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REVIEW OF THE CAUSES AND IMPLICATIONS OF THE ASSOCIATION BETWEEN COWBIRDS AND LIVESTOCK

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Abstract. The Brown-headed Cowbird (*Molothrus ater*) participates in a well-known association with livestock, yet the full nature of the benefits of this association for cowbirds remains unclear. Historically, cowbirds were associated with American bison (*Bison bison*) on the Great Plains, but are now found across most of the United States. Cowbirds may benefit from livestock because grazing, or the presence of livestock itself, facilitates foraging opportunities. Livestock may create cowbird feeding microhabitats, increase insect abundance, provide foods in their manure, and may make food more visible by flushing insects when grazing. Due to this close association, livestock can influence the number and distribution of cowbirds. The presence of livestock tends to increase densities of cowbirds locally and can create gradients of parasitism pressure within a landscape. Research in primarily undeveloped sites in the Sierra Nevada and the Front Range of New Mexico confirm the influence of livestock on cowbird distributions. Cowbirds are extremely adaptable and can exploit a variety of anthropogenic food sources. Still, in areas where other artificial food sources are absent, the presence of livestock may be essential for continued cowbird presence or prolonged egg production. The strong bond between cowbirds and livestock has led to the use of livestock removal (i.e., rotation of livestock away from host breeding habitat) as a management technique to reduce parasitization of host nests. The effectiveness of this technique, as well as other aspects of the commensalistic relationship between cowbirds and ungulates, requires further study.

Key Words: brood parasitism, Brown-headed Cowbird, commensalism, foraging, grazing ungulates, livestock grazing, livestock removal, *Molothrus ater,* songbirds.

The Brown-headed Cowbird (*Molothrus ater*) is an obligate brood parasite that often reduces the success and productivity of the nests it parasitizes (Robinson et al. 1995a). As its name implies, the cowbird participates in a well-known association with livestock and is often observed in large numbers among herds of these grazers (Friedmann 1929, Bent 1958, Mayfield 1965, Morris and Thompson 1998). Although cowbirds undoubtedly engage in foraging activities when with livestock, the full nature of the benefits they receive through this association remains unclear. Cowbirds were historically believed to have been primarily a grassland species, typically found in association with American bison (*Bison bison*; Mayfield 1965). As bison were eliminated and replaced by cattle and other domestic livestock, the cowbird has readily adjusted to the change. The "buffalo-bird" of the past has become the "cowbird" of the present (Friedmann 1929).

Historically, cowbirds were restricted to the Great Plains, probably due to the shortage of open, short-grass feeding areas elsewhere (Friedmann 1929, Mayfield 1965). It was not until the native forests of the eastern United States were opened up and interspersed with agriculture and livestock that cowbirds were able to invade (Mayfield 1965). In the western United States, agriculture, irrigation, human development, and widespread livestock grazing have probably all contributed to the cowbird's spread (Rothstein 1994). At present, the cowbird has become one of the most widespread bird species in the United States. In many regions, cowbirds now parasitize a large proportion of nests, often across many species within bird communities (see Robinson et al. 1995a for examples). As a result, cowbird parasitization is often implicated as a contributor in perceived declines of neotropical migrant songbirds (Brittingham and Temple 1983, Finch 1991).

In this paper, we examine the potential causes of the association between cowbirds and livestock and discuss the implications of this association in terms of its influence on the distribution of cowbirds and cowbird parasitization. We use case studies from two well-researched western sites to focus more closely on how this association influences cowbird movements and parasitization frequencies of hosts in primarily undeveloped regions. We examine the question of cowbird dependence on livestock during the breeding season, particularly as it applies to the potential effectiveness of livestock removals as management strategies to reduce cowbird parasitization. Finally, we discuss what we think are the important research needs on this topic. We emphasize western rangelands because livestock grazing is a dominant land-use in the West (Sabadell 1982), and we think that in many undeveloped regions of the West, the presence of livestock is a primary factor influencing cowbird distribution and abundance.

WHY DO COWBIRDS ASSOCIATE WITH LIVESTOCK?

Although the association between cowbirds and grazing ungulates is well-recognized, remarkably little research has been done on the causes of this association. Early accounts by Great Plains explorers (summarized in Friedmann 1929) recorded the common observation of cowbirds with bison. Cowbirds were also associated with other native ungulates and are still occasionally observed with herds of elk (*Cervus elaphus*; C. Goguen, pers. obs.). The destruction of millions of bison in the late nineteenth century was followed by the introduction of millions of domestic livestock (reviewed in Knopf 1994). Cowbirds have apparently adapted to this switch and, in addition to cattle, are also known to associate regularly with horses, sheep, and other domestic animals (Friedmann 1929, Lowther 1993).

Several not necessarily mutually exclusive hypotheses can be postulated as possible explanations for the current association between cowbirds and livestock:

1. Livestock may act as perches or protective cover (Morris and Thompson 1998). In grassland habitats where cowbirds often feed, perches and protective cover from predators are rare. Livestock may provide elevated sites for social interactions and displays, protective cover while birds forage, and possibly provide females with perches for nest searching.

2. Livestock, or livestock-holding facilities, may be used as obvious gathering points for social interactions (Rothstein et al. 1987). Cowbirds are often found in groups when among livestock, and some social displaying occurs (Rothstein et al. 1986b, 1987). Rothstein et al. (1986b) refuted this hypothesis as the primary explanation for cowbird aggregations with livestock based on two arguments: (1) Cowbirds are opportunistic in their use of space, and will stop commuting to sites where large groups normally aggregate if feeding opportunities arise closer to their breeding ranges. (2) Although some social interactions occur at the large aggregations, most time is spent either feeding or loafing.

3. Cowbirds associate with livestock because the presence of livestock, or livestock grazing itself, facilitates foraging opportunities (Friedmann 1929, Mayfield 1965). Under this hypothesis, aggregations of cowbirds with livestock are not necessarily the result of active social interactions but, rather, may be passive aggregations due to limited, prime feeding sites, or due to the general selection pressures that favor group foraging, such as predator detection (Rothstein et al. 1986b).

4. Cowbirds associate with livestock as a result of a hard-wired response to a cattle-like stimulus (i.e., bison) with which they evolved, even though this response does not generate the same, if any, benefits at present. When studying animal behavior in a human altered environment, it is necessary to consider that the behavior may simply be an artifact of superimposing a stimulus on an otherwise well-adapted response (Gavin 1991). The ultimate causes that led to this association may be unimportant under current human-altered conditions; however, the innate response of cowbirds to grazing mammals remains. If this hypothesis is true, then determination of the causes of this association must take place under natural conditions (e.g., with bison).

Currently, the third hypothesis, which we will refer to as the foraging site hypothesis, appears to have the most support (Friedmann 1929, Mayfield 1965, Morris and Thompson 1998). The primary evidence for the foraging site hypothesis is the fact that feeding is the main behavior cowbirds exhibit when with livestock (Rothstein et al. 1986b, Morris and Thompson 1998; C. Goguen, unpubl. data). Cowbirds are omnivorous, feeding on both seeds and arthropods, and forage primarily on the ground in areas of short vegetation (Lowther 1993). Once again, several, nonmutually exclusive hypotheses can be proposed to explain the manner in which livestock may provide or enhance cowbird foraging opportunities:

1. Grazing may create or enhance microhabitats for cowbird foraging. Livestock grazing, by creating areas of short vegetation, may provide sites where a cowbird can forage more easily. Cowbirds often feed on mowed lawns and highway berms, suggesting that a reduction in grass height alone creates cowbird foraging opportunities (Mayfield 1965). Grass height alone, however, does not appear to explain cowbird behavior as cowbirds will abandon customary prairie feeding sites immediately following cattle removal to move to other actively grazed sites to feed with cattle (See CASE STUDY 2—THE FRONT RANGE, NEW MEXICO, below).

2. Grazing may increase foraging habitat quality by increasing grassland invertebrate abundance. Many studies have shown that grasshopper densities tend to increase with livestock grazing (Smith 1940, Nerney 1958, Holmes et al. 1979, Jepson-Innes and Bock 1989). Further, densities of foraging female cowbirds appear to be positively related to invertebrate density (Morris and Thompson 1998). This suggests that cowbirds may be found with grazing mammals simply because grazed areas have more invertebrates. We question this hypothesis as the main

explanation of a cowbird-livestock association based on the observation that cowbirds in actively grazed pastures usually forage close to livestock (Morris and Thompson 1998; C. Goguen, unpubl. data). If cowbirds were selecting grazed areas only because of higher insect densities, then they should be able to select any region of the pasture in which to feed, regardless of the proximity to an ungulate.

3. The presence of livestock may increase food availability via livestock body parasites, insects attracted to livestock, or insects and seeds in manure. Early naturalists speculated that cowbirds fed upon intestinal worms of ungulates extracted from their manure, removed and ate body parasites such as ticks, or captured flying insects attracted to ungulates such as horseflies (Friedmann 1929). Although arthropods often make up a substantial proportion of a cowbird's diet, particularly during the breeding season, Beal (1900) found little evidence in cowbird stomachs of the ungulate-attracted arthropods described above. Still, manure often contains seeds and larval insects that may be eaten by cowbirds. In the Sierra Nevada, cowbirds foraging in horse corrals appear to obtain most food by probing and pecking into horse manure (Rothstein et al. 1980). Additionally, trampling actions of horses commonly expose for cowbird consumption insect larvae under hard manure cakes (Rothstein et al. 1987). Food obtained from manure may be particularly important at holding facilities (e.g., corrals) where livestock are concentrated.

4. Cowbirds may obtain food from the forage provided to domestic livestock by humans. Cowbirds are commonly found in large numbers at corrals or feedlots, sites with high densities of livestock that are maintained by human feeding (Rothstein et al. 1984, Coker and Capen 1995, Morris and Thompson 1998). Cowbirds likely benefit from these sites by feeding on seeds in hay or on waste grains. This does not explain the association of cowbirds with free-ranging cattle or wild ungulates, however.

5. Finally, livestock may make grassland insect foods more visible to cowbirds by flushing invertebrates from vegetation during their grazing activities. Friedmann (1929) proposed that grazing ungulates increase the cowbird's ability to detect invertebrates in grassland vegetation. These invertebrates are normally stationary and camouflaged, but can be readily located when flushed by ungulate feeding or footsteps. This explanation is supported by studies that demonstrate that "hide-and-flush" grassland insects, such as grasshoppers and leafhoppers, comprise the majority of animal food in cowbird diets (Beal 1900). Observations of foraging cowbirds also support this explanation. When in herds of cattle, cowbirds tend to group around foraging and moving cows rather than stationary, resting cows; as a cow forages, cowbirds move along behind the feet and mouth of the cow and dart after insects that are flushed with each footstep (C. Goguen, pers. obs.). This is similar to the benefit that the Cattle Egret (*Bubulcus ibis*) obtains from its association with grazing animals (Telfair 1994).

IMPLICATIONS OF A COWBIRD-LIVESTOCK ASSOCIATION

Based on the above, it appears that, at the least, cowbirds benefit in a commensalistic relationship with livestock because of the enhanced feeding opportunities provided. Cowbirds are well known for their ability to separate their egg-laying and feeding ranges due to their parasitic nature (Rothstein et al. 1986b). In fact, most studies of cowbird movements have shown that cowbirds spend their mornings in areas of high host densities engaged in breeding activities, then commute to afternoon feeding sites, often in association with livestock (Rothstein et al. 1984, Teather and Robertson 1985, Thompson 1994). Historically, the breeding range of the cowbird depended upon the distribution of large ungulates (Mayfield 1965). This suggests that the presence of domestic livestock may influence the numbers and distribution of cowbirds.

How Does the Presence of Livestock Influence Cowbird Density?

The close link of cowbirds to livestock leads to the general prediction that cowbird densities should be higher on actively grazed areas, and maybe grazed areas in general, than on ungrazed. Results of western studies evaluating the effects of livestock grazing on cowbird densities are varied, but some patterns, based on vegetation type, appear to exist (Saab et al. 1995). In western riparian and shrubsteppe systems, the patterns observed agree with the prediction; cowbird densities tended to be higher in actively grazed areas (Reynolds and Trost 1981, Mosconi and Hutto 1982, Knopf et al. 1988, Schulz and Leininger 1991). In studies of western grasslands, however, cowbird densities were high, but no difference was detected among different grazing intensities (Kantrud 1981, Kantrud and Kologowski 1982).

Two grazing studies that conflict with the predicted patterns of cowbird densities raise important points concerning the evaluation of livestock effects on cowbird density. Goguen and Mathews (1998) found no significant difference in cowbird abundance between actively grazed and ungrazed pinyon-juniper (*Pinus edulus—Ju-*

niperus spp.) woodlands. They attributed this result to the ability of cowbirds to commute far beyond the grazing fenceline to ungrazed areas (See CASE STUDY 2—THE FRONT RANGE, NEW MEXICO, below). Taylor (1986) studied riparian areas that were either ungrazed all year or winter-grazed at various intensities. Livestock were not present to provide feeding opportunities for cowbirds on any of the sites during the breeding season, but cowbird abundance was higher in ungrazed sites. Host densities were also higher on ungrazed sites, probably because winter grazing had reduced the vegetation density on the grazed sites. Cowbirds appear to select breeding habitats with high host densities (Thompson et al. in press). This suggests that cowbirds were commuting from feeding areas outside the study sites and selecting breeding habitats based on host densities. The important point raised by these two studies is that cowbird mobility and breeding behavior, as well as grazing effects on host habitats, can confound attempts to assess the influence of livestock on cowbird abundance.

DOES THE PRESENCE OF LIVESTOCK INFLUENCE COWBIRD BREEDING DISTRIBUTIONS AND PARASITISM RATES ON LOCAL AND LANDSCAPE SCALES?

Although cowbirds have the ability to commute substantial distances between breeding and feeding ranges, most commute <3 km (Rothstein et al. 1984, Thompson 1994). If livestock are essential for providing feeding sites, then we predict that cowbird densities and parasitization rates decrease with distance from livestock. In a general sense this prediction has substantial support. Numerous studies have shown that cowbird numbers and parasitization rates are highest in areas closest to cowbird feeding sites (Verner and Ritter 1983, Airola 1986, Young and Hutto *this volume*). In the Sierra Nevada, higher numbers of cowbirds and parasitized nests were found in areas near human developments, horse corrals, and free-ranging livestock (Verner and Ritter 1983, Airola 1986). In New Mexico, the probability of a Plumbeous Vireo (*Vireo plumbeus*) nest becoming parasitized decreased with increasing distance from cattle grazing (C. Goguen, unpubl. data). In Vermont, the probability of a forest disturbance patch being occupied by a cowbird was positively related to the number of livestock sites (e.g., pastures or corrals) within 7 km (Coker and Capen 1995). In the midwestern United States, levels of parasitization were negatively correlated with percent forest cover, probably because non-forested areas tended to contain cowbird feeding habitat, such as livestock pastures (Robinson et al. 1995b). These studies, as a whole, suggest that livestock distributions can influence cowbird distributions at both local and landscape scales.

THE INFLUENCE OF LIVESTOCK ON COWBIRDS IN PRIMARILY UNDEVELOPED, WESTERN LANDSCAPES: CASE STUDIES

To examine further the link between cowbirds and livestock, we selected two well-studied sites in the West to examine in detail. These sites were primarily undeveloped, meaning that few human alterations beyond the introduction of domestic livestock were present. We focus on these sites because they present an opportunity to examine cowbird behavior when livestock are responsible for most feeding opportunities. They also represent conditions that are common in the western United States.

CASE 1—THE SIERRA NEVADA, CALIFORNIA

The Sierra Nevada runs in a northwest to southeast direction through eastern California, between California's Central Valley and the deserts and Great Basin of Nevada. Coniferous forest, riparian, and mountain meadow vegetation cover a wide range of elevations and, although human impacts (e.g., logging, grazing) are pervasive, human developments remain relatively rare (Verner and Ritter 1983; S. Rothstein, pers. comm.). Free-ranging cattle are locally common during the summer, and horse corrals at pack stations are widespread (Rothstein et al. 1987). The Sierra Nevada constitutes one of the last major regions in the continental United States to be colonized by the cowbird. Few cowbirds were present prior to the 1940s (Rothstein et al. 1980, Rothstein 1994). Since colonization, the spread of cowbirds has been well documented, and much research has investigated the causes of the invasion and the factors that currently influence the abundance and distribution of cowbirds (Rothstein et al. 1980, 1984, 1986b, 1987; Verner and Ritter 1983, Airola 1986).

These studies established anthropogenic food sources, including livestock, as a primary factor allowing invasion of the Sierras by cowbirds and suggested that current cowbird distributions, and perhaps even prolonged egg-production ability, depended on the presence of these food sources. On the eastern slope of the Sierra Nevada, where human developments were present, cowbirds aggregated at horse corrals, bird feeders, and campgrounds for afternoon feeding (Rothstein et al. 1980, 1984). In the moderately developed northern Sierra, parasitization frequencies of hosts were highest in areas closest to regularly occupied human and livestock sites (Airola 1986). In the semi-wilderness of the west slope,

cowbird abundance was negatively correlated with distance from horse corrals, and even preferred breeding habitats (e.g., riparian) tended to have few or no cowbirds in regions >10 km from horse corrals (Verner and Ritter 1983). Summer cattle grazing also occurred, and although cowbirds arrived and laid some eggs before cattle or horses were introduced each spring, the peak cowbird egg-laying period was apparently delayed until after livestock arrival (Verner and Ritter 1983). This delay caused female cowbirds to miss the peak period of host clutch initiations and implies a pivotal importance of livestock for prolonged cowbird breeding in this undeveloped region.

Although no species is currently threatened due to parasitism within the Sierra Nevada, one management implication is clear: controlling the spread of cowbirds there will need to involve controlling the spread of human-created food sources (e.g., concentrating further development into areas already affected; Rothstein et al. 1980, Airola 1986). Livestock appear to be particularly important where other anthropogenic disturbances are lacking. In these regions, increasing the distribution and numbers of horse corrals or free-ranging livestock may increase the proportion of area susceptible to cowbird parasitism. Further, introduction of livestock earlier in the spring could result in a longer cowbird laying period with greater overlap between cowbirds and hosts (Verner and Ritter 1983).

Case 2—The Front Range, New Mexico

The Front Range is a general term for the mountains and foothills at the western edge of the Great Plains in Colorado and northern New Mexico. Along this range, grasslands of the Plains are replaced by coniferous forests on the mountain slopes creating a natural prairie-forest interface. In northeastern New Mexico, the Front Range forms along the foothills of the Sangre de Cristo Mountains. Cattle grazing is the primary land-use of this sparsely inhabited region, particularly in lower-elevation shortgrass prairie and pinyon-juniper habitats. We have studied cowbird-livestock interactions on adjacent ungrazed and actively grazed rangelands in this region since 1992 (Goguen and Mathews 1998).

Our initial research examined grazing-induced differences in bird species composition and nesting success in pinyon-juniper woodlands (Goguen and Mathews 1998). We predicted that cowbird parasitism would be an important influence on nesting success, particularly in actively grazed woodlands where livestock provide cowbird feeding sites. Cowbird parasitism did prove to be important, but parasitization frequencies of most hosts did not differ between actively grazed and ungrazed sites (Table 1). We attributed our inability to detect an influence of livestock grazing to a problem of scale. All ungrazed study plots were 4 km or less from active cattle grazing. Given the high mobility of cowbirds, we hypothesized that female cowbirds breeding on ungrazed sites commuted to adjacent grazed areas to feed with livestock; in effect, the scale at which our study plots were distributed among grazing treatments was finer than the scale of cowbird movements.

TABLE 1. Cowbird parasitization frequencies of common host species breeding in grazed and ungrazed pinyon-juniper woodlands in northeastern New Mexico, 1992–1995 (adapted from Goguen and Mathews 1998)

Species	Percent nests parasitized (sample size)	
	Ungrazed	Grazed
Plumbeous Vireo (*Vireo plumbeus*)	86 (29)	86 (36)
Western Tanager (*Piranga ludoviciana*)	89 (19)	80 (20)
Blue-gray Gnatcatcher (*Polioptila caerulea*)	76 (41)	76 (41)
Spotted Towhee (*Pipilo maculatus*)	0 (30)[a]	26 (23)
Western Wood-Pewee (*Contopus sordidulus*)	12 (41)	24 (33)

[a] Spotted Towhee nests were parasitized significantly more frequently on grazed plots. Parasitization frequencies for all other species did not differ by treatment.

To assess how the distribution of cattle influenced cowbird feeding behavior and movements, in 1994 we initiated an intensive study of cowbird behavior. We performed surveys of cowbird abundance and we radio-tracked female cowbirds in both actively grazed and ungrazed areas. Cowbird surveys consisted of a system of point counts performed weekly, mid-May through July, along fixed routes in actively grazed and ungrazed prairie and pinyon-juniper woodlands. Surveys were conducted in the morning and afternoon to evaluate daily patterns of behavior and habitat use. Results from these surveys (C. Goguen, unpubl. data) suggest that cowbirds tend to spend mornings engaged in breeding activities in pinyon-juniper woodlands of grazed and ungrazed sites (Fig. 1a) but move in the afternoons to common feeding sites in grazed prairies with cattle herds (Fig. 1b). The rarity of cowbirds on ungrazed prairies in the afternoon demonstrates the importance of cattle for foraging opportunities. Additional evidence for this is suggested by the precipitous decline in cowbird numbers in the grazed prairies during afternoons late in the summer (Fig. 1b). This drop in detections coincided with the removal of

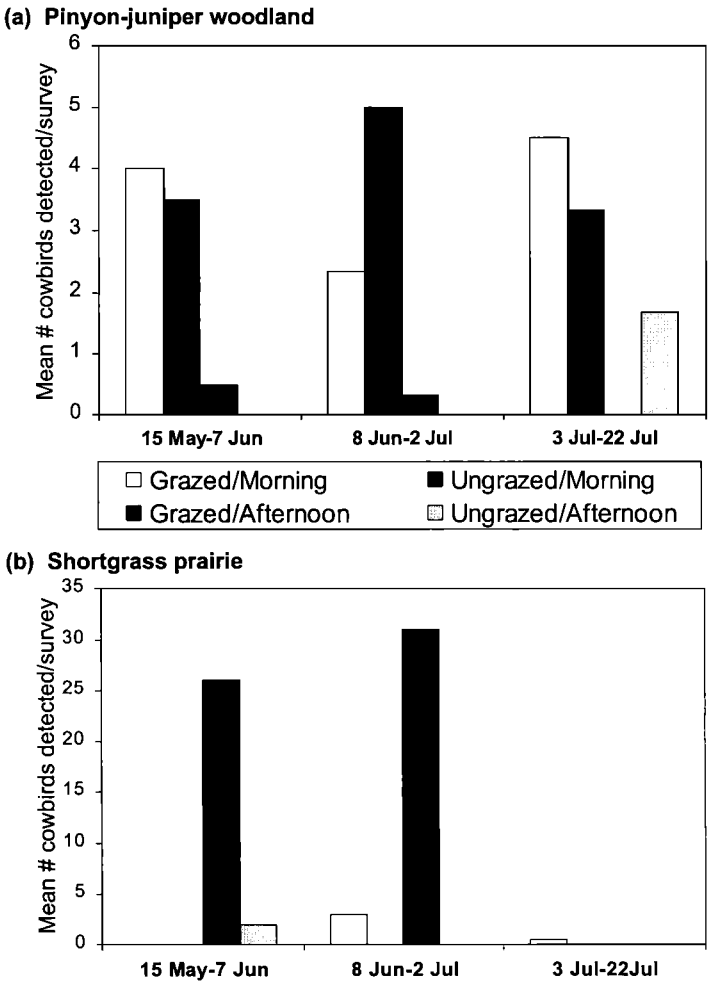

FIGURE 1. Mean numbers of cowbirds detected during point-count surveys of (a) pinyon-juniper and (b) shortgrass prairie vegetation, based on treatment and time of day (based on unpublished data of C. Goguen). Legend abbreviations refer to the treatment and time of survey, for instance "Grazed/Morning" means surveys were done on grazed sites in the morning. Note that the scale of the y-axes differs between (a) and (b).

cattle from the grazed pasture by 2 July. Radiotelemetry data corroborate these conclusions. Seventy-six percent of feeding locations of female cowbirds were with grazing livestock; an additional 22% occurred at livestock corrals (C. Goguen, unpubl. data). Further, when cattle were removed from the principal feeding pasture, female cowbirds immediately shifted to other pastures that remained actively grazed, even though these sites were 1 to 2 km farther away from their egg-laying ranges (C. Goguen, unpubl. data). These observations support our hypotheses of scale effects and cowbird movements between grazing treatments, and demonstrate the potential landscape-level influence of livestock grazing via commuting cowbirds.

DO COWBIRDS DEPEND ON GRAZING UNGULATES DURING THE BREEDING SEASON?

Results described in the case studies above introduce a question, the answer to which is likely to become increasingly important and controversial over the next several years: Do cowbirds depend on grazing ungulates during the breeding season? In both case studies, cowbird movements and distributions were linked closely to livestock, and, in fact, the physical presence of livestock appeared to be an important element of high-quality feeding sites for cowbirds. From a purely ecological perspective, this question is interesting because it provides

insight into fundamental questions of ecology; that is, what controls the abundance and distribution of a species? From a management perspective, however, this question is potentially controversial because it raises the possibility that livestock removal could be used as a management strategy to reduce cowbird parasitism.

In a broad sense, the answer to the question of whether cowbirds depend on grazing ungulates during the breeding season is "no". Cowbirds are extremely adaptable and readily exploit a variety of anthropogenic food sources, ranging from recently tilled agricultural fields (Thompson 1994) to lawns, campgrounds, and bird feeders (Mayfield 1965, Verner and Ritter 1983, Rothstein et al. 1984). But what if the question is narrowed? Do cowbirds depend on livestock in regions where other anthropogenic food sources are absent or rare? This applies to many regions in the West. The answer to this question is less clear. In the undeveloped sites described in the case studies, cowbirds fed almost exclusively with livestock and bred in lower densities in areas distant from livestock. Without manipulative experiments, however, we have no way of knowing whether cowbirds depend on livestock in these regions, or if they can breed there regardless, but concentrate near livestock because food is easily obtained. In the western Sierra Nevada cowbirds survive several weeks without livestock in early spring (Verner and Ritter 1983). The evidence that females delayed most breeding until after livestock were introduced, however, has led to the hypothesis that even though cowbirds can survive without livestock, females may require the high rates of intake of invertebrate foods that livestock provide to maintain egg production (Rothstein et al. 1987). Low energetic costs of egg production argue against this hypothesis (Ankney and Scott 1980), but the foraging efficiency and diet of cowbirds with and without livestock remains unknown (Lowther 1993).

LIVESTOCK REMOVAL AS A TECHNIQUE TO MANAGE COWBIRD PARASITISM

The exclusion of livestock from sensitive habitats (e.g., riparian) is clearly important in creating and maintaining habitat structure for many bird species (Taylor 1986, Taylor and Littlefield 1986, Rothstein and Cook in press). The close association between livestock and cowbirds has also led to the proposal for, and implementation of, livestock removal as a management tool to protect some endangered songbird species from cowbird parasitism (J. Agyagos, pers. comm.; D. Ahlers, pers. comm.). Livestock removal entails the rotation of livestock away from host breeding habitat, at least during the critical spring and summer breeding months, in an effort to reduce parasitization. Often this technique involves removing or minimizing livestock presence within a certain radius of the critical habitat to act as an impediment to cowbird commuting.

In the Southwest, two endangered subspecies, the Least Bell's Vireo (*Vireo bellii pusillus*) and the Southwestern Willow Flycatcher (*Empidonax traillii extimus*), currently experience high parasitization rates (Franzeb 1989, Harris 1991). Livestock removal has been proposed as a management technique for both of these riparian breeding subspecies, and has been recently initiated to protect flycatchers in Arizona and New Mexico (J. Agyagos, pers. comm.; D. Ahlers, pers. comm.). As an example of its application, on the Coconino National Forest in Arizona, livestock are rotated out of public lands in a 6.8-km-radius area around an occupied flycatcher site from April through July (J. Agyagos, pers. comm.). This radius is based on maximum commuting distances observed by Rothstein et al. (1984).

Although the idea of livestock removal to reduce parasitization is intuitively appealing, the effectiveness of this technique remains unknown. Additionally, many factors, such as the availability of alternate cowbird food sources or the size of the livestock removal radius used, may influence its success. Still, under many circumstances livestock removal techniques may provide effective management of cowbirds, and offer an interesting opportunity to do "adaptive management" (Walters 1986). To assess their effectiveness, workers initiating livestock removal programs should incorporate baseline monitoring of cowbird abundance and nests of all host species, post-treatment monitoring, and the use of experimental controls when possible. Experimental removals comparing developed and undeveloped regions would also be useful.

RESEARCH NEEDS

Although the Brown-headed Cowbird is rapidly becoming one of the most studied bird species in North America, surprisingly little is understood about the relationship with livestock that earned this species its name. To conclude, we have summarized several of the main aspects of this association that we feel require further research:

(1) Basic understanding of the causes and benefits of the cowbird-livestock association.—Although feeding is undoubtedly a primary reason for cowbirds to associate with livestock, the importance of social interactions at these feeding groups, and the mechanics of food facilitation by livestock remain unclear.

(2) The dependence of cowbirds on grazing

ungulates, and livestock removals.—The effectiveness of a livestock removal program probably hinges on the degree of dependence of cowbirds on livestock in the region of concern. Given the potential costs of livestock removals (e.g., public relations, manager's and rancher's time and money, lost opportunities to protect the species with alternative techniques), manipulative experiments are needed to evaluate the many unknowns: Do livestock removals reduce parasitization rates in developed regions where other anthropogenic feeding sites exist? Do livestock removals reduce parasitism rates in undeveloped regions? What is the proper scale for removals, i.e., how far must livestock be withdrawn to prevent cowbird commuting?

(3) Effects of grazing management strategies.—A variety of grazing systems exist, yet little is known about how different systems affect cowbirds. For example, do increased stocking densities lead to higher cowbird densities? Can seasonal grazing strategies be used over large regions to move cowbirds away from sensitive areas during the breeding season?

(4) Necessity of livestock or other anthropogenic sources for prolonged cowbird reproduction.—It has been hypothesized that cowbirds need access to high-quality feeding sites, such as livestock, to sustain a high egg-laying rate throughout the breeding season. Studies comparing cowbird foraging efficiency and egg production rates with and without livestock would be useful to assess the validity of this hypothesis.

(5) Role of native ungulates.—Today, because of the prevalence of livestock, native ungulates play a much smaller role in cowbird ecology than they have historically. Bison grazing, however, is becoming popular as an alternative grassland management tool to cattle grazing (Plumb and Dodd 1993). Although from an ecological perspective, bison foraging behavior and food preferences differ from cattle (Plumb and Dodd 1993), bison provide feeding opportunities for cowbirds, just as cattle do. Comparisons of cowbird behavior and parasitism effects with bison versus cattle would be useful. From an evolutionary perspective, these comparisons may also provide insight into the ultimate causes of the cowbird-livestock association.

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