. 2002*b*). Additionally, Pedersen et al. (2006) isolated the same serotypes of *S. enterica* from pigeons, cattle feed, water troughs, and cattle feces within dairies, implicating pigeons as a potential source of *S. enterica*. Currently, it is unknown if pigeons move among livestock facilities or use the surrounding habitat. Data characterizing the movement patterns, habitat use, and activities of pigeons are needed to develop an understanding of their capacity to spread pathogens within and between commercial livestock facilities. Therefore, the objective of our study was to estimate home-range areas, travel distances, activities, and habitat use of rock pigeons using commercial dairies and feedlots in Weld County, Colorado, from December 1, 2004, to September 1, 2005.

## Study area

The study was conducted in western Weld County, Colorado, because it has many feedlots, dairies, and associated pigeons. Weld County is located in northern Colorado on the eastern slope of the Rocky Mountains at an elevation of 1,525 m above sea level. Precipitation averages about 0.4 m per year, and average monthly temperatures varied from -0.5° C in January to 24.0° C in July, 2005. Land use within the study area was primarily animal and plant agriculture interspersed with fallow fields, small towns, and grasslands.

## Methods

We characterized pigeons as either residents (i.e., birds that roosted within livestock facilities) or nonresidents (i.e., birds that roosted outside of livestock facilities), based upon a preliminary assessment of 3 radio-marked birds that we tracked for approximately 1 week in December, 2004. We located pigeon roosts during night searches of livestock facilities, abandoned structures, industrial facilities, and under bridges.

Pigeons roosting adjacent to livestock facilities were not used in this study. This exclusion allowed for a clear distinction between resident and nonresident pigeons. Nonresident pigeon roosts were physically separated ≥250 m from animal pens, grain elevators, or silage piles, so the birds would have to select food sources outside livestock facilities or cross open farm land, housing developments, or fallow fields to access feed within livestock facilities. We selected 250 m because it is equivalent to the distance pigeons would fly to cross an average-sized field within the study area.

We hypothesized that resident and nonresident pigeons would exhibit different daily activities and movements. We predicted that nonresident pigeons would visit a greater number of livestock facilities, have larger home-range areas, travel greater distances for food and water, and have different daily activity patterns than did resident pigeons.

### Livestock facilities

We selected cattle feedlots or dairies containing ≥2 roosting pigeons as resident roost sites. Cattle herd size within these facilities ranged between 300 and 2,500 cattle. All resident roost sites contained equipment barns, silage piles, grain elevators, grain silos, animal pens, water troughs, and feed bunks. Equipment barns consisted of any building that housed farm machinery or vehicles. Silage piles consisted of covered, chopped corn storage piles. Grain elevators consisted of grain lifts used to load feed trucks with silage and feed additives. Grain silos consisted of corn and feed additive storage structures. Animal pens consisted of the animal holding structure. Water troughs consisted of any water holding receptacle within the animal pens. Feed bunks consisted of any feed storage receptacle, typically located along the outside edge of the pen.

### Trapping

Our research protocol was reviewed and approved by our institutional animal care and use committee prior to any data collection (USDA, National Wildlife Research Center QA-1237, J. Carlson, study director). All pigeons were trapped at night using spotlights, hand

nets, and mist nets (Williams and Corrigan 1994). Pigeons were initially weighed and examined for injuries. Any pigeon that was too small for radio transmitters, injured, or appeared in poor health was excluded as a candidate for radio tracking. The minimum weight accepted for radio-marked pigeons was 300 g, and radio-marked birds averaged 347 ± 42 g. The transmitters averaged 2.7% of pigeon body weight, which was below the recommended 3% (Whitey et al. 2001). Radio-marked pigeons were arbitrarily selected from the pool of acceptable pigeons collected from each roost site. Thirty-one pigeons (14 residents and 17 nonresidents) were fitted with radio transmitters from 10 different pigeon roosts: 5 roosts on livestock facilities and 5 roosts off livestock facilities.

## Radio tracking

All radio-marked pigeons were fitted with Advanced Telemetry Systems (ATS) pigeon backpack transmitters, model A1250 (Advanced Telemetry Systems, Isanti, Minn.). Transmitters emitted signals 18 hours per day (from 0500 hours until 2300 hours), 3 days per week (Friday, Saturday, and Sunday). Transmitters weighed 9.5 grams, having a pulse rate of 40 pulses per minute (ppm) and a pulse width of 20 milliseconds (ms) with a transmitter life of 321 days.

We established standardized tracking methodology to avoid autocorrelation of location estimates (Otis and White 1999). We tracked pigeons in order of transmitter frequency, systematically changing the starting frequency each day. Only 1 pigeon location was recorded per observation. The minimum time interval between subsequent locations for any individual exceeded 1 hour. Pigeons were tracked using 2 different ATS radio tracking receivers, models FM-100 and R-2000. Pigeons were positively identified by the presence of the backpack transmitter and monitored with binoculars or spotting scopes from 25 to 50 m away. This was necessary to avoid influencing pigeon activity while data were being collected. We recorded site, location within site, date, time, and activity for each observation. All location data were collected using Magellan SportTrak™ Map GPS units and entered as Universal Transverse Mercator (UTM) coordinates; Datum NAD 1983.

## Home range

Home-range areas were estimated using 100% minimum convex polygon (MCP) and fixed-kernel percentage volume contours (FK). Other publications have suggested using more than 1 home-range estimator (Harris et al. 1990, Lawson and Rodgers 1997) and that one of the estimators should be 100% MCP because it is the most comparable estimator among studies (Kenward 2001, Moraes and Chiarello 2005). We selected the FK estimator because it provided the most realistic estimates of area use by radio-marked pigeons. The FK estimator is able to identify multiple centers of activity, is robust for analyzing outlier data, and allows the user to calculate home-range areas within any desired probability contour (Otis and White 1999, Kenward 2001, Kernohan et al. 2001). We selected 95% and 50% probability contours and estimated the contour smoothing parameter (bandwidth) using least squares cross validation (LSCV). Home-range areas ($Km^2$) were calculated for MCP and 95% and 50% FK probability contours.

All home-range estimates were created using Hawth's Analysis Tools (Spatial Ecology LLC). We entered pigeon location data separately for each radio-marked pigeon. We analyzed home-range data using SAS 9.1 (Statistical Analysis Software, Cary, North Carolina, USA). We made comparison of home-range areas between resident and nonresident pigeons using the Wilcoxon Rank Sum Tests. Correlations between sampling intensity (i.e., number of location observations) and home-range area estimates were assessed for 100% MCP, 95% fixed kernel, and 50% fixed kernel area estimates using Pearson Correlation Coefficients.

We used only pigeons with sufficient numbers of location observations to estimate home-range areas; 10 resident pigeons and 4 nonresident pigeons were used in the home-range analysis. We used the following criteria for inclusion in the analysis: (1) ≥ 50 point locations per bird; (2) resident pigeons remained roosting within active livestock facilities, and nonresident pigeons remained roosting at sites physically separated from livestock facilities for the duration of the study. Criteria were established based upon literature that suggests 50 location observations is a minimum threshold for reliable FK home-range estimation (Seaman et

al. 1999). Unfortunately, high pigeon mortality (i.e., 10 nonresidents and 2 residents) and lost transmitters (i.e., 3 nonresidents and 2 residents) limited the numbers of pigeons with an adequate number of location observations for home-range area analysis. One pigeon switched roosting locations (Resident 344-1). Because this bird continued to reside within a livestock facility, it was used in the analysis of home range.

## Pigeon travel distance

Using shape files created in ArcGIS 9.0, distance between points matrices were constructed with Hawth's Analysis Tools. The linear distance matrix generated estimates of travel distances between observed locations for each respective pigeon (Beyer 2004). We recorded travel distances in meters and measured them as straight-line distances from each pigeon roost to all point locations for each bird, respectively. Travel distance estimates were analyzed using SAS 9.1. A means model was constructed to estimate average travel distance for each of the 14 radio-marked pigeons. Means model output was used to test for differences in linear travel distance by roosting status (i.e., resident or nonresident).

We detected heteroscedasticity between travel distances for resident and nonresident pigeons ($\alpha > 0.05$; Levene's test for homogeneity). Therefore, Welch's ANOVA was used to test for the effect of roosting status on travel distances (DeBeuckelaer 1996). Mean travel distances are reported by roosting group with 95% confidence intervals. The dependent variable was mean travel distance and the independent variable was roosting status.

## Activity

We used data from all radio-marked pigeons with location observations to characterize daily pigeon activities. Weighted percentage of time engaged in activities were estimated for 26 pigeons (i.e., 13 resident and 13 nonresident pigeons). Activity data were weighted by the number of observations (sampling intensity) collected for each radio-marked pigeon. Pigeon activity was recorded at each observation event. If the pigeon flushed before the activity was documented, the observation was not recorded. All pigeon activities were characterized by 4 general activity classes: loafing, flying, feeding, and drinking. Activity observations generally did not exceed more than a few minutes, and data were systematically collected throughout the day from sunrise to sunset. No data were collected after pigeons returned to their roosts.

Loafing activity consisted of perching on any structure. Flight activity included any travel within or among sites. Feeding activity consisted of any foraging behavior, including eating grit or spilled feed within grain silos or on roads. Drinking activity consisted of drinking from any source, such as puddles, canals, crop rows, or water troughs. Perching on a water tower or open water trough did not qualify as drinking. When the birds were observed sitting on a trough but not drinking, the activity was recorded as loafing.

Weighted scores and mean percentages were calculated using Microsoft Excel (Microsoft, Redmond, Wash.). We analyzed activity data using the Kolmogorov-Smirnov 2 sample test with SAS 9.1 software.

## Habitat use

We used 14 pigeons to test for differences in the number of livestock facilities visited by resident and nonresident pigeons. Only pigeons with reliable home-range area estimates were included in the analysis. Analysis was conducted using an unpaired 2 sample t-test. Mean percentages and 95% confidence intervals were estimated.

We used data from all radio-marked pigeons with location observations to characterize habitat use. We generated weighted percentage estimates of habitat use for 26 pigeons (i.e., 13 resident and 13 nonresident pigeons). Habitat-use data were weighted by the number of observations collected for each radio-marked pigeon. Habitat use was defined as having 2 levels of spatial resolution, that is, sites and locations within a site. Site was defined as any habitat within which a pigeon was found (e.g., livestock facility, lake, and field). Location was defined as the areas used by pigeons within a site. For example, when a pigeon was found on a livestock facility, the site data referred to the specific livestock facility, and the locations within sites referred to the structures the pigeons utilized (e.g., feed bunker, water trough, or animal pen). Locations within sites other than livestock facilities were too few to

allow for statistical comparisons within and between roosting groups.

We conducted tests of within and among roosting group effects for sites and locations within livestock facilities using the Kruskal-Wallis and the Kolmogorov-Smirnov tests. We used Kruskal-Wallis to test for differences within roosting groups using a nonparametric 1-way ANOVA. We used Kolmogorov-Smirnov to test for differences between roosting groups. The Kolmogorov-Smirnov test identified which specific sites and locations within sites the greatest deviations between roosting groups occurred. All weighted percentage estimates were calculated using Microsoft Excel. Kruskal-Wallis, Kolmogorov-Smirnov and the unpaired 2 sample *t*-test analysis were conducted using SAS 9.1.

## Results

### Home range

Of 31 radio-marked pigeons, 12 birds were found dead (2 resident and 10 nonresident pigeons), and the disposition of 5 pigeons was unknown at the completion of the study. The remaining 14 pigeons were used to estimate home-range areas. Among these 14 pigeons, we observed no relationship between the number of location observations and the size of home-range areas for MCP (r = -0.21, df = 13, $P$ = 0.47), 95% fixed kernel (r = -0.38, df = 13, $P$ = 0.18), and 50% fixed kernel (r = -0.39, df = 13, $P$ = 0.17)

**Table 1**. Home-range area estimates for ($n$ = 14) radio-marked rock pigeons using minimum convex polygons (MCP) and fixed-kernel (FK) analyses. Bird = unique identification given to the radio-marked pigeons; Roost location = resident (On) or nonresident (Off) bird; Observations = number of location observations collected per pigeon; Home-range area = area (km$^2$) associated with each home-range estimate. All home-range data were collected from pigeons trapped within Weld County, Colorado, December 1, 2004, to September 1, 2005.

| Bird | Roost location | Observations ($n$) | Home-range area (km$^2$) | | |
|---|---|---|---|---|---|
| | | | MCP | FK 95% | FK 50% |
| 344-2 | On | 50 | 9.263 | 5.649 | 0.900 |
| 355 | On | 57 | 0.015 | 0.009 | 0.002 |
| 384 | On | 77 | 0.194 | 0.152 | 0.013 |
| 394 | On | 60 | 0.148 | 0.053 | 0.008 |
| 463 | On | 57 | 0.619 | 0.160 | 0.044 |
| 504 | On | 62 | 1.385 | 2.079 | 0.307 |
| 604 | On | 50 | 0.055 | 0.118 | 0.015 |
| 653-2 | On | 59 | 0.037 | 0.081 | 0.007 |
| 704 | On | 63 | 1.233 | 0.709 | 0.163 |
| 854 | On | 73 | 0.153 | 0.047 | 0.007 |
| 872-2 | Off | 51 | 14.926 | 14.357 | 3.688 |
| 594-2 | Off | 68 | 16.830 | 4.704 | 0.396 |
| 644-2 | Off | 54 | 8.748 | 2.840 | 0.364 |
| 696-2 | Off | 52 | 3.323 | 2.940 | 0.601 |

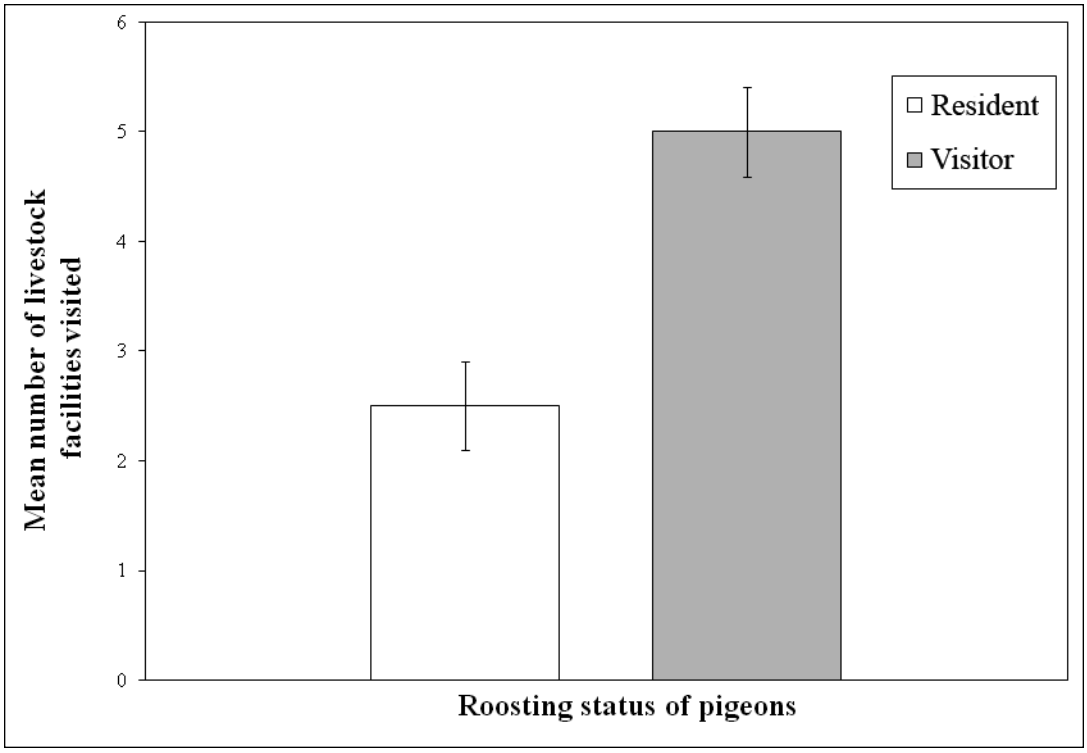


**Figure 1.** Mean number of livestock facilities visited by resident ($n$ = 10) and nonresident ($n$ = 4), radio-marked rock pigeons. Error bars denote the standard errors associated with the mean estimates for each roosting group. All data were collected in Weld County, Colorado, December 1, 2004, to September 1, 2005.

estimates, suggesting sampling intensity of ≥50 point locations was adequate to estimate home areas.

Nonresident pigeons had larger MCP home-range areas compared to resident pigeons ($T_{10,\,4}$ = 48, $P$ = 0.004). Median MCP home-range areas for resident and nonresident pigeons were estimated at 0.174 km$^2$ and 11.837 km$^2$, respectively. We analyzed area estimates for 95% and 50% fixed kernels separately. Nonresident pigeons had larger 95% fixed kernel home-range areas relative to resident pigeons ($T_{10,4}$ = 47, $P$ = 0.007). The 95% fixed kernels produced median area estimates of 0.099 km$^2$ and 3.822 km$^2$ for both resident and nonresident pigeons, respectively. Similarly, nonresident pigeons had larger 50% fixed kernel home-range area estimates compared to resident pigeons ($T_{10,\,4}$ = 47, $P$ = 0.007). The 50% fixed kernels produced median area estimates of 0.010 km$^2$ and 0.499 km$^2$ for resident and nonresident pigeons, respectively. All 3 area estimates indicate strong effects of roost location on home-range areas (Table 1).

## Travel distance

Levene's test for homogeneity of variances was significant ($F_{1,\,12}$ = 5.66, $P$ = 0.04), suggesting unequal variances among pigeon roosting groups. Using Welch's ANOVA, resident and nonresident pigeons' mean travel distances differed ($F_{1,\,3.32}$ = 9.13, $P$ = 0.05). Resident pigeons traveled an average of 292 m (95% CI, -196 ≤ $\bar{x}$ ≤ 782), whereas nonresident pigeons traveled an average of 2158 m (95% CI, 1383 ≤ $\bar{x}$ ≤ 2932).

## Activity

We observed no difference in activities between resident and nonresident pigeons ($KS_a$= 0.63, $P$ = 0.83). Resident pigeons ($n$ = 13) spent 81% (SE = 12%) of their time loafing, 16% (SE = 3%) feeding, 3% (SE = 0.6%) drinking, and 0.6% (SE = 0.3%) flying. Visitor pigeons ($n$ = 13) spent 76% (SE = 25%) of their time loafing, 18% (SE = 7%) feeding, 3% (SE = 1%) drinking, and 3% (SE = 2%) flying.

## Habitat use

The mean number of livestock facilities used

by nonresident pigeons was greater than that observed for resident pigeons ($t_{8.85}$ = 4.37, $P$ = 0.002). Nonresident pigeons visited an average of 5 facilities (95% CI, $3.70 \leq \bar{x} \leq 6.30$), and resident pigeons visited an average of 2.5 facilities (95% CI, $1.59 \leq \bar{x} \leq 3.41$) between December 1, 2004, and September 1, 2005 (Figure 1).

***Site use.*** Resident and nonresident pigeons used sites selectively (Figure 2). Livestock facilities were used by resident pigeons more than all other available landscapes ($\chi^2_6$ = 53.19, $P$ < 0.001). Excluding time spent loafing at their roost sites, nonresident pigeons used livestock facilities more than all other available habitat types ($\chi^2_6$ = 21.27, $P$-value = 0.003). Comparisons among roosting groups suggest that nonresident and resident pigeons had different site-use patterns ($KS_a$= 5.57, $P$ < 0.001), with the maximum deviations occurring from visitation rates to livestock facilities.

***Locations within sites.*** Comparisons among roosting groups suggested that nonresident and resident pigeons had different habitat use patterns within livestock facilities ($KS_a$= 3.66, $P$ < 0.001) with the maximum deviations occurring from visitation rates to grain elevators (Figure 3).

We detected differences in time spent at locations within livestock facilities for resident pigeons ($\chi^2_7$ = 33.72, $P$ < 0.001). We observed no difference in time spent at locations within livestock facilities for nonresident pigeons ($\chi^2_7$ = 11.69, $P$ = 0.11).

## Discussion

Nonresident pigeons visited more livestock facilities and traveled farther than did resident pigeons. This is consistent with previously published literature of urban pigeon populations, which suggests that 2 types of pigeon foraging flocks exist: regular and sporadic visitors (Lefebvre and Giraldeau 1984, Sol and Senar 1995). We showed that pigeons in agricultural landscapes demonstrated spatial-use patterns similar to that of their urban counterparts. Resident pigeons were characterized by small home-range areas with consistent food sources, and nonresident pigeons were characterized by large home-range areas with longer travel distances that were typical of pigeons with disjunct feeding and roosting sites (Janiga 1987, Sol and Senar 1995).

Based upon previously published research (Pedersen et al. 2006) and this study, we hypothesize that nonresident pigeons are

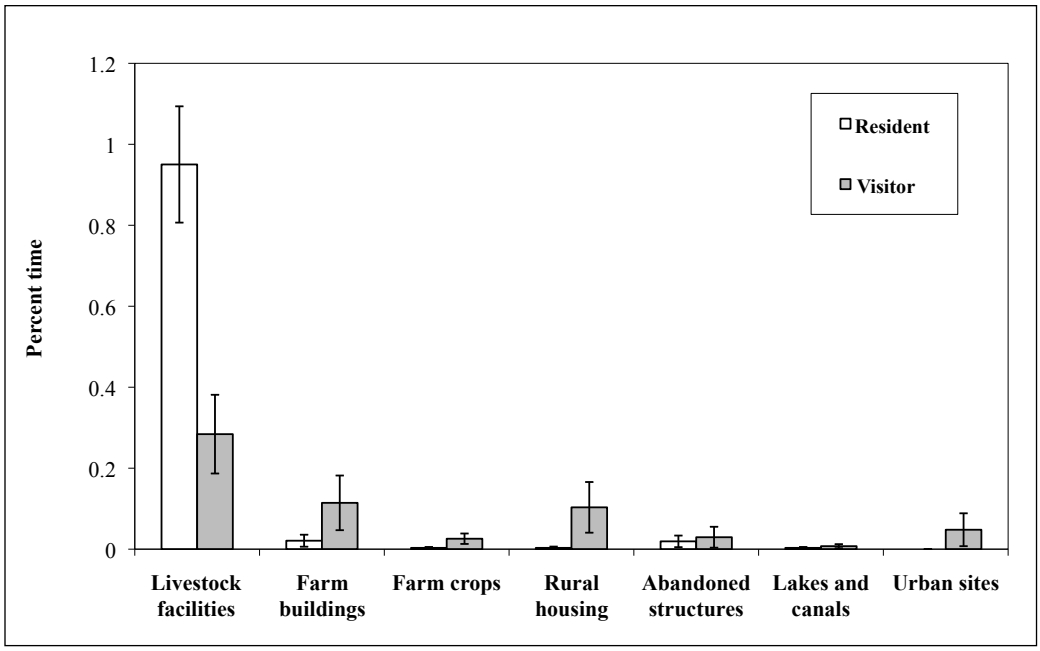


**Figure 2.** Weighted percentage estimates of time spent at sites by resident ($n$ = 13) and nonresident ($n$ = 13) radio-marked rock pigeons. Error bars denote the standard errors associated with the mean estimates for each roosting group. All data were collected in Weld County, Colorado, December 1, 2004, to September 1, 2005.

a high risk group for vectoring pathogens among livestock facilities and resident pigeon populations in northern Colorado. Thus, we predict that controlling nonresident pigeon roosts will have the greatest impact on reducing any pigeon-borne pathogen transmission that occurs among livestock facilities. Consequently, control of resident pigeon roosts will have a greater impact on reducing the maintenance and amplification of pathogens within livestock facilities than control of nonresident pigeon roosts.

Habitat-use data for resident pigeons supports Lefebvre and Giraldeau's (1984) prediction that pigeons provided abundant and reliable food sources will not utilize multiple feeding sites. Site-use data clearly show resident and nonresident pigeons using habitat within the landscape selectively, with both roosting groups preferring to feed within livestock facilities. We observed few pigeons feeding outside of livestock facilities, even though many other potential feeding sites within the MCP home-range areas of nonresident pigeons existed. Many of these alternate sites were closer to nonresident roosts than some of the feedlots they visited (e.g., agricultural crops, urban dumpsters, rural houses, and the Weld County Landfill). We hypothesize that pigeons use livestock facilities disproportionally more than other feeding sites because livestock facilities consistently provide abundant and highly nutritious food sources. Consequently, we predict that excluding pigeons access to livestock feed and water will be the most effective way to reduce pigeon use and occupancy of livestock facilities.

The locations within livestock facilities data helped identify specific areas that pigeons use and contaminate. The data suggest that resident pigeons used grain elevators and equipment barns more often than other structures within livestock facilities. It appeared that resident pigeons used these locations for loafing and roosting. Locations that contain feed, such as grain elevators, should be considered high-risk for pigeon-borne pathogens because feed can become contaminated by pigeon feces and then subsequently ingested by cattle; oral ingestion is the route of infection for fecal-oral pathogens, such as *S. enterica* (Wray and Davies 2000). Using a variety of commercially available bird exclusion devices, such as monofilament line, netting, porcupine wire, and electrified lines may deter pigeons from roosting at specific locations and encourage them to move to alternate locations within livestock facilities (Andelt and Burnham 1993, Williams and

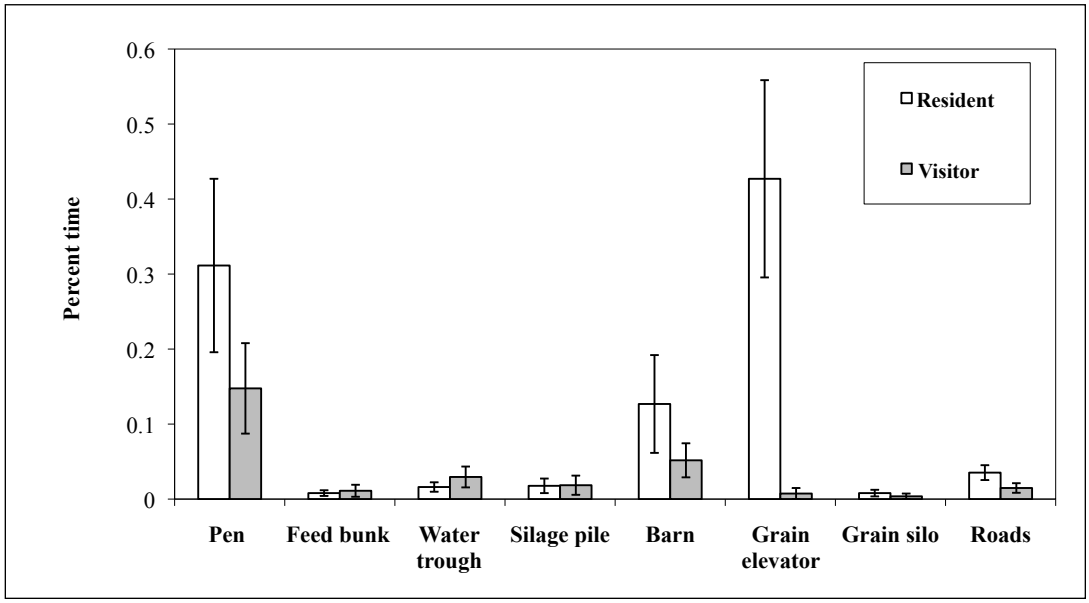


**Figure 3.** Weighted percentage estimates of time spent at locations within sites by resident ($n$ = 13) and nonresident ($n$ = 13), radio-marked rock pigeons. Error bars denote the standard errors associated with the mean estimates for each roosting group. All data were collected in Weld County, Colorado, December 1, 2004, to September 1, 2005.

Corrigan 1994). Thus, roosting deterrents in key structures may reduce the amplification of pathogens within livestock facilities.

When pigeons are perceived as a health risk in livestock facilities, controlling their populations may be a cost-effective way to reduce the occurrence of pathogens. Pigeons can be easily controlled on livestock facilities by the operators, but removal of the resident pigeons alone will not eliminate the source of the problem. Removal of pigeons on feedlots in conjunction with nonresident roost control will be the best way to eliminate high-risk individuals, while simultaneously preventing future problems. Unfortunately, control of nonresident pigeons is logistically much more complicated than control of resident populations. Livestock facility operators will not have the resources or ability to control pigeon populations across large geographical areas. Control of nonresident roosts will have to be coordinated through appropriate wildlife management agencies. Population control can be costly, and wildlife management agencies may lack the financial resources to implement pigeon control operations. Thus, cooperative service agreement between wildlife management agencies and livestock facility operators will probably be necessary to implement any large-scale pigeon control program. In the absence of a pigeon control program, removal of resident pigeon roosts, in conjunction with continued hazing and shooting of nonresident pigeons on livestock facilities, will likely be the most practical option for reducing the risk of pigeon-borne pathogens within and among facilities.

If it is determined that pigeon populations need to be controlled, then nonresident pigeons can be managed best by targeting roosts. Large numbers of pigeons can be removed by a few individuals, and exclusionary devices can then be used to prevent future occupancy. Also, targeting nonresident roosts may translate into large areas of effective bird control. This would increase the effectiveness of any operational control program and invariably reduce contact between pigeons within different livestock facilities and mitigate a potential route for the spread of pathogens among pigeons and the facilities they frequent.

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**James C. Carlson** (photo) is a wildlife biologist with the National Wildlife Research Center in Fort Collins, Colorado. His research focuses on wildlife damage in livestock operations. He received a bachelor's degree in wildlife biology from the University of Montana in 1996 and a master's degree in ecology from Colorado State University in 2005. In his free time he enjoys mountain biking and telemark skiing in the mountains of the western United States.

**Larry Clark** (photo unavailable) is the director of the National Wildlife Research Center (NWRC) in Fort Collins, Colorado, having served in this role since 2008. He previously served as the NWRC assistant director and project Leader for avian disease research and wildlife repellent discovery and development. He received a bachelor's degree in zoology from the University of Maryland, a master's degree in biology from Northern Arizona University, and a doctorate degree in biology from the University of Pennsylvania. He was also a recipient of a Public Health Service, National Research Service Award post-doctoral fellowship. When not working, he enjoys fly fishing and bird watching.

**Michael F. Antolin** (photo unavailable) has been professor of biology, at Colorado State University since 1992. He received his Ph.D. degree (1990) from Florida State University. His research interests include population biology and evolution of infectious diseases, especially plague in prairie dogs and chronic wasting disease in mule deer. He enjoys the outdoor life in Colorado, both in his garden and in the mountains, plains, and deserts of the West.

**Mo D. Salman** (photo unavailable) is a professor of veterinary epidemiology in the Animal Population Health Institute of College of Veterinary Medicine and Biomedical Sciences at Colorado State University. He holds appointments in the Department of Clinical Sciences. His educational background is in veterinary medicine, preventive veterinary medicine, and comparative pathology. His veterinary degree was from University of Baghdad, Iraq, and his MPVM and Ph.D. degrees were from University of California at Davis. He is a diplomate of the American College of Veterinary Preventive Medicine (ACVPM) and a fellow of the American College of Epidemiology (ACE).