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Site Use of European Starlings Captured and Radio-Tagged at Texas Feedlots during Winter

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ABSTRACT: We radio tagged and tracked 50 European starlings between December 2008 and January 2009 at 3 feedlots in the northern Texas Panhandle. Daily fidelity to sites of capture (home feedlots) was different among the 3 radio-tagged cohorts. Cohorts from Sites A and C were recorded at home feedlots on 48 and 59% of tracking days, respectively. The Site B cohort was at its home feedlot 95% of days. There were qualitative differences in use of home feedlots between cohorts A and C. The former were nearly obligate in their use of concentrated animal feeding operations (CAFO), whereas the latter tended to balance their use between CAFO and a nearby urban center. Six birds (12%) used either one or both of the counterpart home feedlots. Of these, 5 permanently switched from their home feedlots and used counterpart home feedlots; one bird captured at Site B alternated between Sites A and C after abandoning its home feedlot. Use of roost sites depended on habitat composition surrounding the study feedlots. Urban habitats were used as roosts by several birds from Sites A and C, whereas birds using Site B roosted at a petroleum refinery and a reservoir. Some Site B individuals used both roost sites during the study period; however, the reservoir was the preferred roost site. Daily activities in habitats away from the home feedlot generally occurred ≤5 km from the home feedlot. For birds from Sites A and C, offsite habitats were mainly urban areas and small CAFO. Increased habitat heterogeneity, as exemplified in our study by urban habitats and CAFO near Sites A and C, seemed to reduce rates of daily use of home feedlots. Heterogeneous environments can complicate management strategies that use DRC-1339 Concentrate for reducing starling numbers at infested CAFO. First, starlings may be erratic in their daily use of a CAFO in complex environments. Secondly, urban areas, when present, may be used as refuges by poisoned birds, leading to adverse public exposure.

KEY WORDS: birds, cattle, European starlings, radio telemetry, roosting, site use, *Sturnus vulgaris*, Texas

INTRODUCTION

European starlings (*Sturnus vulgaris*) are an introduced, Old World passerine species abundant and widespread in North America. In 2006, European starlings (henceforth, starlings) were the fourth most abundant breeding bird in North America (Sauer et al. 2009). The breeding population in North America is probably 200 million, which is about ⅓ of the world's population (Feare 1984). During winter, starlings forage at sanitary landfills, abattoirs, and concentrated animal feeding operations (CAFO). Open-trough feeding systems used mainly by CAFO in cattle production are heavily exploited by starlings from early fall through winter. Starlings may aggregate at smaller CAFO by the tens-of-thousands and by the hundreds-of-thousands at larger facilities (Gaukler et al. 2008, Linz et al. 2008). Starlings eat about 3 metric tons of cattle feed per 1,000 birds per winter (Besser et al. 1968). Moreover, they may cause indirect costs to livestock producers. For example, starlings deplete the high-energy content of feeds through selective foraging, which can cause reduced rates of weight gain (Besser et al. 1968, Homan et al. 2010). Lastly, although evidence remains circumstantial, starlings may be contaminating feed and water supplies with bacterial and viral pathogens carried in their feces. This may cause diseases to spread within and among livestock herds, and from this source into the public food chain (Linz et al. 2007, Colles et al. 2008, LeJeune et al. 2008, Gaukler et al. 2009).

Our objectives were to 1) quantify daily use of CAFO by wintering starlings, 2) identify use of other habitats offsite, 3) estimate distances ranged during daily activities, and 4) locate and monitor roosts. Our goal was to acquire knowledge on spatial use and wintering behavior of starlings using CAFO that could help in developing more effective strategies for managing large populations of starlings with DRC-1339 Concentrate (3-chloro-4-methylaniline hydrochloride), an avicide used by USDA Wildlife Services. Our results may also be useful for estimating distances that wintering starlings could disperse pathogens among CAFO.

STUDY AREA

The study sites were near Dumas, Texas, (35.86°N, -102.01°E) in Moore County in the northern Texas Panhandle. Moore County (2,300 km²) had 20,000 human inhabitants in 2008. The study area lies in the Western High Plains ecological region (Omernik 1995). The general topography consists of smooth, undulating plains with elevations ranging from 800 to 1,200 m above sea level. The region has a semi-arid climate with 46 cm of precipitation, annually. The average temperature is

13°C. During the study period, daily average temperatures ranged between -10° and 12°C, with a mean temperature of 4°C, 2°C above the 30-yr average. Precipitation totaled 0.2 cm, 3 cm below the 30-yr average.

Blue grama (*Bouteloua gracilis*) and buffalo grass (*Buchloe dactyloides*) were the native vegetation. The extensive tracts of prairie shortgrasses have been converted for agricultural uses and energy development. Small grains (e.g., sorghum and wheat) and corn were the major crops. Corn is produced mainly for livestock feed and is often raised by use of center-pivot irrigation systems. In 2008, corn and small grains were planted on 24,000 and 65,000 ha, respectively, representing 39% of the county's land area (USDA NASS 2010). Moore County has about 170,000 head of cattle and calves in production. Surrounding counties were also included in the study area because of several large feedlots in the vicinity of Moore County. The total study area was approximately 20,000 km². All of the surrounding counties were within the Western High Plains ecoregion.

METHODS
Site Selection

In early December 2008, we searched for CAFO. We found 20 CAFO with potential to consistently attract starlings (Figure 1). Of these, 5 sites held trappable numbers (≥1,000) on consecutive visits; all were cattle feeders. We selected 3 study sites with an average distance between them of 18 km (±2.7). They ranged in size from 22,000-75,000 ($\bar{x}$ = 48,000 ±15,000) head. We wanted the study sites to be close as possible to each other to improve the chances of having a quantifiable number of inter-site exchanges by radio-tagged cohorts. The other 17 CAFO in the study area were visited and monitored weekly throughout the study period ending 28 January 2009.
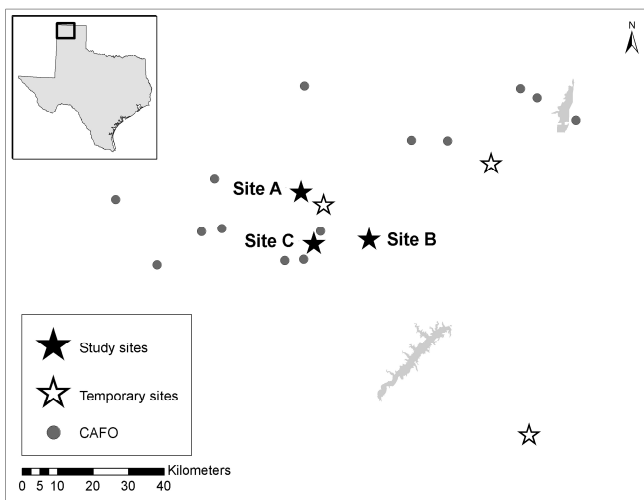

Figure 1. Locations of Concentrated Animal Feeding Operations (CAFO) in the study area used to track movements and site use of radio-tagged European starlings captured at 3 cattle feedlots in Texas during December 2008.

Radio Tagging

Mist nets and decoy traps were used for capturing. We allowed natural variation to determine the sex ratio of the birds we radio tagged. The birds were aged and sexed according to external characteristics (Kessel 1951, Schwab and Marsh 1967, Smith et al. 2005). We used Model A2440 VHF radio transmitters (frequency range: 164.000 - 167.999 MHz; Advanced Telemetry Systems, Inc., Isanti, MN). The radios weighed 2 grams, generated 40 radio pulses min⁻¹, and had a warranted battery life of 50 days. The optimum line-of-sight transmission range was about 2 - 3 km, but ranges were generally ≤1 km with our receiving systems (Homan et al. 2006). The radio transmitter was mounted on the anterior dorsal surface of the starling's fused pelvic region by a loop harness consisting of narrow elastic cord (~1 mm diameter). The harness slid over both legs and fit snugly in the proximal portions of the thighs (Rappole and Tipton 1991). The transmitter was attached to the top of the elastic harness by excavating shallow grooves in the transmitter's surface, placing the harness laces in the roughened grooves, and gluing over with epoxy (Mennill 2000, LeJeune et al. 2008). Total mass of the radio and harness was 2.2 g. Birds used for the study were ≥75 g so that the radio pack was ≤3% of body mass. Before releasing the radio-tagged birds, we identified each transmitter by its frequency and checked for its functionality. The birds were banded on the left leg with a No. 2 U.S. Fish and Wildlife Service aluminum band and released immediately thereafter.

Tracking

We provided a 3-day acclimation period before collecting data, which allowed the birds to become accustomed to the radio harness. Presence-absence was monitored at the 3 study sites with a fixed receiving system. The system consisted of an elevated, 6-element yagi antenna cabled to a programmable, data-logging receiver (R4500s Digital Signal Processor; Advanced Telemetry Systems, Inc.). The station was placed in a panoramic location away from buildings and other objects that could dampen or block radio signals. The fixed systems ran 24 hr day⁻¹ and were powered by 12-volt deep-cycle marine batteries. The battery-receiver complex was placed in weatherproof containers. We downloaded stored data every 2 - 3 days to a laptop PC. All receivers were time and date synchronized prior to deployment. We used a 6-sec scan time for each radio frequency (*n* = 50). When a frequency was detected, the receiver would monitor it for 90 sec and store the strongest signal recorded during that time. Signals were stored every 30 min, with only the strongest signal being saved over that time. The saved data included date, time, radio frequency, number of radio pulses in 90-sec intervals, and signal strength. We also installed fixed receiving systems at 3 other CAFO in the study area (Figure 1). The receiving systems were installed temporarily, usually for about 7 - 10 days. We felt these sites, which were being used consistently by large flocks of starlings, should be monitored more closely than was achievable through our mobile receiving system.

The mobile receiving system was used to search for radio-tagged birds not attending CAFO monitored by fixed receiving systems. The mobile unit was a 4-wheel drive pickup truck with a roof-mounted, rotatable set of antennae consisting of dual 6-element yagis. Each yagi was cabled to a null-peak system box, which in turn was linked by coaxial cable to a R4500s DSP with a GPS unit. The mobile receiving system made visits 1 - 2× weekly to all CAFO in the study area. It also tracked birds at offsite habitats, roost sites, and staging areas.

Analyses

The decimal-degree coordinates of the locations of each radio-tagged bird were imported into a dynamic, inquiry-oriented, base map in GIS. The base map consisted of a mosaic of high-resolution (1-m), digital orthophoto quadrangles of the study area, along with county and city boundaries, and roadways. The base map was used to assign habitat type when data were taken offsite by the mobile receiving system. The study site where the bird was initially captured was classified as the bird's home feedlot. Site use and comparisons among study sites were based on this classification. Offsite use was described by the percentage of active cohort members using a site, because one bird could use multiple sites, combined percentages of offsite use could exceed 100%. Radio-tagged birds that switched feedlots to a counterpart study feedlot, and remained committed after switching, were reclassified to the new site's cohort. We used the metric 'tracking days' to quantify percentage use of study sites between 0900-1600 h. Daily use of the home feedlot was calculated by dividing total number of days that a bird's radio signal was detected at its home feedlot by total number days from the end of the acclimation period until the end of the study period (28 January). Tracking success was the total number of days that a bird's radio signal was detected anywhere in the study area divided by the same denominator as described above. Proportions were converted and reported as percentages.

The raw data were culled and extracted using Visual Basic® for Applications. The application platform was Excel®. Birds were analyzed individually and in combination by site using Excel pivot tables. Differences among home feedlots in percentage daily use and tracking success were tested with the Kruskal-Wallis test using multiple comparisons (Siegel and Castellan 1988). We could not assess for statistical differences in percentage daily use between sexes because of an imbalance in

sample size that strongly favored males over females. Statistical significance was accepted at $P \leq 0.05$. Means were reported with standard errors.

RESULTS
Daily Activities

Of 50 starlings radio tagged (13F, 36M, 1 Unk), 48 provided data following the 3-day acclimation period (Table 1). More starlings were radio tagged at Site B ($n = 20$) than either Sites A ($n = 15$) or C ($n = 15$) because Site B had the largest population of starlings (~150,000). Sites A and C had populations estimated at ≤5,000. Daily fidelity to home feedlots was different among the 3 radio-tagged cohorts ($\chi^2 = 23.8$, 2 d.f., $P <0.001$). Cohorts from Sites A and C were present at home feedlots on 48% (SE = 8, $n = 15$) and 59% (SE = 7, $n = 14$) of tracking days, respectively, whereas the Site B cohort was at its home feedlot 95% (SE = 4, $n = 19$) of days. Percentage daily use was not statistically different between Sites A and C. Despite the significantly lower rates of daily use by cohorts A and C, tracking success did not differ among the 3 study sites ($\chi^2 = 5.2$, 2 d.f., $P =0.07$). When not present at home feedlots, birds used sites that averaged 5 ± 0.8 km from the home feedlot (Figure 2); offsite habitats used ranged from 1 - 9 km from home feedlots. For birds from Sites A and C, favorite offsite habitats were urban areas or small-sized CAFO; 64% of Site A birds used a small dairy to the southeast, and 71% of Site C birds used an urban area to the south. Birds from Site B spent nearly all of their day at the home feedlot or in the open fields and pastures surrounding it. Only 2 birds from Site B were located offsite; they were using a petroleum refinery 7 km northwest of Site B. The birds were recorded at the refinery only once, and it occurred during the first hour (0900 h) of the daily activity period. In both instances, the birds moved back to Site B by 1100 h. These same birds also used the refinery as their roost site.

Six birds (12%) switched affiliation to counterpart home feedlots during the study period (Table 2). Of these, 5 became fully committed to the new sites after switching sites, whereas one bird captured at Site B alternated between Sites A and C after abandoning Site B. Site A was the least autonomous of the 3 study sites, with 3 birds of 15 sampled (20%) relocating to either Feedlots B or C (with one bird using both, serially). Feedlot B had 2 birds of 19 tagged (10%) relocating to either Feedlot A or C; and lastly, Feedlot C had one bird of 14 tagged (7%) switching to Feedlot B. Except for one instance

Table 1. Percentage daily use of 3 feedlots by European starlings that were captured and radio tagged at the feedlots during December 2008 in the northern Texas Panhandle.

Sites	Sample Size	Capture Dates	Average Days Tracked[1]	% Tracking Success[2]	% Daily Use Home Feedlot[3]
A	15	12/11-12	33 ± 3	72 ± 7	48 ± 8
B	19	12/5-6	41 ± 3	79 ± 5	95 ± 4
C	14	12/14-16	28 ± 2	65 ± 5	59 ± 7

[1] Total number of days 3-days post transmitter attachment that a radio-tagged bird's radio frequency was logged by either a fixed or mobile receiving system
[2] Percentage of days between the end of the 3-day acclimation period and the last day of the study (28 January 2009) that a transmitter signal was recorded in the study area by either a fixed- or mobile receiving system
[3] Percentage of days between the end of the 3-day acclimation period and the last day of the study (28 January 2009) that a transmitter signal was recorded at the feedlot (i.e., Sites A-C) where the bird the was captured (home feedlot)

Table 2. Six radio-tagged European starlings that switched use of study sites during a radio telemetry project conducted at 3 feedlots (Sites A-C) in the northern Texas Panhandle during winter 2008-2009.

Bird	Sex	Capture Site	Captured (month/day)[1]	New Site	Date Arrived	Last Logged[2]
4095	M	A	12/12	B	12/15	1/28
4344	M	A	12/12	B	12/15	1/19
4369	M	A	12/12	C-B[3]	12/22-12/31	1/28
4032	F	B	12/5	A&C	—[4]	1/28
5556	M	B	12/5	A	12/18	1/26
4157	M	C	12/14	B	1/19	1/28

[1] There was a 3-day acclimation period following the date of capture and attachment of the radio tag.
[2] The final day of the study was 28 January 2009.
[3] Bird 4369 serially switched from Sites C to B, remaining at Site B upon moving there on 31 December.
[4] Bird 4032 never committed to either Sites A or C and used both sites intermittently throughout the study.
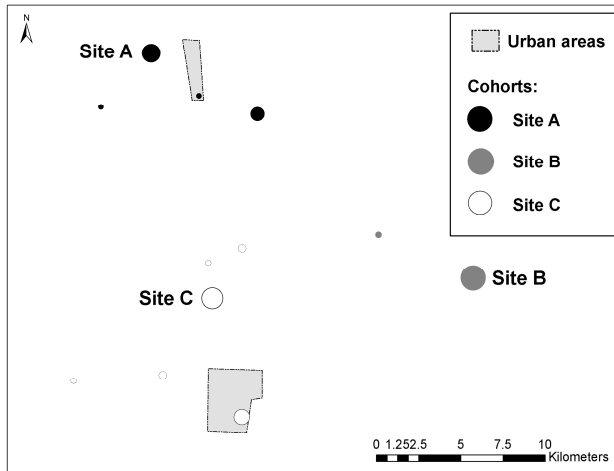

Figure 2. Daytime use (9:00-16:00) by cohorts of radio-tagged European starlings captured at 3 study sites in Texas during December 2008. The circled areas are graduated proportionally to represent use. The proportions were derived by dividing the number of individual birds using a site by the number of members in the site's active cohort. The proportions by site were calculated with replacement so it was possible for an individual to contribute to multiple sites.

involving one day, once birds switched feedlots they never returned back to use their original home feedlot. Therefore, the percentage of inter-site switching can be considered each site's turnover rate for the study period.

Roosting

No birds using Site B roosted in urban areas, whereas 33% ($n = 5$) of birds from Site A and 78% ($n = 11$) from Site C used this habitat. Unlike Site C, however, where the urban area was the primary roosting site, the preferred roost (47%, $n = 7$) for Site A birds was a dairy (open-sided construction) 4 km to the southwest of Site A. One bird from Site A used the same urban roost used birds from Site C (Figure 3). The bird maintained this behavior (i.e., 42-km roundtrip flights from its roost to Site A) for 7 days, then switched its daily allegiance to Site C. The sharing of a roost site by members of different cohorts also occurred at an industrial area between Sites B and C. A petroleum refinery and a stand of common reed (*Phragmites australis*) were used by Site B birds. Nine birds from Site B used both sites. Over the study period, 58% ($n = 11$) of birds using Site B used the refinery and

63% ($n = 12$) used the stand of common reed. The roost in common reed, 33 km southeast of Site B in a reservoir, was used more often (i.e., total days) than the refinery roost. A roost site at the dam on the east end of the reservoir was used by one bird. This site had historically been a major roosting site. The bird using this site quickly joined the major roost site to its west and never returned to the east end. The reservoir roost was a mixed-species roost, including several species of blackbirds. Roosting at the study sites occurred at Sites B ($n = 3$) and C ($n = 3$). There were no instances of different cohort members sharing the same study-site roosts. The use of study site feedlots for roosting was sporadic, with the birds also using the roosts associated with each study site.
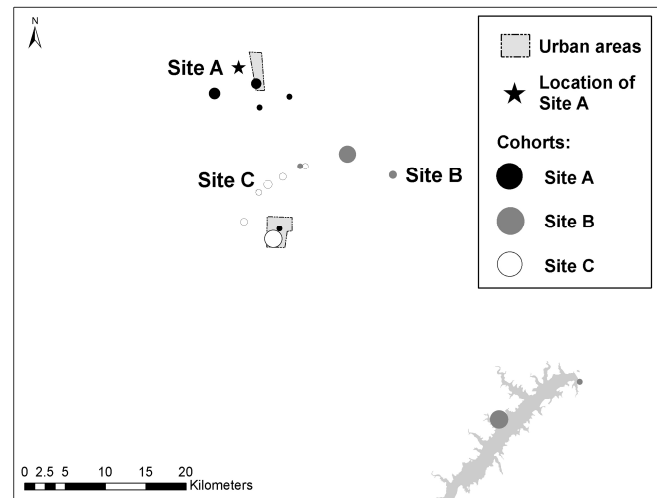

Figure 3. Roost sites of radio-tagged European starlings captured at 3 study sites in Texas during December 2008. The circled areas are graduated proportionally to represent use. The proportions by site were calculated with replacement so it was possible for an individual to contribute to multiple sites.

DISCUSSION
Daily Activities

Outside of the migratory periods, starlings limit their movements and use small-sized areas for foraging and loafing activities. Starlings may also return daily to specific sites, often for several weeks or longer (Caccamise 1991). Site fidelity has been a recurring theme in all our radio telemetry projects conducted thus far on wintering starlings using CAFO (Gaukler et al.

2008, LeJeune et al. 2008). A thorough knowledge of the habitats and food resources within a confined area may provide a survival advantage. Using the same area and restricting movements could lower predation risks and enhance foraging success (Caccamise and Morrison 1986, Tinbergen 1981). Selection pressure from predation and inefficient foraging may be the reason that site fidelity behavior is also used by starlings in urban-rural landscapes (Morrison and Caccamise 1985, Caccamise and Morrison 1986, Homan et al. 2006).

In Kansas, radio-tagged starlings did not start expanding their daily activity areas until mid February (S. M. Gaukler, No. Dakota St. Univ., unpubl. data). This period probably coincided with initial defense of breeding territories for local birds and the onset of pre-migratory restlessness in transient populations. Based on the observations in Kansas, the project in the Texas Panhandle probably finished a few weeks before the start of pre-migratory restlessness for birds in this region. If the study had gone into February, we would have likely seen an increase in use of offsite habitats, larger daily activity areas, and more exchanges of cohort members among study feedlots.

We had an imbalance between the number of male and female starlings captured, with males comprising 73% of the radio-tagged sample. Samples collected at CAFO tend to have more males than females, and apparently our sample was not an anomaly. Highly skewed distributions in starling sex ratios have been observed at CAFO by Feare (1980) and Glahn et al. (1987). Indeed, the sample collected by Glahn et al. (1987) consisted of 72% males. The results in our study should be considered in light of this imbalance, and we are not certain if females truly fit the same model of behavior we have described; however, we believe that unbalanced sex ratios are probably inherent in wintering populations of starlings using CAFO, and that our sample was random and the results applicable to the population. Sexual habitat selection in birds is widespread during the non-breeding period (Hill and Ridley 1987, Marra 2000). The bias toward male starlings at CAFO is probably from what is termed 'interference behavior', which results from intraspecific conflicts between dominant and subordinate individuals over habitat resources (Gauthreaux 1978). Starlings have a monogamous mating system and any analysis on the impacts of state-level management programs at CAFO on regional breeding populations should take the interference phenomenon into account. Additionally, the unbalanced sex ratios at CAFO could affect results of bioenergetic models used to make DRC-1339 mortality estimates from treatments at CAFO. Among the several variables used in bioenergetic models is bird mass, and it may be necessary skew mass distributions toward males (Homan et al. 2005).

Roosting

Use of roost sites depended on the habitat composition of the landscape in which the feedlots occurred. The influence of urban habitat on roost choice was very strong at Site C, with nearly 80% of the starlings roosting in urban habitat. The urban area near Site A was much smaller in size and was used by a smaller percentage of the Site A cohort. The low rate of use of urban habitat compared to Site C was probably related to the lower number of good roosting sites. The birds using Site B never used urban habitats for roosting, even though the urban roost of the Site C cohort was closer to Site B (16 km) than the reservoir roost. We observed that the birds using the reservoir roost would leave *en mass* about an hour before sunset, with the flightline quickly attaining an altitude of several hundred meters. They took a direct bearing for the reservoir roost, and we never saw flocks breaking away from the flightline. Urban areas in agricultural ecosystems rarely get to the size that could accommodate such a large congregation of starlings. We speculate that very large groups of roosting starlings generally will choose roost sites in areas where human disturbance is minimal (Homan et al. 2006, LeJeune et al. 2008). Often these sites are in dense stands of emergent cover with stable water depths. Such sites will often be used by the majority of the population in the area, as was the case for starlings that were using CAFO in Ohio and Kansas (Gaukler et al. 2008, LeJeune et al. 2008). We believe that the contiguous stand (≥10 ha) of emergent vegetation at the reservoir roost was the reason that Site B held a much larger population of starlings than the other study sites. Among the CAFO used by Gaukler et al. (2008), the one with the largest daily population of starlings (250,000) was also the one nearest (20 km) the largest stand of dense emergent vegetation.

Management Implications

Site B was a CAFO in a homogenous agricultural landscape. The starling population using it had low rates of weekly turnover (1%) and high rates of daily visits, apparently because of the lack of habitat diversity within ranges typical used by starlings for daily activities. Thus, population management with DRC-1339 Concentrate at this site (and sites like it) should carry a low risk of negative publicity from die-offs and be highly effective at reducing the targeted population. Conversely, Sites A and C would be more difficult to manage, with greater chances for negative publicity and reduced efficacy because of the diversity of the surrounding habitats and the way these habitats were used by starlings (Caccamise 1990).

Daily site use differed qualitatively between Sites A and C. The birds from Site A remained more or less obligate users of CAFO, whereas the Site C group were generalists, using urban habitat and CAFO. By the end of the first week in January, the majority of Site A birds had abandoned their home feedlot and had moved to a small dairy 7 km to the southeast. The abandonment began with a few birds moving to the dairy in late December. With minor exceptions, the daily use variables for Sites A and C need to be interpreted differently. At Site A, daily use represented the percentage of days that the cohort used the site. At Site C, it was the percentage of birds using the site on any given day. Our mobile tracking system indicated that on some days the Site C birds never left urban habitat. The urban area by Site C was large enough that it probably offered adequate foraging and loafing opportunities for starlings. The qualitative differ-

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ences in daily use between sites would require different management strategies if DRC-1339 Concentrate was used. Site A could be a success or failure, depending on awareness of the applicator to changes in use of the targeted site and on local knowledge of possible alternate CAFO that birds were using. This knowledge could be gained through viewing high resolution satellite images to locate neighboring CAFO near (<10 km) the targeted CAFO. Satellite images are available for viewing and downloading from the World-Wide Web (e.g., Google Earth™ and Microsoft® Virtual Earth™). A DRC-1339 treatment at Site C has the potential to reduce the starling population using it by 60%, with 40% of the birds not likely to be present. At Site C, knowledge of the locations of surrounding CAFO would not help much because the birds at Site C preferred urban habitat over any of the offsite CAFO. The slow-acting nature of DRC-1339 avicide would likely cause die-offs to occur in the urban area. Thus, using DRC-1339 to manage the population at Site C may not be the best management option.

Persistent fidelity to sites and use of small-sized areas for daily activity also has implications for the transmission of pathogens among CAFO. Over the study period, 12% of the pooled, radio-tagged sample established residence at a feedlot different than the capture-site feedlot. We estimated that the total population size we sampled from was 170,000 birds. Assuming that our sample accurately represented use behavior by the study population, each radio-tagged bird represented 3,500 birds. This extrapolates to about 21,000 birds in the population moving from one CAFO to another; certainly, enough individual movement among feedlots for starlings to be a potential risk if they are biological vectors of pathogens. The role of starlings in the transmission of *Salmonella enterica* and coccidian protozoa at cattle feedlots is currently being done in the northern Texas Panhandle (A. Franklin, National Wildlife Research Center, Fort Collins, CO, unpubl. data). Preliminary results suggest that starlings may be a source for *S. enterica*, but not coccidia (J. Carlson, National Wildlife Research Center, Fort Collins, CO, unpubl. data). If true, then starlings could be responsible (at the least) for spreading *S. enterica* within herds. The rate and distance of transmission of *S. enterica* bacteria among neighboring CAFO may be limited by the starling's strong site fidelity during the wintering period, which reduces the number of inter-CAFO visits and exposure times.

ACKNOWLEDGEMENTS

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