Effect of a reduction in cattle stocking rate on brown-headed cowbird activity

Richard M. Kostecke, James A. Koloszar, and Donald C. Dearborn

Abstract Brood-parasitic cowbirds (*Molothrus* spp.) can severely impact host populations. Cowbird removal is the primary means of reducing parasitism. As an alternative to removal, we evaluated the reduction of cattle stocking rate as a tool to shift cowbird-breeding activity away from a breeding area of a sensitive host. Activity of radiotagged, female brown-headed cowbirds (*M. ater*) breeding on Fort Hood, Texas, a United States Army installation that contains a large population of federally endangered black-capped vireos (*Vireo atricapilla*), was monitored 2 years before and 2 years after a reduction in cattle stocking rate. We predicted that cowbirds would respond to the reduction by shifting both foraging and breeding activities toward more distant herds of cattle. Reduction in stocking rate did not have the desired effect of shifting cowbird breeding areas off the study area, though parasitism rates were lower following the reduction. Following the reduction, cowbirds eventually shifted foraging activity off the study area to sites where more cattle were present and tended to commute greater distances between breeding and foraging sites. Assuming that commute distance between breeding and foraging sites was energetically limiting, the cost of the increased commute may have reduced the number of eggs produced by female cowbirds over the breeding season, thus reducing parasitism. Effectiveness of our stocking rate reduction, even when applied at a large scale (9,622 ha), was reduced by the presence of alternative foraging sites within distances that cowbirds were willing to commute. Removal of cowbirds by trapping likely will remain the most effective means of maintaining a sustainable black-capped vireo population on Fort Hood.

Key words black-capped vireo, brood parasitism, brown-headed cowbird, commute distance, grazing, *Molothrus ater*, songbird conservation, Texas, *Vireo atricapilla*

Brood-parasitic brown-headed cowbirds (*Molothrus ater*) can have severe negative impacts on the reproductive success of their hosts (Marvil and Cruz 1989, Hayden et al. 2000), thus reducing host population viability (Robinson et al. 1995). In such cases, active management of cowbirds may be necessary to reduce nest parasitism rates (Rothstein and Cook 2000). Active management typically involves trapping and killing large numbers of cowbirds. This practice has been successful in some situations (Griffith and Griffith 2000), but has been subject to criticism. Namely, removal programs are costly and have no foreseeable endpoint (De Groot et al. 1999, DeCapita 2000, Rothstein and Cook 2000). Although host populations may rebound during periods of low parasitism resulting from cowbird removal, cessation of removal frequently results in a resurgence of high parasitism rates, low host reproductive success, and a reduction of host population viability. Managers are generally aware of the shortcomings of removal programs. For example, the recovery plan for the federally endangered black-capped vireo (*Vireo atricapilla*) states, "the current practice of site-specific cowbird removal, by itself, will not provide for long-term recovery of specific populations" and "additional

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methods of reducing the threat from cowbirds need to be investigated" (United States Fish and Wildlife Service [USFWS] 1991:34).

An alternative method of managing cowbirds might be cattle management. In landscapes where cattle provide the primary foraging opportunities for cowbirds (Morris and Thompson 1998, Goguen and Matthews 1999), it may be possible to modify activity areas of cowbirds by relocating cattle or reducing stocking rates (Goguen and Mathews 2000). However, brood parasitism and its consequent lack of parental care have allowed the spatial decoupling of cowbirds' breeding and foraging areas, and cowbirds routinely commute between different habitats to engage in each of these activities (Rothstein et al. 1984, Thompson 1994). Thus, it is not clear that causing a spatial shift in cowbirds' foraging areas would necessarily result in a concomitant shift in their breeding area.

Our interest in cowbird management stems from concern over a population of black-capped vireos breeding on Fort Hood Military Reservation in central Texas. The impact of cowbird parasitism on black-capped vireos is severe (USFWS 1991). A cowbird removal program was implemented on Fort Hood in 1988 and has been successful in reducing the frequency of parasitism on black-capped vireo nests (Eckrich et al. 1999). Nevertheless, there is interest in evaluating other management options. Shifting breeding activity of cowbirds off Fort Hood might offer an alternative or complementary management technique for protecting black-capped vireos because the land surrounding Fort Hood was primarily agricultural and thus would not be occupied in great numbers by this host species.

We assessed the impact of a reduction of cattle stocking rate on Fort Hood on cowbird activity and movements. We tested 3 alternative hypotheses: 1) reduction of cattle stocking rate would cause cowbirds to shift all activities (foraging and breeding) toward more distant herds of cattle; 2) reduction of cattle stocking rate would cause cowbirds to shift their foraging areas toward more distant herds of cattle, but cowbirds would continue to use the same breeding areas; and 3) cowbirds would maintain their initial breeding and foraging areas despite the reduction in cattle stocking rate.

Study area

The Fort Hood Military Reservation occupies approximately 88,500 ha within the Crosstimbers and Southern Tallgrass Prairie Ecoregion (The Nature Conservancy 1997) within Bell and Coryell counties in central Texas. Land area on Fort Hood was 65% perennial grassland and 31% woodland (United States Army Land Condition Trend Analysis Program, unpublished data). Fort Hood was used primarily for military training, but also was managed for other uses (e.g., recreation, fish and wildlife habitat, and cattle grazing).

Our study was conducted on the eastern portion of Fort Hood (hereafter "East Range") in an area bordered to the north by the Fort Hood property boundary, to the south and east by Belton Reservoir, and to the west by East Range Road (Figure 1). The study area encompassed 9,622 ha dominated by mixed Ashe juniper (*Juniperus ashei*) and oak (*Quercus* spp.) woodlands. A number of perennial grasslands and shrub complexes occurred within this area, including several large, open pastures where cattle were concentrated. Black-capped vireo nesting habitat occurred within the study area. Habitat similar to that found on the East Range existed elsewhere on Fort Hood. Private lands adjacent to our study area were predominantly used for cattle grazing and hay production. Other landscape features of these private lands included bottomland drainages, old fields, patchy woodlands, and row crops (i.e., corn and milo).

Areas equivalent in size to our East Range study area with similar landscape configuration and structure did not exist on Fort Hood, thus limiting our ability to establish controls and replicates. Access to much of Fort Hood was restricted (i.e., the Live Fire area; Figure 1). Thus, establishment of controls and replicates would have been limited to the Southeast Range, West Range, and West Fort Hood. Unlike our study area, the Southeast Range borders developed areas (i.e., the Fort Hood Cantonment and the City of Killeen) and contained fewer black-capped vireos (The Nature Conservancy of Texas, Fort Hood, Texas, unpublished data). The landscapes of the West Range and West Fort Hood contained woodland habitat similar to that found on the East Range, but this habitat was more fragmented. Stocking rate of cattle also varied widely across Fort Hood (T. W. Buchanan, Army Natural Resources Management Branch, Fort Hood, Texas, personal communication). Political resistance to cattle reductions elsewhere on Fort Hood further restricted our ability to implement replication.

A base-wide, year-round cowbird trapping program has been implemented on Fort Hood since

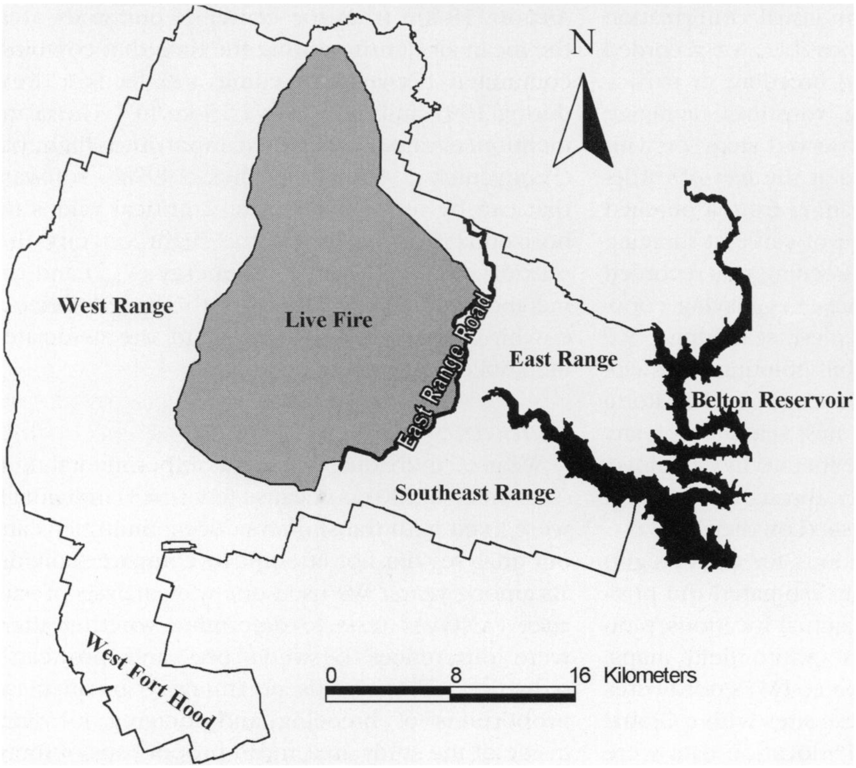

Figure 1. Location of East Range study area on Fort Hood, Texas, where activity and movements of radiotagged female brown-headed cowbirds were monitored during 1995–1998.

1988 (Eckrich et al. 1999). However, cowbird trapping was curtailed within the interior of our study area from 1994-1998 to reduce its potentially confounding influence on the results of our cattle manipulation. Because trapping was mandated by the Biological Opinion issued for Fort Hood (USFWS 1993), we could not curtail trapping efforts outside of the East Range.

Methods

We monitored space use of female cowbirds by radiotelemetry from 1995-1998. We experimentally reduced the number of cattle on the study area by 86%, from 752 animal units (au; 1 au = 1 bull, 1 cow, or 1 cow and calf) in 1995-1996 to 103 au in 1997-1998. This reduction decreased both the size and number of herds present on the study area. Numbers of cattle on the study area were approximately the same between years within pre- and post-cattle reduction time periods. We compared pre- and post-cattle reduction activity patterns of female cowbirds in the study area.

Due to a combination of logistical difficulties in removing cattle from open, remote ranges with rough terrain and political resistance, a full cattle removal was not possible. We relocated cattle to West Fort Hood, approximately 30 km from our East Range study area (Figure 1). However, a limitation of our study design was that cattle were not removed, and stocking rates were not reduced, on military and private lands immediately adjacent to the study area. Stocking rates of these adjacent lands were difficult to estimate. However, several herds of approximately 100 au each were present on these lands (T. W. Buchanan, Army Natural Resources Management Branch, Fort Hood, Texas, personal communication).

We captured cowbirds primarily with small, portable cowbird traps (1.22 m × 1.22 m × 2.13 m) within breeding habitat in the study area; we captured a few individuals with mist nets (Eckrich et al. 1999). We operated traps in the same areas in all years. Captured cowbirds were marked with USFWS bands and a unique combination of color bands. Female cowbirds were fitted with radiotransmitters only upon recapture, to avoid losing transmitters by placing them on transient migrants. Transmitters weighed 1.4-1.7 g. Because transmitters should weigh only 3-5% of the recipient's weight (Cochran 1980), we fitted only females weighing $\geq$30 g with transmitters. We attached transmitters to females following Raim (1987); these had an expected battery life of 60 days.

We collected telemetry data from 1 April to 15 July, 1995-1998. We used a systematic tracking schedule to optimize the independence of locations and to adequately represent daily behavior (White and Garrot 1990). The tracking schedule was divided into 5 sample intervals: 1) 0500-0800, 2) 0801-1100, 3) 1101-1400, 4) 1401-1700, 5) 1701-0500. We attempted to obtain daily locations for each bird during each time interval.

We determined locations by visual confirmation or triangulation. Whenever possible, we recorded whether the bird was foraging, breeding, or participating in other behaviors (e.g., roosting). Foraging was recorded if a bird was observed alone or with other cowbirds on the ground at the feet of cattle, pecking at the ground, or gleaning from a perched position. Presence or absence of cattle at foraging locations also was recorded. Breeding was recorded if a bird was observed in the act of egg laying, copulation, territorial displays, or nest searching. We defined territorial displays as bill pointing, bill swiping, chattering, or chasing with other females (Rothstein et al. 1986). We defined nest searching as any female observed alone and deliberate in her movement (or lack of movement) through vegetation potentially containing host nests (Lowther 1993).

We marked telemetry locations for direct sightings with flagging and initially estimated the positions to within 10 m of their actual locations, plotting them on 1:24,000 ortho-photo field maps. Universal Transverse Mercator (UTM) coordinates were derived by revisiting these sites with a Global Positioning System (GPS). GPS location data were either real-time or post-processed to obtain position accuracy of 3-5 m. We used ArcView® (Version 3.0a, Environmental Systems Research Institute, Inc., Redlands, Calif.) in conjunction with 1:24,000 ortho-photographs to determine UTM coordinates when GPS data were not available; this method was assumed to have a similar level of accuracy. For locations based on triangulations, we drew bearings on 1:24,000 ortho-photographs with a UTM grid overlay.

Over the course of the study we determined parasitism rates (percentages of nests where at least one cowbird egg or nestling were found) for black-capped vireo nests located on the East Range, as well as other areas of Fort Hood (i.e., West Range, West Fort Hood, and Live Fire) (Eckrich et al. 1999; The Nature Conservancy of Texas, Fort Hood, Texas, unpublished data). We checked all nests every 4-5 days until fledging.

To assess the impact of increased commute distance on cowbirds following reduction of stocking rate, we modeled the potential egg-production costs of increased commute distance between breeding and foraging areas. For adult females at our study site, on average, mass = 34.5 g, wingspan = 29.7 cm, and wing area = 160.7 cm^2 (wing measurements made according to Pennycuick 1999*a*). Based on weather data from the Killeen Municipal Airport, 18 km from the center of our study area, the mean air density during the time that cowbirds commuted between breeding and feeding areas during 1997 and 1998 was 1.19 kg/m^3. The aforementioned values were then input into Flight.bas (Pennycuick 1989, Pennycuick 1999*b*), software that can be used to calculate 2 critical values for horizontal flapping flight: the flight velocity that maximizes distance per unit energy (V_{mr}) and the metabolic cost (J/s) of flying at this speed. For our cowbird data, $V_{mr} = 16.1$ m/s and the associated metabolic cost = 2.82 J/s.

Data analysis

We used individual females as experimental units (Garton et al. 2001). Because few ($n = 3$) individuals were fixed with transmitters during multiple years, our analyses did not attempt to compare individuals among years. We used one-way analysis of variance (ANOVA) tests to determine whether there were differences between pre- and post-cattle reduction time periods or among years in mean proportions of breeding and foraging locations inside of the study area, mean proportions of foraging locations inside and outside of the study area where cattle were present, and mean breeding-foraging commute distance (Zar 1999). We measured commute distances by calculating the mean distance from the center of a female's breeding activity to each of her feeding locations. We used this method because a female's breeding locations were typically tightly clustered (as a result of the use of restricted home ranges or territories for breeding), whereas a female's foraging locations were generally more widely scattered. We used spatial analysis tools in ArcView to determine locations and distances. Proportion data did not meet parametric assumptions of normality, even after arcsine transformation (Zar 1999). However, the bimodal distributions of our proportion data were unlikely to drastically affect validity of parametric tests, even with our small sample sizes (Bart et al. 1998). If an ANOVA was significant, we used a least significant difference (LSD) test to separate means (Zar 1999). Statistical significance was assessed at $\alpha = 0.10$ as we were willing to be more liberal in accepting evidence for the efficacy of this management technique because of its potential effect on an endangered species (i.e., we considered Type I error to be less important than Type II error). We conducted all analyses with JMP® Statistical Discovery Software (SAS Institute 2000).

Results

We fitted 67 female cowbirds (20 in 1995, 12 in 1996, 16 in 1997, and 19 in 1998) with radiotransmitters. We restricted analyses to the 39 females (12 in 1995, 8 in 1996, 9 in 1997, and 10 in 1998) for which we had at least 30 locations for all behaviors pooled. The total number of locations for these females combined was 719 in 1995, 733 in 1996, 782 in 1997, and 769 in 1998. Mean numbers of locations per female were 60, 92, 87, and 77 in 1995, 1996, 1997, and 1998, respectively.

The proportion of foraging locations inside of the study area differed between the 2 pre-cattle reduction years ($F_{1,17}=3.821, P=0.066$) and between the 2 post-cattle reduction years ($F_{1,18}=4.239$, $P=0.055$). Because of these differences, we could not pool data within pre- or post-cattle reduction time periods. Thus, we made comparisons among years instead of between pre- and post-cattle reduction time periods. The proportion of foraging locations located inside of the study area differed among years ($F_{3,35}=4.356$, $P=0.010$). The proportion of foraging locations within the study area was lowest in 1998, 2 years post-cattle reduction (Table 1).

The proportion of breeding locations inside of the study area did not differ between the 2 pre-cattle reduction years ($F_{1,18}=0.310$, $P=0.584$) or between the 2 post-cattle reduction years ($F_{1,16}=0.933, P=0.349$). Thus, data were pooled for analysis by pre- and post-cattle reduction time periods. The proportion of breeding locations inside of the study area did not differ between pre- and post-cattle reduction time periods ($F_{1,36}=0.010, P=0.922$).

The proportion of foraging locations, inside and outside of the study area, that were associated with cattle did not differ between the 2 pre-cattle reduction years or between the 2 post-cattle reduction years ($P\geq0.137$). Thus, for analysis, we combined pre-cattle reduction years and also post-cattle reduction years. The proportion of foraging locations inside of the study associated with cattle was lower in the post-cattle reduction time period ($F_{1,28}=8.254$, $P=0.008$) (Table 1). Outside of the study area, the proportion of foraging observations that were associated with cattle did not differ between pre- and post-cattle reduction time periods ($F_{1,23}=0.360, P=0.554$).

The mean commute between breeding and foraging areas differed between the 2 pre-cattle reduction years ($F_{1,14}=6.380, P=0.024$), but not between the 2 post-cattle reduction years ($F_{1,16}=2.123, P=0.164$). Thus, we made comparisons among years instead of between pre- and post-cattle reduction time periods. Mean breeding-foraging commute distance differed among years ($F_{3,30}=4.409$, $P=0.011$). Mean breeding-foraging commute only increased in the second year after the reduction in stocking rate (Table 1).

Cowbird parasitism rates of black-capped vireo nests decreased on the East Range following the reduction in stocking rate. Pre-stocking rate reduction, parasitism rates were 18.5% ($n=65$ nests) in 1995 and 34.8% ($n=23$) in 1996. Following reduction, parasitism rates were 1.6% ($n=62$) in 1997 and 2.4 % ($n=41$) in 1998. On average, parasitism rates in 1997 and 1998 were 13 times lower than during pre-stocking rate reduction years. Mean parasitism rates were 9.3% ($n=113$), 20.9% ($n=87$), 12.2% ($n=112$), and 9.8% ($n=88$) for the West Range, West Fort Hood, and Live Fire combined during 1995-1998, respectively.

Table 1. Activity of female cowbirds before and after a reduction in cattle stocking rate on Fort Hood, Texas, during 1995–1998. Mean values and associated 90% confidence intervals are presented. Within a row, analysis of variance indicated that values with the same superscript letter were not different (α = 0.10).

	Pre-cattle reduction time periods			Post-cattle reduction time periods		
Cowbird activity	1995	1996	Total	1997	1998	Total
Proportion foraging inside study area	0.65^{A} (0.49–081)	0.89^{A} (0.69–1.09)	0.75 (0.58–0.91)	0.71^{A} (0.52–0.90)	0.34^{B} (0.16–0.53)	0.51 (0.35–0.68)
Proportion breeding inside study area	0.98 (0.92–1.03)	0.96 (0.90–1.02)	0.97^{A} (0.93–1.01)	0.99 (0.94–1.05)	0.95 (0.90–1.01)	0.97^{A} (0.93–1.01)
Proportion of feeding sites inside study area associated with cattle	0.71 (0.52–0.91)	0.87 (0.66–1.12)	0.79^{A} (0.64–0.93)	0.45 (0.18–0.72)	0.44 (0.15–0.73)	0.44^{B} (0.25–0.64)
Proportion of feeding sites outside study area associated with cattle	0.84 (0.63–1.06)	0.80 (0.53–1.07)	0.83^{A} (0.66–0.99)	0.75 (0.45–1.05)	0.97 (0.75–1.18)	0.90^{A} (0.72–1.07)
Breeding–foraging commute distance (km)	2.69^{B} (1.67–3.71)	1.67^{B} (0.65–2.69)	2.18 (1.43–2.94)	2.93^{AB} (1.96–3.89)	4.15^{A} (3.19 –5.11)	3.54 (2.82–4.25)

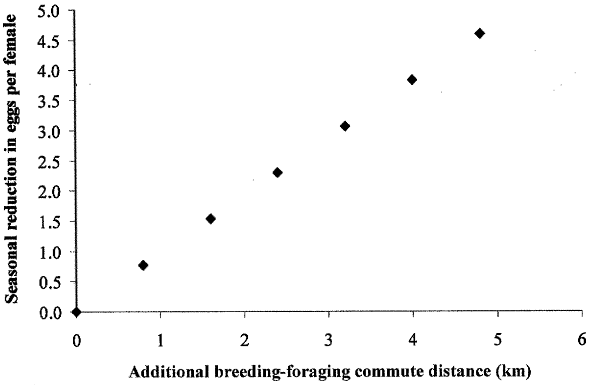

Figure 2. Potential seasonal reduction in eggs produced by female brown-headed cowbirds based on commute distance between breeding and foraging areas on Fort Hood, Texas (1995–1998).

The mean commute between breeding and feeding areas was 1.6 km greater in post-cattle reduction years, which translated to a daily cost of 0.2802 kilojoules (kJ) expended in the extra commuting. The cowbird breeding season at Fort Hood was approximately 90 days, yielding a season-long cost of 25.222 kJ for the extra commuting. Among Passeriformes, the cost of producing an egg was related to egg mass by 5.499 kJ/g (Rahn et al. 1985). Cowbird eggs weigh approximately 3 g (Lowther 1993), yielding a production cost of 16.497 kJ/egg. Therefore, we determined that the increased breeding-foraging commute over the entire breeding season costs the energetic equivalent of 1.53 eggs. Our model indicated that the reduction in seasonal egg production per female is positively associated with commute distance (Figure 2).

Discussion

Cowbird abundance and parasitism rates have been found to increase with proximity to cowbird foraging sites (e.g., areas of active cattle grazing) (Morse and Robinson 1999, Goguen and Mathews 2000). This relationship suggests that manipulation of cattle grazing patterns might be used to influence cowbird activity and movements. However, there has been little study of cowbird response to cattle grazing manipulations, despite their potential as a tool to reduce parasitism rates. In New Mexico, following a full cattle removal, cowbirds extended their commute distance and expanded their foraging ranges in order to access actively grazed areas (Goguen and Mathews 2001). Manipulation of cattle grazing patterns on our study area also affected cowbird movements. Cowbirds eventually shifted their foraging activity off the study area to more distant sites where more cattle were present while maintaining breeding ranges in the study area. Although we did not conduct a full cattle removal, our results were generally similar to those of Goguen and Mathews (2001), except that the shift in cowbird foraging activity on Fort Hood was not immediate, only becoming evident 2 years after the reduction in cattle stocking rate.

The time lag in cowbird foraging response following reduction of cattle stocking rate might be related to changes in vegetation structure in the study area between 1997 and 1998. While herbaceous biomass (kg/ha) in 1997 ($\bar{x}$ = 2867.13, 90% CI = 2465.60–3268.70) was greater than during the pre-cattle reduction time period ($\bar{x}$ biomass in 1996 = 758.06, 90% CI = 431.50–1084.60), it was lower than in 1998 ($\bar{x}$ = 3760.91, 90% CI = 3359.30–4162.50) (L. L. Sanchez, The Nature Conservancy of Texas, Fort Hood, Tex., unpublished data). Cowbirds are noted for foraging in sparsely vegetated areas (Friedmann 1929, Mayfield 1965, Morris and Thompson 1998). Thus, habitat conditions following reduction of stocking rate may have initially remained favorable for cowbird foraging, despite an increase in herbaceous biomass. However, vegetation may have recovered sufficiently by 1998 to make the study area less favorable as a cowbird foraging site. Alternatively, the difference in foraging response between 1997 and 1998 may be due to the influence of off-site factors. For example, availability of alternative foraging sites (e.g., cattle pastures and crops) outside of the study area during 1998 may have been responsible for the observed shift in foraging activity. Unfortunately, without a control or replication, we can only speculate whether on- or off-site factors were truly responsible for the observed shift in foraging activity.

Regardless of mechanism, the shift of foraging activity off the study area by 1998 resulted in an eventual increase in daily commute distance between breeding and foraging areas. This increase may impose an energetic cost on female cowbirds, constraining resources available for reproduction (Goguen and Mathews 2000). Recent studies suggest that female cowbirds may produce only 3-8 eggs per season (Alderson et al. 1999, Hahn et al. 1999). Thus, based on our energetic model, the cost of the increased commute may have a potentially substantial impact on seasonal egg production. Also, our energetic model suggested that additional increases in commute distance would further decrease seasonal egg production per female. Data were not available to assess whether cowbird egg production was actually limited by energetic costs. However, cowbirds' willingness to commute long distances in some instances (Curson et al. 2000) suggested that commute distance may not necessarily be energetically limiting. Such may be the case for cowbirds on our study area, where commute distances were relatively short. The energetic cost of an increased commute distance may manifest itself only at larger scales.

Because female cowbirds exhibit breeding-site fidelity (Dolbeer 1982), maintenance of breeding ranges within the study area following the reduction in cattle stocking rate was likely related in part to females returning to pre-cattle reduction breeding ranges. Once breeding ranges have been established, females have been found to extend their commute distance rather than desert their chosen breeding range (Goguen and Mathews 2001). Cowbirds regularly commute distances as great as 7 km between breeding and foraging areas (Rothstein et al. 1984, Thompson 1994, Gates and Evans 1998). In some instances, cowbirds have even been observed to commute distances of 10-15 km on a regular basis (Curson et al. 2000). Foraging sites on lands immediately adjacent to our study area were often within 5 km and well within documented commute distances for cowbirds. Thus, regardless of whether stocking rate was reduced, cowbirds may have lacked an incentive to shift their breeding ranges as the energetic cost for maintaining breeding areas in the study area while commuting to foraging sites outside of the study area likely was minimal.

Despite an inability to shift female cowbird breeding ranges off the study area, reduction in stocking rate appeared to have a desirable effect. Outside of the East Range, parasitism rates remained relatively constant (the spike in parasitism rate in 1996 was also reflected in the East Range data and was likely due to factors other than Fort Hood's cowbird management program). Hence, higher parasitism rates on the East Range during 1995 and 1996 can be attributed to the curtailment of trapping. Lower parasitism rates on the East Range in 1997 and 1998 can be attributed to the reduction in stocking rate. Goguen and Mathews (2000) reported a decrease in cowbird abundance and a substantial, concomitant decrease in parasitism with increasing distance from actively grazed areas. In our case, even a reduction of stocking rate and hence cowbird foraging opportunities may have been sufficient to reduce parasitism rates.

Trapping outside of our study area may have affected parasitism rates by removing females breeding on the study area but drawn to traps as foraging sites. However, we banded all females captured within our study area. If any of these females were trapped outside of our study area, we released them. Unbanded females originating from breeding areas on our study area may have been removed, but in light of the substantial increase in parasitism rate following curtailment of trapping and substantial decrease in parasitism rate following stocking rate reduction, the potential removal of unbanded females likely did not have a large affect on parasitism rates.

Management implications

Reduction of cattle stocking rate did not have the desired effect of shifting female cowbirds' entire (i.e., breeding and feeding) activity areas off the study area. Only foraging activity was shifted off the study area. The only potential benefit of this shift in foraging activity might be the energetic cost of the increased commute distance between breeding and foraging areas. As a consequence of the increased commute distance, female cowbirds may have less energy available for egg-laying. In the absence of data on whether cowbird egg-laying was actually energetically limited, the conservation benefit to songbirds of increased commute distance by female cowbirds remains speculative. Assuming breeding-foraging commute distance was limiting, our energetic model suggested that the cost of the increased commute distance could translate to a small, but potentially meaningful, reduction in number of cowbird eggs per season.

Cattle grazing manipulations are likely to be most effective when applied at large scales and in the absence of alternative foraging sites. Despite the large scale (9,622 ha) of our stocking rate reduction, we failed to shift female cowbirds' breeding ranges off our study area, largely due to the presence of alternative foraging sites outside of our study area but within distances cowbirds were willing to commute. Although we did affect a modest shift in cowbird foraging activity and a subsequent increase in commute distance between breeding and foraging areas, our results were not as dramatic or rapid as those reported by Goguen and Mathews (2001), despite our stocking rate reduction being applied on a scale similar to that of their cattle removal. The success of Goguen and Mathews' (2001) cattle removal hinged largely on the lack of alternative foraging sites near their study area.

In our case a larger-scale stocking rate reduction may have proven more effective, but could not be implemented because of land-use practices (e.g., established grazing leases) on adjacent military and private lands. Such inability to manipulate cattle at scales large enough to affect cowbird activity and movement is likely to be a common management problem. Thus, in areas like Fort Hood, where cattle could not be manipulated at a scale large enough to mitigate against the presence of readily available alternative foraging sites, techniques such as cowbird removal by trapping and shooting will continue to be the most effective management option (Goguen and Mathews 2000). However, in situations where cattle can be manipulated at a large enough scale to affect cowbird activity and movement and within appropriate landscapes (i.e., ones where alternative foraging sites are not available), manipulations should be conducted before female cowbirds establish breeding ranges in the spring (Goguen and Mathews 2001). Also, to reduce parasitism, cattle would need to be removed or stocking rates reduced only for the duration of the songbird nesting season.

Even if large-scale cattle manipulations are impossible, smaller-scale cattle manipulations might still be useful in cowbird management. Some trapping programs have been ineffective because the cowbirds foraged over large areas (Rothstein et al. 1987). Manipulation of grazing regimes might be used to concentrate foraging cowbirds and increase trapping efficiency (Goguen and Mathews 2001). Indeed, greater trapping success has resulted from concentrating cattle in several instances (B. Armstrong, Texas Parks and Wildlife Department, Kerrville, Texas, personal communication; S. G. Summers, The Nature Conservancy of Texas, Fort Hood, Texas, unpublished data).

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