COWBIRDS AND HOST REPRODUCTIVE SUCCESS

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TABLE OF CONTENTS

LIST OF TABLES

EXECUTIVE SUMMARY

In 1994, we initiated a study of brown-headed cowbird (Molothrus ater) parasitism on 2 neotropical, migratory songbirds in the LCRV: the Arizona Bell's vireo (Virco belli arizonae) and the yellow-breasted chat (Icteria virens). In 1994-1995, the brown-headed cowbird was the second most abundant species in the lower Colorado River valley. Ninety percent of vireo (late first and second broods) and 80% of chat nests in the valley were parasitized. Overall nesting success was 11% for the Bell's vireo and *25%* for the yellow-breasted chat. Nest failure was significantly associated with parasitism for both species. These data indicated that parasitism may be the primary mortality agent for nesting songbirds in the lower Colorado River valley.

In 1996, cowbird trapping was initiated at the Bill Williams River National Wildlife Refuge (NWR). In 1997, this effort was expanded and 9 plots were established for nest-searching. At 3 plots, adult cowbirds were removed by trapping (Treatment A); at 3 plots, adult cowbirds were removed and cowbird eggs were addled (Treatment B); and at 3 plots, no cowbird control was implemented (Reference plots). An additional cowbird trap was established at the Bill Williams Delta, at the confluence with the Colorado River.

Cowbird abundance was lower on Bill Williams River NWR in 1997 and 1998 (post-cowbird control) than in 1994-1995 (pre-cowbird control). During 1997, the greatest decline in cowbird abundance was on the treatment plots. Cowbird abundance was lower in 1998 than 1997 on all except one treatment transect. In fact, the percentage decrease in cowbird abundance was greater on the reference transects relative to the treatment transects. We interpret this overall decline in cowbird numbers as resulting from our cowbird removal program: that is, the traps are decreasing cowbirds area wide, and not just near the treatment transects. Thus, it appears that repeated removal is having a cumulative effect on cowbird abundance; the relatively high capture rate of cowbirds at the Bill Williams Delta-which appears to be a location of concentrated cowbird activity-is apparently assisting with the overall lowering of cowbird abundance in the riparian (host nesting) areas of the refuge. This conclusion is supported by the high return rate (17%) of birds banded during 1997: we appear to be capturing a relatively high proportion of the birds using the area. As in 1997, the abundance of many potential host species was lower in 1998 than either 1994-95 or 1997. The yellow-breasted chat decreased on 5 of 6 transects compared to 1997 abundances; Bell's vireos, however, increased in abundance on 5 of 6 transects.

The ratio of cowbirds to suitable host species was 20-31% on all transects surveyed in 1994-1995 at Bill Williams River NWR. Ratios above 10% are associated with high levels of parasitism in other regions (Donovan et al., in press, Thompson et al., in press, cited in Rogers et al. 1997). In 1997, these ratios ranged from 0-6% on transects with cowbird removal and 5-14% on transects without cowbird removal. In 1998, the ratios ranged from 0-1% on treatment transects and from 0-6% on reference transects. These results suggest that parasitism rates were lower along the Bill Williams River in 1997 and 1998 relative to 1994-95, particularly in areas with cowbird removal.

Parasitism rates on vireo (late first and second broods) and chat nests were much lower in 1997 (38% and 10%, respectively) and 1998 (17% and 18%, respectively) than 1994-1995(92 and 73%, respectively; Averill and Lynn, Unpubl. data). Thus, parasitism rates for vireos continued to decline during 1998, while those for chats increased slightly (but remained 4 times lower than 1994-

95 rates). Past studies indicated that parasitism rates >25% (Robinson et al. 1993) or >30% (Layman 1987) could threaten survival of local populations of host species by destabilizing a population and increasing the probability of local extinction due to stochastic events. Finch (1983) also suggested that parasitism levels >30% could jeopardize the existence of regional riparian bird populations. Therefore, parasitism rates during 1998 had fallen below the level thought to be of conservation concern. During 1998, parasitism rates were 2.75 times lower on treatment plots relative to reference plots for vireos, and 1.70 times lower for chats. Thus, although parasitism rates were lower overall during 1998, it appears that treatments also had a substantial influence on parasitism rates for vireos and chats. However, there was no corresponding increase in abundance of Bell's Vireos, and only a slight increase in numbers of Yellow-breasted Chats, in the study area.

During 1998, first brood attempts by vireos had a substantially lower parasitism rate (11%) than second broods (26%). Likewise, nesting success of first broods (71%) was substantially higher than second broods (45%). Thus, a parasitism rate of 26% appears to negatively impact nesting success of vireos. During 1997, first broods had a very low parasitism rate (6%) relative to the high (70%) rate for second broods Nest success for first and second broods (90% and 44%, respectively) was apparently related to parasitism rate, as in 1998. Note, however, that the nest success for second broods was about the same, even though the 1997 parasitism rate was 2.7 times that of 1998. Thus, vireo nesting success apparently declines rapidly when parasitism approaches *25%,* but does not decline further at even very high rates of parasitism.

In 1997, 30% of parasitized nests along the Bill Williams River had >1 cowbird egg; in 1994-1995, ~45% of parasitized nests in the LCRV had >1 cowbird egg. During 1998, only 17% of vireo nests and 18% of chat nests had >1 cowbird egg. For vireos, Reference plots had 28% of the nests with >1 cowbird egg, while treatment plots had only 6% with >1 cowbird egg. Likewise for chats, there were fewer nests with >1 cowbird egg on treatment plots (13%) compared to Reference plots (22%). Both Bell's vireo and yellow-breasted chat nestlings have a lower chance of fledging from multiply parasitized nests than singly parasitized nests (Averill 1996). However, vireos are unlikely to fledge any of their own young from a parasitized nest; therefore, reducing the intensity of parasitism alone will not benefit the virco population.

Overall nesting success (the probability of fledging at least one host young) was higher in 1997 and 1998 than 1994-1995 (pre-cowbird control). Approximately 65% of vireo nests were successful in 1997, 50% in 1998 were successful, whereas only ~11% were successful in 1994-1995 (late first and second broods). Approximately 80% of chat nests were successful in 1997, 73% in 1998, whereas ~30% were successful in 1994-1995. Vireo nests on Treatment B plots had a higher nesting success (91%) than the other plots (Reference plus Treatment A, ~50%) during 1997; Treatment B plots were also more successful (74%) than all other plots combined in 1998 (43%), suggesting a beneficial effect of cowbird egg removal on vireo nesting success. Likewise, for chats Treatment B plots had much higher nesting success (93% success) than the other plots combined (68%) during 1998; this comparison was not possible for 1997 because of a low sample size.

Predation was the leading cause of nest failure for Bell's vireos and yellow-breasted chats in 1997 and 1998. However, the percent of nests that were depredated in 1997 (~18% for the vireo and 21% for the chat) was low compared to 1994-1995 (~37% for the vireo and 44% for the chat). Likewise, predation remained low for vireos (21%) and chats (15%) in 1998. It is possible that the lower predation rate can be attributed to the lower abundance of cowbirds. Arcese et al. (1996) hypothesized that parasitism and predation rates are associated because cowbirds depredate host nests found late in the nesting cycle to hasten renesting. This hypothesis predicts that unparasitized nests will have a higher predation rate than parasitized nests. However, in areas where female cowbirds have overlapping territories, it is expected that cowbirds will depredate nests with the eggs of conspecifics. In 1994-1995, many cowbird eggs were found on the ground below vireo nests (Averill 1996). It was suggested that competing cowbirds ejected the eggs of conspecifics to replace them with their own. In 1997 and 1998, only 2 instances of cowbird eggs below host nests were documented.

The average number of vireo and chat eggs, nestlings, and fledglings per successful nest was higher in 1997 and 1998 than 1994-1995 (Averill, unpubl. data). The average number of vireo and chat eggs, nestlings, and fledglings in *unparasitized nests* in 1994-1995 (Averill 1996) was similar or higher than the mean value for nests in the treatment plots in 1997-98. Therefore, overall low fledging success in 1994-1995 appears to be attributable to the high parasitism rates. In 1997 and 1998, vireo nests with the highest mean number of fledglings per successful nest were in plots where cowbird eggs were addled (Treatment B). Thus, it appears that removal of cowbird eggs or young may be necessary to boost reproductive success of small host species, such as the Bell's vireo, in areas with high cowbird abundance.

Reducing parasitism rates (through cowbird trapping) and making cowbird eggs inviable (through addling) will not improve songbird nesting success if parasitism is not the primary cause of nest failure. Stutchbury (1997) found that cowbird trapping did not increase nesting success of hooded warblers because predation was the major factor limiting nesting success. However, cowbird removal has increased the reproductive success of Kirtland's warblers (Kelly and DeCapita 1982), least Bell's vireos, and black-capped vireos (Robinson et al. 1995). Along the Bill Williams River, nest failure was high in years of high cowbird abundance (1994-1995) and low in the years (1997-98) with lower cowbird abundance. Although more years of data collection are needed, it appears that parasitism was the primary cause of nest failure before cowbird control was implemented, especially for small host species such as the Arizona Bell's vireo. Removal of cowbirds appears to have resulted in lower parasitism rates and higher nesting success for both vireos and chats. However, the abundance of vireos and chats has not changed substantially between 1994-95 and 1997-98 despite cowbird control. This does not mean, however, that control is not *preventing* a reduction in host abundance by allowing for the production of an ample number of offspring to offset post-fledgling mortality, including that incurred during migration and on wintering grounds. This is the most likely conclusion given that our control program has apparently reduced parasitism rates below those thought to result in population declines.

Cowbird trapping is an investment in time, money, and personnel. Along the Bill Williams River, cowbird traps were visited every 1-2 days in the summertime. It typically took 1.5-2 hours/visit to monitor 6 traps along a linear stretch of the River. This cost may be outweighed by the benefits of low parasitism rates for nesting songbirds. Nest searching (and egg addling) is a larger time investment, but this additional cost may also be outweighed by the benefits for small host species. Searching for vireo nests takes relatively little time once personnel are familiar with species-specific behavior (1 nest every 3-5 hours). Chat nests were relatively more difficult to locate, taking about 5-8 hours to locate a nest. At the relatively low parasitism rates seen during 1998, addling cowbird eggs and removing cowbird hatchlings might not be indicated. However, some nest monitoring remains necessary to determine the parasitism rates being experienced by hosts so the intensity of adult cowbird removal can be determined. Because first broods of vireos largely escaped parasitism (at least in years/areas with low cowbird abundance), all of the nest-searching effort could be concentrated in June.

In 1996, 130 female cowbirds were removed from 2 traps on Bill Williams River NWR. In 1997, 67 female cowbirds were removed from 6 traps placed on the refuge and 67 female cowbirds were removed from a trap that was located at the Bill Williams Delta in a possible flyway between cowbird foraging and breeding sites. During 1998, 24 females were removed from the refuge and an additional 16 were removed from the Delta trap. Because the riparian area of the Bill Williams River is a relatively isolated strip of vegetation amid a desert landscape, it may not be rapidly recolonized by cowbirds as original birds are removed. Therefore, fewer and fewer cowbirds may be caught in subsequent years, as was noted between 1997 and 1998. Such a pattern has been observed along the Kern River in California (M. Halterman, Kern River Preserve, pers. comm.).

Overall, 72 cowbirds were released during 1997: 46 males, 19 females, and 7 juveniles. Sixty-five cowbirds were released from the office trap: 46 males and 19 females. Overall, 167 cowbirds were released during 1998: 77 males, 37 females, and 53 juveniles. Fifty-four cowbirds were released from the office trap: 41 males, 1 female, and 12 juveniles. One-hundred thirteen cowbirds were released from the refuge traps: 36 males, 38 females, and 41 juveniles. Of 69 cowbirds banded and released in 1997 at Bill Williams River NWR, 12 (17.4%) were recaptured during the 1998 field season. Eleven of 50 (22.0%) males were recaptured, and 1 of 19 (5.3%) females were recaptured. Two of the 50 male cowbirds were recaptured by other researchers: 32 km north at Lake Havasu City (Mohave Co.).

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INTRODUCTION

The brown-headed cowbird (scientific names in Appendix 1) is a brood parasite known to lay its eggs in the nests of over 220 species (Friedmann and Kiff I 9X5). One hundred forty four species, primarily open-cup nesters of the order Passeriformes, have successfully raised cowbird young. Nesting success of host species is frequently lower in parasitized nests. Rothstein (1975)
reported a 40-98% decrease in nesting success in parasitized nests of4 common host species. Cowbird parasitism may be the primary mortality agent for some passerines, and has been implicated in the near extirpation of the least Bell’s vireo in Baja California (Franzreb 1990) and the Kirklland's warbler in Michigan (Walkinshaw 1972).

The lower Colorado River valley (LCRV) is an important thoroughfare and breeding ground for neotropical migrants in the western United States, and many riparian-obligate songbirds have experienced population declines in this region(Rosenberg et al. 1991). Past studies indicate that local populations of songbirds are experiencing a high incidence arid intensity (i.e. multiple cowbird eggs per nest) of brood parasitism. Averill (1996) found parasitism rates o£40-90% oh Arizona Bells vireos, yellow-breasted chats, blue grosbeaks, and common yellowtbroats breeding in the LCRV between late April and early July 1994-1995 Parasitized Bell’s vireo and yellow-breasted chat nests fledged significantly fewer young than unparasitized nests. Similar results were found for Abert’s towhee and black-tailed gnatcatcher populations in the LCRV (Conine 1982 Fiucli 1983). Abert's towhee nests initiated after April (Finch 1983) and black-tailed gnatcatcher nests initiated after March (Conine 1982) had high parasitism rates and low nesting success. Low nesting success of passerines species breeding in the LCRV appears to coincide with the onset of the brown-headed cowbird breeding season (eggs deposited April to July; Rosenberg et al. 1991:336).

Heavy cowbird parasitism on several bird species was documented as early as Grinnell's exploration of the LCRV (Grinnell 1914). Resident bird species, such as black-tailed gnatcatchers and Abert's towhees, may be able to persist despite high parasitism rates by raising a brood before the cowbird breeding season commences (Rosenberg et al. 1991:265). However, many neotropical migratory songbirds have breeding seasons that largely or completely overlap that of the cowbird in the LCRV. In addition, the destruction of gallery riparian forest in the valley since the turn of the century has probably increased the vulnerability of many species to cowbird parasitism (Rosenberg et al. 1991:283).

Brown-headed cowbirds were several times more abundant than most host species breeding in the LCRV between 1993-1995 (Neale and Sacks 1994, Lynn et al. 1996). The landscape of the valley allows cowbirds to flourish: the once extensive Fremont cottonwood-willow forest (Rosenberg et al. 1991) is now fragmented and surrounded by agricultural/urban development that provides abundant forage for cowbirds. The high breeding bird density in southwestern riparian areas, the high edge-to-area ratio of narrow, fragmented corridors, and the proximity of cowbird breeding and foraging sites has favored expansion of the cowbird at the expense of local populations of breeding birds. In addition, the predominant vegetation in the LCRV is the exotic saltcedar. This tree species is heavily used by breeding birds in some regions of the southwest, but not in the LCRV due to the lack of shelter it provides from the extreme summer heat (Hunter et al. 1988). Therefore, the highest density of breeding songbirds in the

LCRV is frequently in remnant cottonwood-willow forest. The high concentration of breeding songbirds in these areas may further facilitate nest-searching for brown-headed cowbirds (see Gates and Gysel 1978, Gates and Giffen 1991 for discussion of density-dependent predation).

Averill (1996) found that salteedar is frequently used as a nesting substrate by Bell's vireos and yellow-breasted chats, especially when there is an overstory of cottonwood and willow. The Bill Williams River, a principal tributary of the lower Colorado River, is the only area in the LCRV with a large (~160 ha), contiguous cottonwood-willow forest with a salteedar understory. Cottonwood revegetation efforts along the lower Colorado River were initiated in the 1970s to create more habitat for breeding songbirds (Rosenberg et al. 1991). These revegetated plots are typically small and linear with little understory (pers. obs.). As of 1995, few birds bred in these plots and those that did experienced high predation and parasitism rates (Averill and Lynn, Unpubl. data). Ideally, habitat restoration through revegetation is the most viable option for permanently reducing predation and parasitism rates (Robinson et al. 1993). However, large-scale restoration of cottonwood-willow forest in the LCRV appears unlikely due to current water-management practices. Other options for lowering cowbird parasitism and raising productivity of local populations of neotropical migrants should be explored.

Cowbird management depends on identifying those aspects of the environment that promote cowbird occupancy and allow survival and successful perpetuation of the species. Cowbirds typically have 2 ranges during the breeding season, one used for breeding and another for foraging, but these may overlap to some extent (see Lowther 1993 for general discussion of cowbird spacing patterns). Cowbirds flock and feed together in open pastures, agricultural lands, campgrounds, urban areas (lawns, feeders), and roadsides (Robinson et al. 1993). Cowbirds are also known to congregate at horse corrals (Rothstein et al. 1987) and areas grazed by livestock (Mayfield 1965). To what extent cowbirds depend on man-made areas for foraging is unknown; Rothstein et al. (1980) suggested that some natural areas may be suitable foraging sites.

Rothstein et al. (1987) found that cowbirds traveled up to 7 km between feeding and nesting sites in the Sierra Nevada. They also found that some cowbirds switched feeding sites and altered their entire range within the breeding season. In addition, female cowbirds were not consistent in their commuting pattern between breeding and feeding sites. Beezley and Rieger (1987) found that female cowbirds returned to riparian areas more consistently than males. This is probably because many males are subordinate (i.e., non-breeders) and may spend more time at feeding sites (Rothstein et al. 1987).

Live-decoy cowbird traps have been successful in managing neotropical migratory songbirds with small populations and narrow geographic ranges (Robinson et al. 1993). However, cowbird traps may not be effective over large, fragmented landscapes that provide cowbirds with numerous feeding grounds. Cowbird trapping was initiated along the Bill Williams River in 1996(2 trap sites near Mineral Wash), but the effect of trapping on parasitism rates and nesting success was not assessed. Therefore, it remains unknown if trapping is a viable option for cowbird management along the Bill Williams River and whether trapping efforts should be expanded to the fragmented riparian areas along the lower Colorado River.

Several aspects of trapping will determine its effectiveness as a cowbird management strategy: trap location, density of traps, and timing of trapping effort (Robinson et al. 1993). Rothstein et al.

(1987) found that trapping cowbirds at the largest and most conspicuous foraging sites in the Sierra Nevada mountains of California had little impact on parasitism rates in the surrounding forest. Traps placed in dense riparian areas (breeding sites) were also found to be less effective than traps placed in adjacent open areas (Collins et al. 1989). To date, the most effective trap placement appears to be between cowbird feeding and breeding sites. Grzybowski (1990) found that such a strategy reduced parasitism on the black-capped vireo from 70% to 20%, and reproductive success increased 6 to 8 fold. However, the distance and degree of distinction between foraging and breeding sites will vary regionally, making the collection of site-specific information necessary to determine proper trap placement.

There is little information on trap density in relation to trapping effectiveness. Grzybowski (Unpubl. data, cited in Robinson et al. 1993) found the effectiveness of cowbird traps in breeding areas to be less than 0.8 km from the trap. The effective distance of a cowbird trap is also likely to vary regionally, as topographic features and vegetation structure will probably influence this measurement.

Timing of trapping is also important. Trapping success (especially of females) on the nesting grounds may decline once breeding begins because cowbirds will concentrate on looking for nests to parasitize rather than foraging (Beezley and Rieger 1987). In addition, subordinate males tend to spend more time foraging on breeding sites than dominant males and, therefore, may account for a large proportion of males trapped on the breeding grounds. The highest trapping success may occur by trapping at breeding sites afier cowbirds arrive but *before* they begin breeding (Kelly and DeCapita 1982). Beezley and Rieger (1987) found that females forage together before the breeding season. Cowbird trapping at these sites would probably be a highly effective management tool. Cowbirds also congregate at winter roe sts and would prove easy targets for elimination at these sites (Robinson et al. 1993). However, unless it is known that the breeding and wintering populations are the same, cowbird control at winter roosts would have little to no effect on local breeding songbird populations.

STUDY OBJECTIVES

The primary goal of this study is to determine the intensity of cowbird control needed in an extremely fragmented landscape, such as the LCRV, in order to raise nesting success of host species to a level typical of other songbird populations (AO%; Martin 1992). Our initial objectives were to:

1. Determine cowbird abundance, parasitism rates, and nesting success of host species in areas where no cowbird control is implemented.
2. Determine cowbird abundance, parasitism rates, and nesting success of host species in areas where adult cowbirds are trapped and removed daily during the breeding season.
3. Determine cowbird abundance, parasitism rates, and nesting success of host species in areas where cowbird eggs and nestlings are removed from nests in addition to adult cowbird removal via trapping.
4. Determine parasitism rates for birds breeding in cottonwood-willow revegetation sites.
5. Determine where locally breeding populations of cowbirds are congregating to forage.
6. Determine if cowbirds that breed in the LCRV winter locally (if funding available).

During 1997 we eliminated objective 6, and during 1998 we further eliminated objectives 4 and S because of limitations in funding and related logistical constraints.

STUDY SITES

In 1997, our study sites were located on the Bill Williams River National Wildlife Refuge NWR) and Havasu NWR. During 1998 we worked only on the Bill Williams (BWRNWR). Only data collected at BWRNWR during both 1997 and 1998 are reported herein (see Averill and Morrison 1998 [1997 final report] for Havasu NWR results).

The LCRV is extremely arid and hot, with an average annual rainfall of *6.5* cm in Yuma, Arizona to 10 cm near Bullhead City, Arizona (Sellers and Hill 1974, cited by Rosenberg et al. 1991:8). Average daily temperatures range from 3 degrees celsius low to 21 degrees celsius high in the winter, and 21 degrees celsius low to 41 degrees celsius high in the spring and summer. Relative humidity ranges from 5 to 20 percent (Sellers and Hill 1974, cited by Rosenberg et al. 1991:8).

The exotic saltcedar tree is the predominant riparian vegetation along the lower stretch of the Colorado River (Hunter et al. 1988). Native riparian vegetation consists of small patches of Fremont cottonwood and Goodding willow, typically with a shrub or low tree understory (pers. obs.). Further from the river are large stands of mesquite, saltbush, quail bush, inkweed, arrowweed, baccharis., and wolfrerry. In areas where long-term flooding occurred, extensive marshes prevail. Surrounding the riparian and marsh plant communities are the desert uplands, dominated by creosote bush, and the desert arroyos, dominated by ironwood and palo verde, Rosenberg et al. 1991:39).

The Bill Williams River NWR is located in La Paz and Mohave counties, Arizona, The Bill Williams River is one of the principal tributaries of the lower Colorado River. Unlike the Colorado River, it is unchannelized and subject to periodic flooding, conditions favorable to cottonwood-willow persistence and regeneration. The Bill Williams River is the site of the largest remaining stand of cottonwood-willow riparian forest (approximately 160 hectares) in the lower Colorado River valley. However, saltcedar is a pervasive understory species on most of the refuge. Extended flooding, as recent as 1993, caused extensive damage to the cottonwood-willow forest. The cottonwood-willow community has also been altered by fires and high soil salinity, situations that favor the spread of saltcedar (Rosenberg et al. 1991:21). Consequently, natural regeneration of cottonwoods and willows is occurring, but few old cottonwood or willow trees remain. The Bill Williams River NWR also has extensive cattail marsh and desert uplands.

Agricultural fields, horse stables, campgrounds, and urban areas are close to the Bill Williams River NWR. These areas may provide forage and roost sites for the brown-headed cowbird. In addition, there are several non-functional ranches that border the cottonwood-willow riparian forest of the Bill Williams River. These field-forest ecotones are ideal habitat for the brown-headed cowbird (Gates and Gysel 1978).

STUDY SPECIES

In 1997 we focused on 3 passerine species known to be common cowbird hosts: Bell's vireo, yellow-breasted chat, and common yellowthroat. Because of difficulty in locating a sufficient ntrnber of common yellowthroat nests (see 1997 report), in 1998 we replaced thc common yellowthroat with the song sparrow. however, initial sampling (spring 1998) indicated that song sparrow nests would not be found in sufficient numbers to warrant sampling this species. Therefore, in 1998 we focused on the Bell's vireo and yellow-breasted chat.

METHODS

Avian Surveying: Variable-width Point Count Method

We used the variable-width point count method (Reynolds et al 1980) to determine relative abundances of cowbirds and host species in areas where cowbirds were and were not removed. We conducted point-count surveys along transects established in 1993 and 1994 on BWRNWR (Neale and Sacks 1994; Lynn et al. 1996; Appendix 2). Point-count stations were frequently established along edges (narrow paths3 roads, desert washes, field-forest boundaries) due to the high level of fragmentation in the lower Colorado River valley, and were located 200 m apart to avoid double counting birds at neighboring points (Bibby et al. 1992). For transect descriptions, refer to Appendix 2 and Map.

We surveyed each point-count station once every 20 days during the breeding season, late March through early July 1997 and 1998 (Appendix 3). We began bird surveys half an hour before sunrise and finished by 3 hours after sunrise. This corresponded to the period of greatest bird activity. Three trained observers surveyed birds, alternating transects visited within the season to spread bias associated with inter-observer variability evenly across all points. We surveyed each transect forwards and backwards on alternating visits to minimize the effect of time of day on bird counts. We did not survey on mornings that were rainy or extremely windy.

We allowed 1 minute to pass before beginning a survey to diminish the effect walking to a point-count station has on bird activity. We recorded all birds seen and heard at each point-count station during a 5 minute interval. Five minutes allowed the majority of birds to be detected while minimizing the chance of counting an individual twice during the same period (Bibby et al. 1992). This requirement is imperative if each counting station is to be statistically independent (Reynolds et al. 1980).

We recorded the distance to each bird as falling into 1 of 5 concentric bands radiating out from the observer (Bibby et al. 1992): 0-30 meters, 31-60 meters, 61-100 meters, 101-150 meters, and >150 meters. We recorded the location of each bird by vegetation type and the specific plant species used whenever possible. We also recorded the sex, age, and activity of each bird. We were especially attentive to common host species and cowbirds, paying particular attention to the sex of each cowbird detected. Female and male cowbirds can be distinguished by their calls. Male chatter calls, emitted once or twice at a time, have little to no variation in frequency of the elements that compose the call. Female chatter calls arc variable and used many times in succession (Rothstein, cited in Lowther 1993). For data sheet and protocol, refer to study proposal (Averill et al. 1997. Lower Colorado River valley cowbird control project. Study design plan submitted to Bureau of Reclamation and U.S. Fish and Wildlife Service, 25 March 1997). Hereafter, this document is referred to only as proposal. Numbers of *Myiarchus* flycatchers (brown-crested and ash-throated flycatchers) were combined for presentation because of some confusion over identification early in. 1998.

Establishment of Nest-Searching Plots

We established nest-searching plots along the same transects used for point-count surveys. We established 12 plots, each between 4 and 5 hectares in size (~40,000-50,000 rn^2) and implemented the following treatments:

Treatment A: Trap and remove adult cowbirds

Treatment B: Trap and remove adult cowbirds, and addle cowbird eggs and remove cowbird young

Reference: No control measures

Because vegetation and landscape features differ by location, we established plots using a randomized block experimental design (Zar 1996; refer to Appendix 2 for plot locations, proposal for plot design). In each block, we located 2 treatment plots adjacent to one another in a matched pairs design, randomly determining which plot received treatment A and which plot received treatment B. We located the reference plot >1 km from the treatment plots. The isolation of reference plots allowed us to determine parasitism rates and host nesting success in areas removed from cowbird trap sites. We delineated the perimeter of each plot with colored flagging (orange = reference, yellow = treatment A, pink = treatment B) and marked reference points at 25 m intervals.

The treatments applied to plot types A and B were reversed between 1997 and 1998. This was done to provide independence between treatments between years. This procedure was necessary because sufficient riparian vegetation does not exist for locating a set of new plots in 1998.

Nest Searching and Monitoring

We visited nest plots every 3-5 days, beginning 10 April and ending 1 July 1997, and beginning 15 March and ending 24 July 1998, to monitor nests and determine parasitism rates and nesting success of host species (Martin and Guepel 1993). We located nests by systematically searching vegetation and observing adult behavior. We used behavioral cues, such as the carrying of nesting material, food, or fecal sacs to discover nest locations (Martin and Guepel 1993). We recorded nest location, nest contents, behavior of adult birds, and interactions with cowbirds. We searched below nests for ejected cowbird eggs and examined the nest lining for buried cowbird eggs once a nest had fledged or failed.

When a nest was discovered, we flagged a nearby location and wrote the following information on the flag: species 4-letter code, a unique nest-identification number, height of nest, compass bearing, and distance to nest. We did not inspect a nest if we suspected the adults were nest building or egg laying to minimize the chance of desertion due to disturbance (Ralph et al. 1993). We did not approach a nest if cowbirds were in the vicinity, but instead marked the location of the nest and returned to cheek it later.

We monitored high nests with the use of a mirror attached to an extendable pole (adapted from Ralph et al. 1993). If it was not possible to check the contents of a nest, we observed adult activity (or lack of activity) so that nesting stage could be determined (Martin and Guepel 1993). We assumed that a nest was successful if fledglings were seen or heard near the nest, if the nest had flattened rims and fecal droppings on the edge (Martin and Guepel 1993), or if the nest had large nestlings close to fledging age at the time of the last nest check and there was no evidence of predation. We assumed that the number and identity of fledglings was equivalent to the number of cowbird and host species nestlings present in the nest at the last visit, as long as these nestlings were within a few days of fledging. We assumed predation had occurred if the entire contents of a nest disappeared before fledging was possible, the nest was torn up or falling out of the tree, or egg fragments were in the nest or on the ground below the nest (Martin and Guepel 1993). We assumed that a nest was abandoned if nest building was incomplete or cold eggs were in the nest on two or more occasions.

We addled cowbird eggs found in Bell's vireo and yellow-breasted chat nests on treatment B plots. We tried not to disturb nests until after the onset of incubation to minimize the chance of desertion caused by human visitation. At this point, we jostled the cowbird eggs and placed them back in the nest. This procedure minimized the chance of nest desertion due to an alteration in clutch volume (Rothstein 1982, 1986; Sealy 1992). If a nest was inaccessible (i.e., cowbird eggs could not be addled), these nests were not included in analyses of treatment effect. Refer to proposal for data sheets and protocol for monitoring nests.

Trap Design and Placement

We trapped cowbirds in modified Australian crow traps. Australian crow traps are traditionally constructed out of wood and chicken wire mesh and measure 6' x 6' x 8' with 2, 1 -1/2" width slits on the ceiling of the cage through which cowbirds enter but rarely escape (Robinson et al. 1993). Eleven cowbird decoy traps, measuring 6' x 6' x 4', were constructed in 1997 using PVC piping for the frame and chicken wire mesh for the walls. This design allowed greater flexibility in trap placement because they were small, light-weight, and highly portable. In addition, each trap was covered with 2 layers of ultra-violet paint to protect the PVC piping from sunlight and heat.

We placed a cowbird trap on the perimeter of each treatment plot such that points within the plot were <800 in from a trap. We located traps on the outskirts of the riparian areas in a partly open setting (not within dense forest, Collins et al 1989) where they were not visible from roads or paths. We placed traps near a tall tree (potential cowbird perch), but not directly below the tree, when possible (Robinson et al. 1993). We placed traps so that they were partly shaded from afternoon sun.

We baited each trap with live cowbird decoys. We trapped decoy cowbirds at Havasu Equestrian horse stables, Lake Havasu City, Arizona. We trapped the first cowbird decoys using potter traps baited with seed. These birds were subsequently used to trap cowbird decoys using a modified Australian crow trap. We kept the decoys in a modified Australian crow trap at the Bill Williams River NWR Headquarters Office until they were put in decoy traps on the refuge. In 1997 we discovered that the office trap attracted many cowbirds; therefore, we kept this trap operational throughout the field season in 1997 and 1998.

Each cowbird trap was stocked with at least 1 female decoy and several male decoys to improve capture rate of female cowbirds (Robinson et al. 1993). The exact number and sex ratio of the decoys in our traps was initially dependent on capturability of cowbirds at local wintering sites.

Marking and Removing Cowbirds

We visited cowbird traps every 2 days, mid-April through June 1997, and mid-April through mid-July 1998. We recorded the age and sex of all cowbirds caught, differentiating females from juveniles by inspection of plumage (Lowther 1993). We marked and released ~25% of all cowbirds caught in the office trap to address the question of where these birds might breed and forage. Though female cowbirds are the primary target for removal (i.e., killing), it was important to mark and release some female cowbirds to determine sex-specific movement patterns. About 35% of captured females were released during the host breeding season. All females captured at the end of the breeding period in 1998 (mid-July) were banded and released to aid in determining over-winter survival rates and site fidelity. This will aid in determining future trap locations that will increase the likelihood of capturing females breeding in a target area. We banded and released cowbird juveniles (young of the year) from all traps. Resighting of these birds as breeding adults may give insight into movement patterns and natal-site fidelity. We banded each cowbird on the left leg with a U.S. Fish and Wildlife Service aluminum band and paint-marked them on the crown in 1997. Painting was used to try to enhance resighting of birds to aid in determining foraging areas. Because the paint did not remain visible for more than a few weeks, in 1998 we instead placed a single color band on the right leg before release.

DATA ANALYSES

Brown-headed Cowbird and Host Species Relative Abundance

We calculated relative abundance for all bird species as the mean number of detections/point/count period. We considered bird detections within 100 meters of each point-count station. We calculated relative abundance regardless of sex due to similarity of male and female calls in most species.

We recalculated the relative abundance of bird species in 1994-1995 (Lynn et al. 1996) using the above criteria so that results would be directly comparable to 1997 and 1998 data. We reported which host species decreased and increased in abundance between study years. Species with <10% change in abundance were not addressed.

For each transect, we calculated cumulative host abundance as the mean number of host species/point/count period. Hosts were considered to be any species that would likely receive a cowbird egg, even if it might be ejected. We calculated suitable host abundance in a similar manner, disregarding species that frequently eject cowbird eggs (Bullock's oriole; Roskaft et al. 1993) and those that feed their nestlings non-insect diets (house finch; Kozlovic 1996). We used the ratio of cowbird to (suitable) host abundance as an indicator of the likelihood of parasitism (see Rogers et al. 1997 for discussion of cowbird host ratios).

To assist with analyzing the trend of host species over time, we developed a ratio between the abundance of host species on the Treatment (T) Transects (B, C, D) and Reference (R) Transects (A, E, F). Over time, a declining index (TIR) would indicate that bird abundance is declining on Treatment Transects relative to Reference Transects, whereas an increasing index would indicate that abundances are increasing on Treatment Transects relative to Reference Transects.

Parasitism Rates and Nesting Success

We calculated brood parasitism rates for Bell's vireos and yellow-breasted chats as the percent of all nesting attempts that were parasitized. We considered a nest parasitized if ≥1 cowbird egg or nestling was observed in the nest or cowbird eggs were discovered on the ground below the nest. We considered a nest unparasitized if it did not fail prior to incubation and final clutch contents were known. Some nests were found during the brooding stage. These nests were considered unparasitized if there were no cowbird nestlings or eggs in the nest. This assumption is probably valid because (1) many of these nests contained 3-4 nestlings (a full clutch size) and (2) Bell's vireos and yellow-breasted chats rarely, if ever, eject cowbird eggs (Rohwer and Spaw 988, Burhans and Freeman 1997). We determined the distribution of cowbird eggs in nests with complete clutches. We reported cowbird egg distribution as the frequency and percent of ilests receiving 0, 1, 2, and 3 cowbird eggs. Calculations were done for each treatment type and overall.

We divided the breeding season into 1-week intervals and reported when vireo and chat nests were found, when clutches were initiated (first egg laid), and approximately when parasitism occurred. For nests that were found after egg-laying, we approximated the date of clutch initiation by back-dating. We assumed that one egg was laid per day and incubation began when the last egg was laid. We assumed a 14 day incubation period for the vireo, an 11 day incubation period for the chat, and an 11 day incubation period for the cowbird; we assumed an 11 day nestling period for the vireo, an 8 day nestling period for the chat; and a 10 day nestling period for the cowbird (Ehrlich et al. 1988).

We calculated nesting success for Bell's vireos and yellow-breasted chats as the percent of nests confirmed active that successfully completed the egg-laying, incubation, and nestling stage. We considered a nest successful if it fledged at least 1 host young. These calculations were done by treatment type and overall, as well as for first and second brood attempts in the Bell's vireo. A nest was considered a first brood attempt if it occurred shortly after vireo arrival in the LCRV and no fledglings were seen with the adult. A nest was considered a second brood attempt if it occurred later in the breeding season and/or fledglings were seen with the vireo pair.

We used 1-way analysis of variance (anova) (Zar 1996) to compare the mean number of host eggs, nestlings, and fledglings per nest by treatment type. When a significant ($P < 0.05$) anova occurred, we used Tukey's multiple comparison test to determine which means significantly differed from one another (Zar 1996). Only nests that successfully completed the egg laying, incubation, and brooding stages respectively were used in calculations.

We attributed the cause of nest failure to abandonment, partial predation followed by abandonment, complete predation, or the fledging of only cowbird young. Separate calculations were done for each species, first and second broods, and parasitized and unparasitized nests.

Analysis of the Effectiveness of Cowbird Control

We visually compared relative abundances of cowbirds and host species obtained in 1994-1995 (pre-cowbird control) with 1997 and 1998 (post-cowbird control). We used the Chi-square test-of-independence (Zar 1996:483) to compare parasitism rates and nesting success of Bell's vireos and yellow-breasted chats across the 3 treatment types (i.e., without cowbird control, with adult cowbirds removed, and with adult and young cowbirds removed). We also compared the percent of nests receiving single and multiple cowbird eggs across treatment types using the Chi-square test-of-independence. We compared the mean number of host species eggs, nestlings, and fledglings across treatment types using anova (as described above). We looked for an association between the number of cowbirds removed and parasitism rates of Bell's vireos and yellow-breasted chats using Spearman's Rank correlation.

RBSULTS

Relative Abundances of Brown-headed Cowbirds and Host Species

Brown-headed cowbird abundance was lower in 1997 than 1994-1995 on all 6 transects surveyed, including 3 transects where cowbirds were not removed in 1997 (Table 1, Appendices 4-11). However, the greatest decrease in cowbird abundance occurred on the transects where cowbirds were actively removed in 1997 (transects B, C, and D). Cowbird abundance decreased by an average of 1.37 cowbirds/point/count period on transects B, C, and D compared to an average drop in cowbird abundance of 0.80 cowbirds/point/count period on transects A, B, and F.

The ratio of abundance of cowbirds to suitable host species declined by 77% from 1994-95 to 1997; the ratio declined 67% from 1997 to 1998 (for a 92% decline from 1994-95 to 1998)(Table 1). During 1998, cowbirds continued to decrease on all transects, except treatment plot C where combined abundance was very low (Appendix 8). There was a greater decrease in combined abundance and cowbird:host ratio on the reference transects (A, E, F) than the treatment transects (B, C, D)(Table 1).

In 1997, all potential host species *except* the yellow-breasted chat, blue grosbeak, and house finch experienced a decrease in abundance on more than half of the transects surveyed. The Bell's vireo decreased in abundance on 4 of the transects surveyed, although they only decreased in rank of abundance on 2 of these transects. The song sparrow decreased in abundance on 5 of the transects surveyed and decreased in rank of abundance on all 6 transects. The summer tanager decreased in abundance and rank of abundance on 4 of the transects surveyed.

During 1998, the vireo increased in abundance on 5 of 6 transects, while the chat decreased on 5 of 6. All other potential host species declined in abundance on over half of the transects except song sparrows, vermilion flycatchers, yellow warblers, and black-tailed gnatcatchers.

The ratio of bird abundance on Treatment Transects to that on Reference Transects (Table 2) indicated that, overall, 5 species were declining and 5 species were either increasing (4 species) or not changing over time. The ratio for Bell's Vireos declined, whereas that for Yellow-breasted Chats increased. The cowbird ratio decreased throughout the study (Table 2).

Cowbird Trapping and Removal

Three hundred eleven cowbirds were removed at Bill Williarns River during 1997:104 on the refuge and 207 at the headquarters office at the Bill Williams River Delta. The ratio of male to female cowbirds removed was 0.55 and 2.09 at the refuge and office, respectively. Sixty cowbirds (11 males, 49 females) were removed from traps on Treatment A plots. Forty-four cowbirds (26 males, 18 females) were removed from traps on Treatment B plots. By transect, 17 cowbirds (5 males, 12 females) were removed on D; 42 cowbirds (19 males, 23 females) were removed on C; and 45 cowbirds (13 males, 32 females) were removed on B. One hundred forty male cowbirds and 67 female cowbirds were removed from the office trap during 1997.

Traps were open on Bill Williams River NWR (transects B, C, and D) from 9 April - 30 June, 1997. The first cowbird (a male) was caught on 13 April. However, most cowbirds were caught between 24 April and 15 May (Table 3). All juvenile cowbirds were caught after 20 June.

One-hundred seventy-four cowbirds were removed at Bill Williarns River during 1998: 54 on the refuge and 120 at the headquarters office at the Bill Williams River Delta. The ratio of male to female cowbirds removed was 1.25 and 6.50 at the refuge and office, respectively. Twenty-five cowbirds (15 males, 10 females) were removed from traps on Treatment A plots. Twenty-nine cowbirds (15 males, 14 females) were removed from traps on Treatment B plots. By transect, 15 cowbirds (10 males, 5 females) were removed on D; 16 cowbirds (10 males, 6 females) were removed on C; and 23 cowbirds (10 males, 13 females) were removed on B. One-hundred-four male cowbirds and 16 female cowbirds were removed from the office trap.

Traps were open at the office trap from 6 April to 4 July 1998, and on the refuge (transects B, C, and D) from 22 April to 15 July 1998. The first cowbird was caught at the office trap 6 April; cowbirds were not captured on the refuge traps until 22 April. No concentrations of captures was noted (Table 4). The first juvenile cowbird was caught during the week of 10-16 June; most (35 of 37; 95%) juveniles were caught between 24 June and 14 July.

Overall, 72 cowbirds were released during 1997: 46 males, 19 females, and 7 juveniles. Sixty-five cowbirds were released from the office trap: 46 males and 19 females Overall, 167 cowbirds were released during 1998: 77 males, 37 females, and 53 juveniles. Fifty-four cowbirds were released from the office trap: 41 males, 1 female, and 12 juveniles. One-hundred thirteen cowbirds were released from the refuge traps: 36 males, 38 females, and 41 juveniles. However, 23 (62.2%) of the released females were let go on the final day of trapping (after banding) to assist with analysis of inter-year site fidelity and survivorship; thus, only 15 females were released during the host breeding period.

Recapture Rates and Movements

Of 69 cowbirds banded and released in 1997 at BWRNWR, 12 (17.4%) were recaptured during the 1998 field season. Eleven of 50 (22.0%) males were recaptured, and 1 of 19 (5.3%) females were recaptured. Two of the 50 male cowbirds were recaptured by other researchers north of the BWRNWR along the Colorado River: 32 km north at Lake Havasu City (Mohave Co.) on 20 April 1998, and 58 'cm north at the Havasu NWR (Mohave Co.). The bird captured at Lake Havasu City was accidentally killed3 whereas the bird at Havasu NWR was released (but not recaptured at BWRNWR).

Parasitism Rates and Nesting Success

Forty three active Bell's vireo nests, 23 active yellow-breasted chat nests, and 2 active common yellowthroat nests were found on Bill Williams River NWR in 1997; 121 vireo and 67 chat nests were found in 1998 (Appendix 12). In 1997, about 0.34 vireo nests were found per person hour, or 1 nest every 3 hours; and 0.21 chat nests were found per person hour, or 1 nest every 5 hours. During 1998,0.19 vireo nests (1 every 5 hours) and 0.12 chat nests (1 every 8 hours) were found per person hour.

Appendices 13-16 show the time of season in which Bell's vireo and yellow-breasted chat nests were found, approximate date of onset of egg-laying (defined here as clutch initiation), and approximate date of parasitism events. The majority of Bell's vireo nests were either initiated in April (probable first broods and early nesting attempts) or June probable second broods and late nesting attempts). Yellow-breasted chat nests were found fairly consistently throughout May and June, with more of these nests initiated in May than June. Parasitism was initiated by the end of May and continued through early July.

Approximately 37% of Bell's vireo nests and 10% of yellow-breasted chat nests were parasitized in 1997 (Table 5). Parasitism rates were highest for the Bell's vireo on the Treatment B plots and lowest on the Treatment A plots. The only cases of parasitism of yellow-breasted chat nests occurred on the reference plots (no cowbird removal). During 1998, about 17% of vireo and 18% of chat nests were parasitized (Table 6). Parasitism rates were about 1.5 times higher for vireos on reference plots, and about double on reference plots for chats.

Twenty-one percent of nests were singly parasitized (received 1 cowbird egg) and 8% were multiply parasitized in 1997 (received >1 cowbird egg; Table 7). Only Bell's vireos were multiply parasitized. Reference and Treatment B plots had a similar distribution of cowbird eggs per nest, whereas Treatment A plots had a lower percentage of singly and multiply parasitized nests. If reference plots (no cowbird control) are compared to all treatment plots combined (cowbird control), there was a lower proportion of singly and multiply parasitized nests at treatment sites. A statistically significant difference in cowbird egg distribution among treatment types could not be determined due to small sample sizes.

About 15-16% of vireo and chat nests were singly parasitized (received 1 cowbird egg) and 2% were multiply parasitized in 1998 (received >1 cowbird egg; Tables S and 9). Reference plots had a higher percentage of singly parasitized nests than either treatment types.

Overall nesting success (the percentage of nests that fledged at least one host young) was 66% for the Bell's vireo and 79% for the yellow-breasted chat in 1997 (Table 10). Thcrc was not a significant association between vireo nesting success and treatment type (X^2 = 4.414, P = 0.110). This P value, although not statistically significant, is close to 0.10 and may represent a biological significance. In other words, high vireo nesting success on Treatment B plots may be due to treatment effects (the addling of cowbird eggs).

Probable first and second broods could be determined for all but 2 vireo nests in 1997. Second broods had significantly higher parasitism rates than first broods in 1997 (Fisher's Exact Test 2-sided P value <0.0001; Table 10). Nest survival was higher for first broods of Bell's vireos than second broods throughout all stages of the nesting cycle, and second brood attempts were significantly less likely to survive to fledge vireo young in 1997 (Fisher's Exact Test, 2-sided P 0.0051). Nesting success was highest for chats on reference plots. There was a fairly large difference in nesting success of yellow-breasted chats on Treatment A and B plots. However, the 2 treatment types were essentially the same for chats because no nests were parasitized on treatment plots. Therefore, nesting success of chats was calculated across all treatment plots. Chat nesting success was not significantly associated with cowbird removal (Fisher's Exact Test 2-sided P -0.255).

Overall nesting success (the percentage of nests that fledged at least one host young) was 50% for the Bell's vireo and 73% for the yellow-breasted chat in 1998 (Table 11). Vireo nesting success on reference plots was about half of that on Treatment A and Treatment B plots. Chat nest success was relatively high (72%) on the reference plots. However, success was even highcr (93%) on Treatment B plots, although success was lower *(59%)* on Treatment A plots (Table 11).

Second vireo broods had higher parasitism rates than first broods in 1997 (Table 10). Nest survival, however, was higher for first broods of Bell's vireos than second broods throughout all stages of the nesting cycle.

Nest failure was attributed to abandonment, predation, or parasitism (raised only cowbirds) during all years of study (Tables 12 and 13). These categories may not be mutually exclusive. In 1994-1995, there was evidence that nest abandonment was associated with parasitism; however, there was no evidence that parasitized nests were more likely to be depredated than unparasitized nests (Averill, 1996). Predation was the leading cause of nest failure for both Bell's vireos and yellow-breasted chats in 1997 and 1998.

Reference plots had a lower mean number of host eggs per nest for Bell's vireos and yellow-breasted chats in 1997 (Table 14). However, the mean number of vireo nestlings/nest was the same or lower in treatment areas (cowbird control) as it was in reference areas (no cowbird control). This could again be the result of low sample sizes in 1997. There is a trend that could become significant as more data is collected: Treatment B plots had the highest parasitism rates and yet had the highest mean number of vireos fledged per nest. Treatment A plots had the lowest parasitism rates, but also had the lowest nesting success for vireos. In addition to removing adult cowbirds, the addling of cowbird eggs may be important to increase nesting success of Bell's vireos. On the other hand, yellow-breasted chat nests on treatment plots (A and B combined) had lower fledging success than nests on reference plots.

There were no significant (*P*.> 0.1) differences in number of eggs, nestlings, or fledglings between reference and treatment plots for vireos in 1998 (Table 15). However, the 0.5 fewer fledglings per nest on Reference plots relative to Treatment B plots was nearly significant (*P* = 0.107), and may indicate a biologically significant effect. Reference plots also had 0.2 fewer eggs per nest than Treatment B plots, but 0.4 fewer nestlings than Treatment B plots

There were significantly (0.05 <*P* < 0.1) fewer eggs laid per nest on Reference plots than either treatment plot types for chats in 1998 (Table 15). Although the number of nestlings (*P* = 0.163) and fledglings (*P* = 0.538) per nest remained lower on Reference plots, these differences were not significant. The magnitude of difference between Reference and treatments remained about the same.

First brood attempts had a greater mean number of vireo eggs, nestlings, and fledglings than second brood attempts in 1997 (Table 16). First brood attempts, which were infrequently parasitized, had approximately the same number of vireo fledglings/nest in reference and treatment plots. Second brood attempts, which were frequently parasitized, appeared to respond positively to cowbird egg addling. Small sample sizes suggest trends but not conclusions.

There were no significant (all *Ps* >0.38) differences in number of eggs, nestlings, or fledglings by plot type for first vireo broods in 1998 (Table 17). However, there were fewer fledglings on Reference plots than on either treatment type (0.3-0.4/nest fewer). Although there was no significant (*P* = 0.526) difference in the number of eggs laid by plot type, there were significantly (both *Ps* = 0.008) fewer nestlings and fledglings on Reference plots than on treatment plots for chats. Reference plots produced 1.0 fewer nestlings and 0.9 fewer fledglings per nest than Treatment B plots (both difference significant at

$P < 0.01$, Tukey's comparison), and 0.6 fewer nestlings and fledglings per nest than Treatment A plots (both differences significant at $P < 0.1$, Tukey's). No significant *($P > 0.1$)* differences between Treatment A and B plots were found for eggs, nestlings, or fledglings in 1998.

Foraging Sites

The largest congregation of brown-headed cowbirds was at Planet Ranch, in the fields. Fields at the ranch were only irrigated infrequently and irregularly during 1997-1998. The cowbirds at Planet Ranch were typically in a mixed flock of blackbirds (red-winged blackbirds and great-tailed grackles. Numbers of cowbirds were variable but appeared to range between 25 and 150 during the study. The male:female sex ratio was difficult to determine, but appeared to range from 5 1 to 1:1. Scattered brown-headed cowbirds were also observed at state parks and campgrounds near Parker Dam, California. Sporadically in May and June, single cowbirds were observed at these and other local parks (e.g., Buckskin Mountain State Park). In addition, a female bronzed cowbird was observed at Buckskin Mountain State Park on 4 June 1997.

DISCUSSION

Cowbird and Host Species Abundance

There was a lower abundance of cowbirds on Bill Williams River NWR in 1997 and 1998 (post-cowbird control) than in 1994-1995 (pre-cowbird control). Cowbird abundance was lower in 1998 than 1997 on all except one treatment transect. In fact, the percentage decrease in cowbird abundance was great on the reference transects relative to the treatment transects. We interpret this overall decline in cowbird numbers as resulting from our cowbird removal program: that is, the traps are decreasing cowbirds area wide, and not just near the treatment transects. During 1997, the greatest decline in cowbird abundance was on the treatment transects. Thus, it appears that repeated removal is having a cumulative effect on cowbird abundance; the relatively high capture rate of cowbirds at the Bill Williams Delta -- which appears to be a location of concentrated cowbird activity -- is apparently assisting with the overall lowering of cowbird abundance in the riparian (host nesting) areas of the refuge. This conclusion is supported by the high return rate (17%) of birds in 1998 banded during 1997: we appear to be capturing a relatively high proportion of the birds using the area.

The abundance of many potential host species was lower in 1998 than either 1994-95 or 1997. The yellow-breasted chat decreased on 5 of6 transects compared to 1997 abundances; Bell's vireos, however, increased in abundance on 5 of6 transects. Overall, however, the trend on Treatment Transects relative to Reference Transects (index) from 1994-95 through 1998 was an increase in chat nurnbers but a decrease in vireo numbers. Overall, there was an equal number of decreasing and increasing trends in abundance of host species. Thus, it appears that the abundance of host species are not responding in a substantial manner to cowbird removal.

The ratio of cowbirds to suitable host species was 20-31% on all transects surveyed in 1994-1995 at Bill Williams River NWR. Ratios above 10% are associated with high levels of parasitism in other regions (Donovan et al., in press, Thompson et al., in press, cited in Rogers et al. 1997). In 1997, these ratios ranged from 0-6% on transects with cowbird removal and 5-14% on transects without cowbird removal. In 1998, the ratios ranged from 0-1% on treatment transects and from 0-

6% on reference transects. These results suggest that parasitism rates were lower along the Bill Williams River in 1997 and 1993 relative to 1994-95, particularly in areas with cowbird removal.

Parasitism Rates and Nesting Success

Parasitism rates on vireo and chat nests were much lower in 1997(38% and 10%, respectively) and 1998 (17% and 18%, respectively) than 1994-1995 (92 and 73%, respectively; Averill and Lynn, Unpubl. data). Thus, parasitism rates for vireos continued to decline during 1998, while those for chats increased slightly (but remained 4 times lower than 1994-95 rates); sample size was low for chats in 1997, however. Past studies indicated that parasitism rates >25% (Robirson et al. 1993) or >30% (Layman 1987) could threaten survival of local populations of host species by destabilizing a population and increasing the probability of local extinction due to stochastic events. Finch (1983) also suggested that parasitism levels >30% could jeopardize the existence of regional riparian bird populations. Therefore, parasitism rates during 1998 had fallen below the level thought to be of conservation concern.

Parasitism rates were 2.75 times lower on treatment plots relative to reference plots for vireos, and 1.70 times lower for chats during 1998. Thus, although parasitism rates were lower overall during 1998, it appears that treatments also had a substantial influence on parasitism rates for vireos and chats.

First brood attempts by vireos had a substantially lower parasitism rate (11% vs 26%) than broods. Likewise, nesting success of first broods (71%) was substantially higher than second (45%). Thus, a parasitism rate of 26% appears to negatively impact nesting success of vireos.

During 1997, first broods had a very low parasitism rate (6%) relative to the high (70%) rate for second broods. Nest su&cess for first and second broods (90% and 44%) was apparently related to parasitism rate, as in 1998. Note, however, that the nest success for second broods was about the same, even though the 1997 parasitism rate was 2.7 times that of 1998. Thus, vireo nesting success apparently declines rapidly when parasitism approaches 25%, but does not decline further at even very high rates of parasitism.

In 1997,30% of parasitized nests along the Bill Williams River had>] cowbird egg; in 1994-1995,745% of parasitized nests in the LCRV had >1 cowbird egg. During 1998, only 17% of vireo nests and 18% of chat nests had >1 cowbird egg. For vireos, Reference plots had 28% of the nests with >1 cowbird egg, while treatment plots had only 6% with >1 cowbird egg. Likewise for chats, there were fewer nests with >1 cowbird egg on treatment plots (13%) compared to Reference plots (22%). Both Bell's vireo and yellow-breasted chat nestlings have a lower chance of fledging from multiply parasitized nests than singly parasitized nests (Averill 1996). However, vireos are unlikely to fledge any of their own young from a parasitized nest; therefore, reducing the intensity of parasitism alone will not benefit the vireo population.

Overall nesting success (the probability of fledging at least one host young) was higher in 1997 and 1998 than 1994-1995 (pre-cowbird control). Approximately *65%* of vireo nests were successful in 1997, *50%* in 1998 were successful, whereas only 11% were successful in 1994-1995. The 1994-1995 were probably biased somewhat low because only late first brood and second brood attempts were included. Approximately 80% of chat nests were successful in 1997, 73% in 1998, whereas 30% were successful in 1994-1995. Vireo nests on Treatment B plots had a higher nesting success (91%) than the other plots (Reference plus Treatment A) (~50%) during 1997; likewise, Treatment B plots were more successful (74%) than all other plots combined in 1998 (43%), suggesting a beneficial effect of cowbird egg removal on vireo nesting success. Likewise, chats on Treatment B plots had much higher nesting success (93% success) than the other plots combined (68%) during 1998; this comparison was not possible for 1997 because of a low sample size.

Predation was the leading cause of nest failure for Bell[1]s vireos and yellow-breasted chats in 1997 and 1998. However, the percent of nests that were depredated in 1997 (~l 8% for the vireo and 21% for the chat) was low compared to 1994-1995 (~37% for the vireo and 44% for the chat). Likewise, predation remained low for vireos (21%) and chats (15%) in 1998. It is possible that the lower predation rate can be attributed to the lower abundance of cowbirds. Arcese et al. (1996) hypothesized that parasitism and predation rates are associated because cowbirds depredate host nests found late in the nesting cycle to hasten renesting. This hypothesis predicts that unparasitized nests will have a higher predation rate than parasitized nests. However, in areas where female cowbirds have overlapping territories, it is expected that cowbirds will depredate nests with the eggs of conspecifics. In 1994-1995, many cowbird eggs were found on the ground below vireo nests (Averill 1996). It was suggested that competing cowbirds ejected the eggs of conspecifics to replace them with their own. In 1997 and 1998, only 1~2 instances of cowbird eggs below host nests were documented.

The average number of vireo and chat eggs, nestlings, and fledglings per successful nest was higher in 1997 and 1998 than 1994-1995 (Averill, unpubl. data). The average number of vireo and chat eggs, nestlings, and fledglings in *unparasitized nests* in 1994-1995 (Averill 1996) was similar or higher than the mean value for nests in the treatment plots in 1997-98. Therefore, overall low fledging success in 1994-1995 appears to be attributable to the high parasitism rates. In 1997 and 1998, vireo nests with the highest mean number of fledglings per successful nest were in plots where cowbird eggs were addled (Treatment B). Thus, it appears that removal of cowbird eggs or young may be necessary to boost reproductive success of small host species, such as the Bell's vireo, in areas with high cowbird abundance.

IS COWBIRD CONTROL A VIABLE MANAGEMENT ALTERNATIVB?

Reducing parasitism rates (through cowbird trapping) and making cowbird eggs inviable (through addling) will not improve songbird nesting success if parasitism is not the primary cause of nest failure. Stutchbury (1997) found that cowbird trapping did not increase nesting success of hooded warblers because predation was the major factor limiting nesting success. However, cowbird removal has increased the reproductive success of Kirtland's warblers (Kelly and DeCapita 1982), least Bell's vireos, and black-capped vireos (Robinson et al. 1995). Along the Bill Williams River, nest failure was high in years of high cowbird abundance (1994-1995) and low in the years (1997-98) with lower cowbird abundance. It appears that parasitism was the primary cause of nest failure before cowbird control was implemented, especially for small host species such as the Arizona Bell's vireo. Removal of cowbirds appears to have resulted in lower parasitism rates and higher nesting success for both vireos and chats. However, the abundance of vireos and chats has not changed substantially between 1994-95 and 1997-98 despite cowbird control. This does not mean, however, that control is not *preventing* a reduction in host abundance by allowing for the production of an ample number of offspring to offset post-fledgling mortality, including that incurred during migration and on wintering grounds. Or, young birds could be dispersing out of our immediate study area. This is the most likely conclusion given that our control program has apparently reduced parasitism rates below' hose thought to result in population declines.

Cowbird trapping is an investment in time, money, and personnel. Along the Bill Williarns River, cowbird traps were visited every 1-2 days in the summertime. It typically took 1.5-2 hours/visit to monitor 6 traps along a linear stretch of the River. However, this cost may be outweighed by the benefits of low parasitism rates for nesting songbirds. Nest searching (and egg addling) is a larger time investment, but this additional cost may also be outweighed by the benefits for small host species. Searching for vireo nests takes relatively little time once personnel are familiar with species-specific behavior (1 nest every 3-5 hours). Chat nests were relatively more difficult to locate, taking about *5-8* hours to locate a nest, At the relatively low parasitism rates seen during 1998, addling cowbird eggs and removing cowbird hatchlings might not be indicated. However, some nest monitoring remains necessary to determine the parasitism rates being experienced by hosts so the intensity of adult cowbird removal can be determined. Because first broods of vireos largely escaped parasitism (at least in years/areas with low cowbird abundance), all of the nest-searching effort could be concentrated in June.

In 1996, 130 female cowbirds were removed from 2 traps on Bill Williams River NWR. In 1997, 67 female cowbirds were removed from 6 traps placed on the refuge and 67 female cowbirds were removed from a trap that was located at the Bill Williams Delta in a possible flyway between cowbird foraging and breeding sites. During 1998,24 females were removed from the refuge and an additional 16 were removed from the Delta trap. Because the riparian area of the Bill Williams River is a relatively isolated strip of vegetation amid a desert landscape, it may not be rapidly recolonized by cowbirds as original birds are removed. Therefore, fewer and fewer cowbirds may be caught in subsequent years, as was noted between 1997 and 1998. Such a pattern has been observed along the Kern River in California (M. Halterman, Kern River Preserve, pers. Comm.).

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Table 1. Ratio of brown-headed cowbird to host species abundance in 1994-1995,1997, and 1998; and change in cowbird abundance between study periods, Bill Williams River National Wildlife Refuge.

Transect	BHCO:ROST			BHCO:SUITABLE HOST			CHANGE IN BHCO[a] ABUNDANCE	
	1994-1995	1997	1998	1994-1995	1997	1998	1997	1998
A	0.29	0.07	0.03	0.31	0.08	0.03	-0.95	-0.14
B	0.25	0.06	0.01	0.27	0.06	0.01	-1.40	-0.26
C	0.24	0.00	0.01	0.25	0.00	0.01	-1.46	0.04
D	0.19	0.04	0.00	0.20	0.04	0.00	-1.24	-0.22
E	0.22	0.11	0.06	0.25	0.14	0.06	-0.58	-0.58
F	0.22	0.04	0.00	0.26	0.05	0.00	-0.88	-0.25
Mean	0.24	0.05	0.02	0.26	0.06	0.02	-1.09	-0.24
SD	0.034	0.037	0.023	0.036	0.047	0.023	0.340	0.202

[a] Change in cowbird abundance between 1994-1995 and 1997(1997 column) and 1998(1998 column).

Table 2. Index of the ratio of bird abundance on Treatment CT) Transects (B, C, D) to Reference (R) Transects (A, E, F). A declining ratio (TIR) over time indicates that birds on Treatment Transects are declining relative to Reference Transects, whereas an increasing ratio indicates that birds on Treatment Transects are increasing relative to Reference Transects.

	Index (TIR)			
Species [a]	1998	1997	1994-95	T/Rtrend
Abert's Towhee	0.58	0.67	0.58	Neutral
Bell's Vireo	1.69	1.89	2.76	Declining
Blue Grosbeak	1.36	1.64	0.92	Increasing
Brown-headed Cowbird	0.29	0.53	0.96	Declining
Bullock's Oriole	0.50	0.46	0.15	Increasing
Common Yellowthroat	0.62	1.47	1.06	Declining
House Finch	0.57	0.43	1.22	Declining
Red-winged Blackbird	_[b]	0.39	1.78	Declining
Song Sparrow	0.91	0.82	1.39	Declining
Summer Tanager	0.35	0.50	0.29	Increasing
Yellow-breasted Chat	1.14	1.09	0.95	Increasing

[a] Only species that are potential hosts and with indices generally >0.1 are presented.

[b] Reference value 0.

Table 3. Date that male, female, and juvenile cowbirds were caught in traps on Bill Williams River National Wildlife Refuge, 1997.[a]

DATE	MALE COWBIRDS[b]	FEMALE COWBIRD S[b]	JUVENILE COWBIRDS
APRIL9-15	1	0	0
APRIL16-31	14	13	0
MAY 1-15	21	42	0
MAY16-31	7	9	0
JUNE 1 - 15	8	15	0
JUNE 16-30	6	7	4

a Only considers 6 traps on Bill Williams River NWR, not trap located at office headquarters. Number of cowbirds caught differs from number of cowbirds removed (reported in text) because some cowbirds escaped from the traps and were not killed. Some of the birds that escaped probably were recaught at a later date. Numbers do not include banded birds that were trapped and released; these individuals frequently re-entered traps.

Table 4. Date that male, female, and juvenile cowbirds were caught in traps on Bill Williams River National Wildlife Refuge, 1998.

DATE	TREATMENT A			TREATMENT B		
	MALE	FEMALE	JUVENILE	MALE	FEMALE	JUVENILE
April22-28	0	11	0	2	2	0
April29-May5	3	7	0	7	6	0
May6-12	2	4	0	3	6	0
May 13 - 19	1	2	0	1	2	0
May2O-26	3	2	0	4	7	0
May27-June2	1	2	0	1	0	0
June3-9	2	1	0	2	4	0
JunelO-16	4	12	1	5	7	0
Junel7-23	4	4	0	5	1	1
June24-30	0	2	5	3	4	3
July 1 - 7	0	2	1	0	2	4
July8-14	1	6	7	5	2	15

Table 5. Number of cowbirds removed and corresponding parasitism rates on Bell's vireos and yellow-breasted chats, Bill Williams River National Wildlife Reflige, 1997.

Category	# Cowbirds Removed		% Parasitism [a.b]	
	total	Female	vireos	chats
Transect				
A	0	0		16.7
B	45	32	44.4	0.0
C	42	23	28.6	0.0
D	17	12	25.0	0.0
E	0	0	25.0	
F	0	0	42.9	50.0
Nest-searching Plot				
Reference	0	0	36.4	25.0
Treatment A	60	49	26.7	0.0
Treatment B	44	18	50.0	0.0
Overall	104	67	37.5	10.0

[a] Dashed line indicates that no nests were found on this transect.

[b] Refer to Appendix 12 for sample sizes of nests by transect and plot type.

Table 6. Number of cowbirds removed and corresponding parasitism rates on Bell's vireos and yellow-breasted chats, Bill Williams River National Wildlife Refuge, 1998.

Category	# Cowbirds Removed		% Parasitism [a]	
	total	Female	BEVI	YBCH
Transect				
Reference Plot A	0	0	33.3	20.0
Plot B Treatment A	15	8	5.3	0.0
Plot B Treatment B	8	5	0.0	0.0
Plot C Treatment A	8	3	12.5	0.0
Plot C Treatment B	6	1	0.0	0.0
Plot D Treatment A	5	3	25.0	40.0
Plot D Treatment B	9	2	0.0	33.3
Reference Plot E	0	0	8.3	40.0
Reference Plot F	0	0	33.3	18.2
Nest-searching Plot				
Reference	0	0	28.1	22.2
Treatment A	28	14	11.4	11.8
Treatment B	23	8	8.8	14.3
Overall treatment	51	22	10.2	13.1
Overall plots (reference +treatment)			16.5	17.9

[a]BEVI = Bell's vireo; YBCH = Yellow-breasted chat.

Tab]e 7. Distribution of brown-headed cowbird eggs in host species nests on Bill Williams River National Wildlife Refuge, 1997[a]

Plot type [b]	# cowbird eggs [c]	Frequency	Percent
Reference	0	13	65.0
	1	5	25.0
	2	2	10.0
	3	0	0.0
Treatment A	0	18	81.8
	1	3	13.6
	2	0	0.0
	3	1	4.5
Treatment B	0	12	63.2
	1	5	26.3
	2	2	10.5
	3	0	0.0
Treatments combined	0	30	73.2
	1	8	19.5
	2	2	4.9
	3	1	2.4
Overall	0	43	70.5
	1	13	21.3
	2	4	6.6
	3	1	1.6

[a]Nests of Bell's vireos, yellow-breasted chats, and common yellowthroats combined. Calculations included only nests at which number of cowbird eggs was determined.
[b]Reference = no cowbird control; Treatment A = removal of adult cowbirds; Treatment B = removal of adult and young cowbirds; Treatment = nests from treatment A and B combined.
[c]Total number of cowbird eggs recorded at a nest, including those with cowbird eggs laid late in the nesting cycle or found on the ground below a nest.

Table 8. Distribution of brown-headed cowbird eggs in Bell's virco nests, Bill Williams River National Wildlife Refuge, 1998[a].

Plot type [b]	# cowbird eggs[c]	Frequency	Percent
Reference A	0	10	66.7
	I	4	26.7
	2	1	6.7
Reference E	0	11	91.7
	1	1	8.3
	2	0	0.0
Reference F	0	20	66.7
	1	9	30.0
	2	1	3.3
Total Reference	0	41	71.9
	1	14	24.6
	2	2	3.5
Plot B Treatment A	0	18	94.7
	1	1	5.3
	2	0	0.0
Plot C Treatment A	0	7	87.5
	I	1	12.5
	2	0	0.0
Plot D Treatment A	0	6	75.0
	1	2	25.0
	2	0	0.0
Total Treatment A	0	31	88.6
	1	4	11.4
	2	0	0.0
Plot B Treatment B	0	12	100.0
	1	0	0.0
	2	0	0.0

Plot C Treatment B	0	7	100.0
	1	0	0.0
	2	0	0.0
Plot D Treatment B	0	10	100.0
	1	0	0.0
	2	0	0.0
Total Treatment B	0	29	100.0
	1	0	0.0
	2	0	0.0
Total all treatments	0	60	93.8
	1	4	6.2
	2	0	0.0
Overall Total	0	101	83.5
	1	18	14.9
	2	2	1.6

[a] Calculations included only nests at which number of cowbird eggs was determined.

[b] Reference no cowbird control; Treatment A = removal of adult and young cowbirds;

Treatment B = removal of adult cowbirds; Treatment = nests from treatment A and B combined.
[c] Total number of cowbird eggs recorded at a nest, including those with cowbird eggs laid late in the nesting cycle or found on the ground below a nest.

Table 9. Distribution of brown-headed cowbird eggs in Yellow-breasted chat nests located inside the plot perimeters on Bill Williams River National Wildlife Refuge, l998[a].

Plot type	# cowbird eggs [c]	Frequency	Percent
Reference A	0	16	80.0
	1	4	20.0
	2	0	0.0
Reference E	0	3	60.0
	1	2	40.0
	2	0	0.0
Reference F	0	9	81.8
	1	I	9.1
	2	1	9.1
Total Reference	0	28	77.8
	1	7	19.4
	2	1	2.8
Plot B Treatment A	0	6	100.0
	1	0	0.0
	2	0	0.0
Plot C Treatment A	0	6	100.0
	1	0	0.0
	2	0	0.0
Plot D Treatment A	0	3	60.0
	I	2	40.0
	2	0	0.0
Total Treatment A	0	15	88.2
	I	2	11.8
	2	0	0.0
Plot B Treatment B	0	7	100.0
	1	0	0.0
	2	0	0.0

Plot C Treatment B	0	1	100.0
	1	0	0.0
	2	0	0.0
Plot D Treatment B	0	4	66.7
	1	2	33.3
	2	0	0.0
Total Treatment B	0	12	85.7
	1	2	14.3
	2	0	0.0
Total all treatments	0	27	87.1
	1	4	12.9
	2	0	0.0
Overall Total	0	55	82.1
	1	11	16.4
	2	1	1.5

a Calculations included only nests at which number of cowbird eggs was determined.
b Reference = no cowbird control; Treatment A = removal of adult and young cowbirds;

Treatment B = removal of adult cowbirds; Treatment = nests from treatment A and B combined.

c Total number of cowbird eggs recorded at a nest, including those with cowbird eggs laid late in the nesting cycle or found on the ground below a nest.

Table 10. Bell's vireo and yellow-breasted chat nesting success, Bill Williams River National Wildlife Refuge, 1997.

Plot Type	% Parasitism (n)[b]	% Nesting Success (n) Egg laying[c]	Incubation[d]	Nestling[e]
		BELL'S VIREO		
Reference	36.4 (11)	100.0 (11)	61.5 (13)	58.3 (12)
TreatmentA	26.7 (15)	93.8 (16)	75.0 (16)	53.3 (15)
Treatment B	50.0 (14)	100.0 (14)	92.9 (14)	90.9 (11)
First Brood	5.6 (18)	100.0 (18)	89.5 (19)	89.5 (19)
Second Brood	70.0 (20)	95.2 (21)	68.2 (22)	44.4 (18)
Overall	37.5 (40)	97.6 (41)	79.1 (43)	65.8 (38)
		YELLOW-BREASTED CHAT		
Reference	25.0 (8)	100.0 (9)	100.0 (8)	100.0 (6)
TreatmentA	0.0 (7)	100.0 (6)	87.5 (8)	62.5 (8)
Treatment B	0.0 (4)	87.5 (8)	100.0 (6)	80.0 (5)
Treatment *	0.0 (12)	92.9 (14)	92.9 (14)	69.2 (13)
Overall	10.0 (20)	95.7 (23)	95.5 (22)	78.9 (19)

a Reference plots had no cowbird removal, Treatment A plots had adult cowbird removal, Treatment B had adult and young cowbird removal, Overall combines nests from all plots.
b Percent of nests that were parasitized. n = number of nests at which parasitism could be determined (refer to methods section).
c Percent of nests that survived through the egg-laying stage. n = number of nests at which survival or failure of the egg-laying stage was definitively known.
d Percent of nests that survived through the incubation stage. n = number of nests at which survival or failure of the incubation stage was definitively known.
e Percent of nests that survived through the nestling stage and fledged ≥1 host young. n = number of nests at which survival or failure of the nestling stage was definitively known.
* Nests from treatment A and B plots combined (no cowbird eggs were found in chat nests in pink plots, rendering treatment A and treatment B essentially the same for yellow-breasted chats).

Table 11. Bell's vireo and yellow-breasted chat nesting success, Bill Williams River National Wildlife Refuge, 1998.

Plot Type	% Parasitism (n)[b]	% Nesting Success (n)		
		Egg laying[c]	Incubation [d]	Nestling [e]
		BELL'S VIREO		
Reference Plot A	33.3 (15)	46.7 (7)	0.0 (3)	0.0 (3)
Plot B Treatment A	5.2 (19)	84.2 (16)	78.9(15)	78.9 (15)
Plot B Treatment B	0 (13)	100.0 (13)	100.0 (8)	92.3 (12)
Plot C Treatment A	12.5 (8)	87.5 (7)	87.5 (7)	75.0 (6)
Plot C Treatment B	0 (7)	71.4 (5)	71.4 (5)	71.4 (5)
Plot D Treatment A	25 (8)	62.5 (5)	25.0 (2)	12.5 (1)
Plot D Treatment B	0 (10)	50.0 (5)	50.0 (5)	40.0 (4)
Reference Plot E	8.3 (12)	75.0 (9)	58.3 (7)	50.0 (6)
Reference Plot F	33.3 (30)	90.0 (27)	60.0(18)	30.0 (9)
First Brood	11.3 (62)	98A (61)	80.6(50)	71.0 (44)
Second Brood	26.3 (57)	75.4 (43)	63.2(24)	44.7 (17)
Total Reference	28.1 (57)	82.4 (28)	49.1(28)	31.6 (18)
Total Treatment A	11.4 (35)	77.7 (94)	68.6 (24)	62.9 (22)
Total Treatment B	8.8 (34)	80.0 (28)	73.5 (25)	73.5 (25)
Overall	16.5 (121)	81.0 (51)	62.0 (75)	50.4 (61)
		YELLOW-BREASTED CHAT		
Reference Plot A	20 (20)	75.0 (15)	65.0 (13)	65.0 (13)
Plot B Treatment A	0 (6)	83.3 (5)	83.3 (5)	83.3 (5)
Plot B Treatment B	0 (7)	85.7 (6)	85.7 (6)	85.7 (6)
Plot C Treatment A	0 (6)	83.3 (5)	66.7 (4)	66.7 (4)
Plot C Treatment B	0 (1)	100.0 (1)	100.0 (1)	100.0 (1)
Plot D Treatment A	40 (5)	80.0 (4)	40 (2)	20.0 (1)
Plot D Treatment B	33.3 (6)	100.0 (6)	100.0 (6)	100.0 (6)
Reference Plot E	40 (5)	100.0 (5)	100.0 (5)	100.0 (5)
Reference Plot F	18.2 (11)	100.0(11)	72.7 (8)	72.7 (8)
Total Reference	22.2 (36)	86.1(31)	72.2 (26)	72.2 (26)
Total Treatment A	11.8 (17)	82.4(14)	64.7 (11)	58.8 (10)
Total Treatment B	14.3 (14)	92.9(13)	92.9 (13)	92.9 (13)
Overall	17.9 (67)	86.6(58)	74.6 (50)	73.1 (49)

a Reference Plots had no cowbird removal, Treatment A plots bad adult and young cowbird removal, Treatment B plots had adult cowbird removal, Overall combines nests from all plots.

b Percent of nests that were parasitized. n = number of nests at which parasitism could be determined.

c Percent of nests that survived through the egg-laying stage. n = number of nests at which survival of the egg-laying stage was definitively known.

d Percent of nests that survived through the incubation stage. n = number of nests at which survival of the incubation stage was definitively known.

Table 12. Causes of nest failure for Bell's vireos and yellow-breasted chats, Bill Williams River National Wildlife Refuge, 1997.

Classification [a]	Cause of Nest Failure		
	Abandoned	Depredated	Raised Cowbirds Only
		BELL'S VIREO	
First Brood	1	1	0
Second Brood	3	5	2
Unparasitized	1	2	0
Parasitized	3	2	2
Overall	4	7	2
		YELLOW-BREASTED CHAT	
Overall	0	4	0

a Nests were classified (when possible) as first or second brood, unparasitized or parasitized, and parasitized nests at which cowbird eggs were addled or not. Overall refers to all nests regardless of classification and includes those nests that could not be classified (thus the discrepancy in numbers for depredated nests). Sample sizes for chats were too small to break down by classification.

Table 13. Causes of nest failure *for* Bell's vireos and yellow-breasted chats, Bill Williams River National Wildlife Refuge, 1998.

Classification [a]	Cause of Nest Failure		
	Abandoned	Depredated	Raised Cowbirds Only
		BELL'S VIREO	
First Brood	9	6	0
SecondBrood	7	12	6
Unparasitized	13	10	0
Parasitized	3	8	6
Overall	16	26	12
		YELLOW-BREASTED CHAT	
Overall	0	10	0

a Nests were classified (when possible) as first or second brood, and unparasitized or parasitized. Overall refers to all nests regardless of classification and includes those nests that could not be classified (thus the discrepancy in numbers for depredated nests). Sample sizes for chats were too small to break down by classification.

Table 14. Average number of host species eggs, nestlings, and fledglings per nest in areas with and without cowbird control, Bill Williams River National Wildlife Refuge, 1997.

Plot Type	Egg [a]			Nestlings [b]			Fledglings [c]		
	X	SD	n	X	SD	n	X	SD	n
				BELL'S VIREO					
Reference	3.0	1.1	6	2.8	1.9	4	2.1	1.3	8
TreatmentA	3.5	0.5	12	2.8	1.2	10	1.9	1.3	8
TreatmentB	3.1	0.9	12	2.4	1.2	12	2.3	1.1	10
				YELLOW-BREASTED CHAT					
Reference	3.0	0.7	5	*2.5*	1.3	4	3.0	1.1	6
TreatmentA	3.4	0.4	7	3.0	0.9	6	3.0	1.0	3
TreatmentB	3.2	0.4	6	2.3	0.5	6	2.0	0.0	4
Treatment *	3.3	0.5	13	2.7	0.8	12	2.4	0.8	7

a n = number of nests that successfully completed the egg-laying stage and final clutch size known.
b n = number of nests that successfully completed incubation and brood size known.
c n = number of nests that successfully fledged young and number of fledglings known.
* Nests from treatment A and B plots combined (no cowbird eggs were found in chat nests in pink plots, rendering treatment A and treatment B essentially the same for yellow-breasted chats). No significant differences in the mean number of vireo or chat eggs, nestlings, and fledglings between the 3 plot types, Kruskall-Wallace test, P> 0.10.

Table 15. Average number of host species eggs, nestlings, and fledglings per nest in areas with and without cowbird control, Bill Williams National Wildlife Refuge, 1 998.

	Eggs			Nestlings			Fledglings		
Plot type	X	SD	n	X	SD	n	X	SD	n
				BELL'S VIREO					
Total Reference Plots	3.6	0.5	37	3.2	0.9	26	3.1	0.9	19
Total Treatment A	3.5	0.6	26	3.3	0.9	27	3.4	0.8	25
Total Treatment B	3.8	0.4	17	3.6	0.6	25	3.6	0.6	25
				YELLOW-BREASTED CHAT					
Total Reference Plots	3.4	0.6	25	3.2	0.8	26	3.2	0.9	25
Total Treatment A	3.8	0.6	13	3.6	1.1	12	3.5	1.1	11
Total Treatment B	3.9	0.7	11	3.7	0.7	14	3.5	0.9	14

a n = number of nests that successfully completed the egg-laying stage and final clutch size known.
b n = number of nests that successfully completed incubation and brood size known.
c n = number of nests that successfully fledged young and number of fledglings known.

Table 16. Average number of Bell's vireo eggs, nestlings, and fledglings in first and second broods in areas with and without cowbird control, Bill Williams River National Wildlife Refuge, 1997.

Plot Type	Eggs [a]			Nestlings [b]			Fledglings [c]		
	X	SD	n	X	SD	n	X	SD	n
				FIRST BROOD					
Reference	4.0	---	1	4.0	0.0	2	2.4	1.1	5
Treatment A	4.0	0.0	4	2.8	1.5	4	2.2	1.2	6
Treatment B	4.0	0.0	4	3.0	1.2	5	2.5	1.2	6
Treatment*	4.0	0.0	8	2.9	13	9	2.3	1.2	12
				SECOND BROOD					
Reference	2.8	1.1	5	1.5	2.1	2	1.7	1.5	3
Treatment A	3.1	0.4	7	2.6	1.1	5	1.0	1.4	2
Treatment B	2.6	0.8	7	1.8	1.0	6	2.0	0.8	4

a n = number of nests that successfully completed the egg-laying stage and final clutch size known.
b n = number of nests that successfully completed incubation and brood size known. n = number of nests that successfully fledged young and number of fledglings known.
* Nests from treatment A and B plots combined (only 1 cowbird egg was found in a first brood nest; this egg was laid late in the incubation stage, rendering treatment A and treatment B essentially the same for first broods).

Table 17. Average number of Bell's vireo eggs, nestlings, and fledglings in first and second broods in areas with and without cowbird control, Bill Williams River National Wildlife Refuge, 1998.

	Eggs [a]			Nestlings [b]			Fledglings [c]		
Plot type	X	SD	n	X	SD	n	X	SD	n
				FIRST BROOD					
Total Ref Plpts	3.9	0.3	12	3.8	0.5	12	3.3.	0.9	9
Total Treatment A	3.8	0.4	14	3.8	0.4	13	3.7	0.6	13
Total Treatment B	3.8	0.4	10	3.6	0.5	11	3.6	0.5	11
				SECOND BROOD					
Total Ref Plots	3.4	0.7	21	2.8	1.0	14	2.8	0.9	10
Total Treatment A	3.5	0.5	16	3.4	0.7	21	3.4	0.5	20
Total Treatment B	3.7	0.5	7	3.8	0.4	10	3.7	0.5	10

a n = Number of nests that successfully completed the egg-laying stage and final clutch size known.

b n = Number of nests that successfully completed incubation and brood size known.

c n = Number of nests that successfully fledged young and number of fledglings known.