ARIZONA COOPERATIVE FISH AND WILDLIFE RESEARCH UNIT December 2007

Glyphosate Applications to Control Buffelgrass in Pima County: Effects on Burrowing Owls

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Wildlife Research Report #2007-07

Glyphosate Applications to Control Buffelgrass in Pima County: Effects on Burrowing Owls

submitted to:

City of Tucson

on

19 December 2007

by

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Suggested Citation: Garcia, V., and C. J. Conway. 2007. Glyphosate Applications to Control Buffelgrass in Pima County: Effects on Burrowing Owls. Wildlife Research Report #2007-07. USGS Arizona Cooperative Fish and Wildlife Research Unit, Tucson, Arizona.

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EXECUTIVE SUMMARY

Many land management agencies have begun efforts to remove buffelgrass (*Pennisetum ciliare*) in southern Arizona. However, the effects of these applications on wildlife are a concern that has been raised by the City of Tucson Technical Advisory Committee (TAC). Burrowing owls prey upon herbivorous insects and small mammals, and hence, TAC members have expressed concern that chemicals contained in glyphosate herbicides (Roundup®, Kleenup®) may bioaccumulate and possibly cause deformities, mortalities, or reduced reproductive success in burrowing owls. Burrowing owls have declined in many portions of their breeding range in North America and are listed as a Species of National Conservation Concern in the U.S.

To determine the effects of treating areas for buffelgrass on burrowing owls, we surveyed for and monitored burrows occupied by burrowing owls in: 1) areas scheduled for buffelgrass treatment in Avra Valley, and 2) control areas in Avra Valley and Tucson. We compared nesting success, number of offspring produced, and morphological measurements of burrowing owls between treatment and control areas. We also examined whether herbicide application resulted in nest abandonment or mortality of burrowing owls.

Treating areas for buffelgrass did not seem to negatively impact burrowing owls, but we had limited statistical power to detect negative effects because so few burrowing owls nested in the treatment areas. Burrowing owls in treatment and control areas did not differ in apparent nesting success, number of offspring produced, or adult morphological measurements. Young juveniles in the treatment area did not weigh as much as juveniles in the control area, but this is based on juveniles from only one nest in the treatment area. We recommend specific actions in the future to minimize negative impacts on burrowing owls when implementing buffelgrass eradication treatments.

INTRODUCTION

One of the conservation tasks proposed in the City of Tucson's Habitat Conservation Plan (HCP) is the application of glyphosate herbicides (Roundup®, Kleenup®) to areas in Avra Valley and other locations around Tucson to control non-native buffelgrass (*Pennisetum ciliare*). However, the effects of these applications on wildlife (especially Burrowing Owls) are a concern that has been raised by the City of Tucson Technical Advisory Committee (TAC) for the HCP. Burrowing owls are one of the priority species in the HCP because they have declined in many portions of their breeding range in North America (Klute et al. 2003), and are listed as a Species of National Conservation Concern in the U.S. (U.S. Fish and Wildlife Service 2002). Burrowing owls prey upon herbivorous insects and small mammals, and hence, TAC members have expressed concern that chemicals contained in glyphosate herbicides may bioaccumulate in burrowing owls and possibly cause deformities, mortalities, or reduced reproductive success. Laboratory research has failed to find a deleterious effect of glyphosate herbicides on birds (Giesy et al. 2000) or evidence that glyphosate bioaccumulates (Malik et al. 1989, Schuette 1998). However, the City of Tucson wants to proceed cautiously due to the abundance of burrowing owls in the areas surrounding Tucson (especially in those areas where glyphosate herbicide applications have been proposed) and the appeal of these owls to local residents. Hence, the TAC approved a field study to examine both the direct and indirect effects of glyphosate applications on burrowing owls.

OBJECTIVES

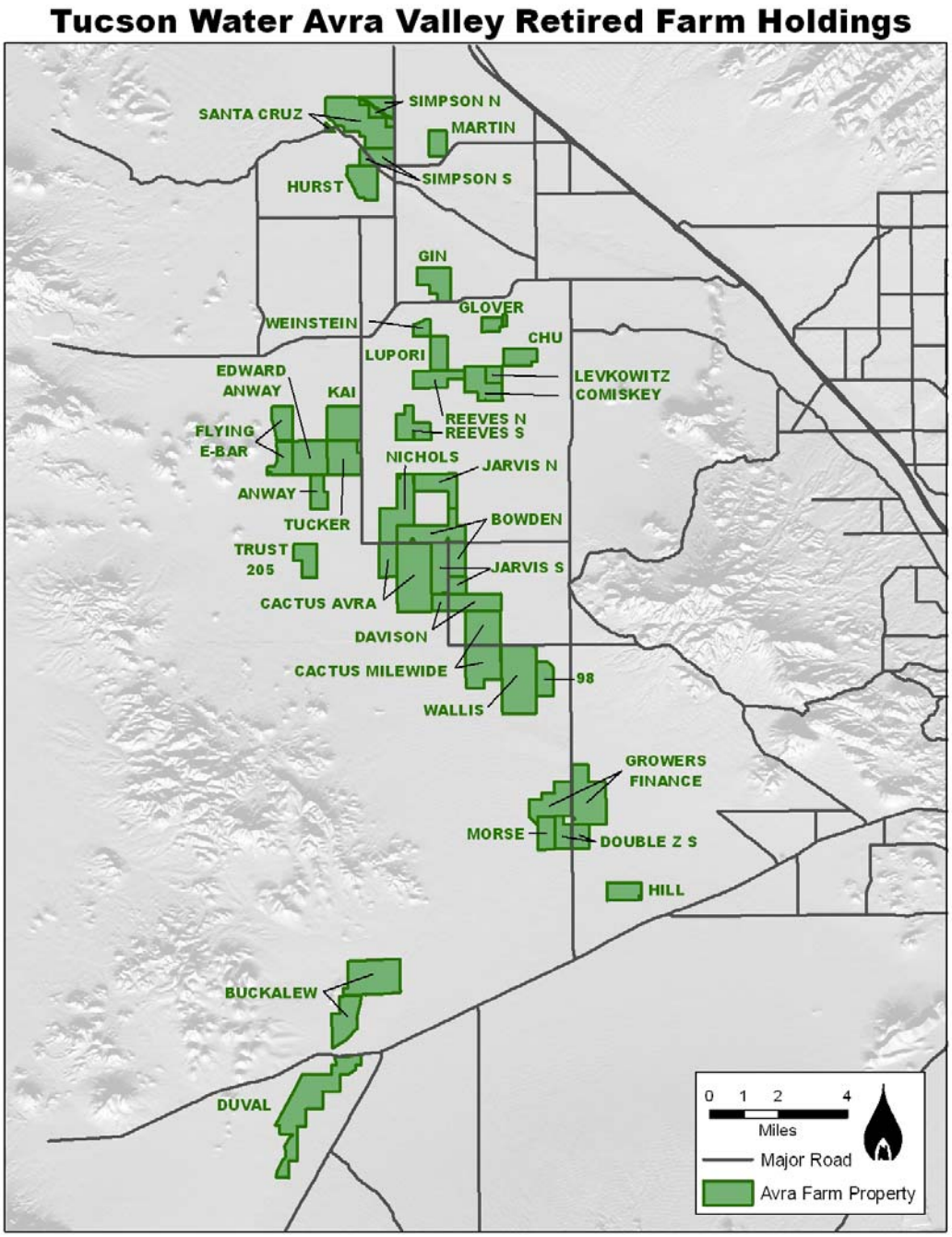
1. Determine whether treating areas with glyphosate herbicide increases mortality or nest abandonment of burrowing owls.
2. Determine whether nesting success, number of juveniles produced, or morphological measurements of burrowing owls differed between areas treated with glyphosate herbicides and control areas.

STUDY AREA

One portion of the study area was a checkerboard set of properties in Avra Valley owned by the City of Tucson that were delineated for buffelgrass eradication (Map 1). A portion of this area was designated as a test area for buffelgrass eradication treatments (Map 2). Avra Valley is between the Tucson Mountains to the east and the Waterman and Roskruge Mountains to the west (Liberti and Wyneken 2006). This area consisted of Sonoran Desertscrub (Brown 1994) that had been previously converted to pasture or farmland but is no longer in use. The area was best described as Sonoran Vacant or Fallow Land (Liberti and Wyneken 2006). These properties were highly degraded due to human activities. The dominant plants in most areas were exotic grasses such as buffelgrass and Bermuda grass (*Cynodon dactylon*), with some vegetation that was consistent with the Arizona Upland subdivision such as velvet mesquite (*Prosopis velutina*), creosotebush (*Larrea tridentata*), foothill palo verde (*Cercidium microphyllum*), and several species of cacti. Each area has received different treatments (Table 1).

The other portion of the study area was in the Tucson Basin within the city limits of Tucson, AZ. Burrowing owls in this portion of the study area occurred mostly along dry washes and roads within urban and commercial development.

Map 1. City of Tucson properties in Avra Valley. Map provided by Michael Liberti, City of Tucson Water Department.



Map 2. Buffelgrass test area in Avra Valley. Map provided by Travis Bean, The Desert Laboratory, University of Arizona.

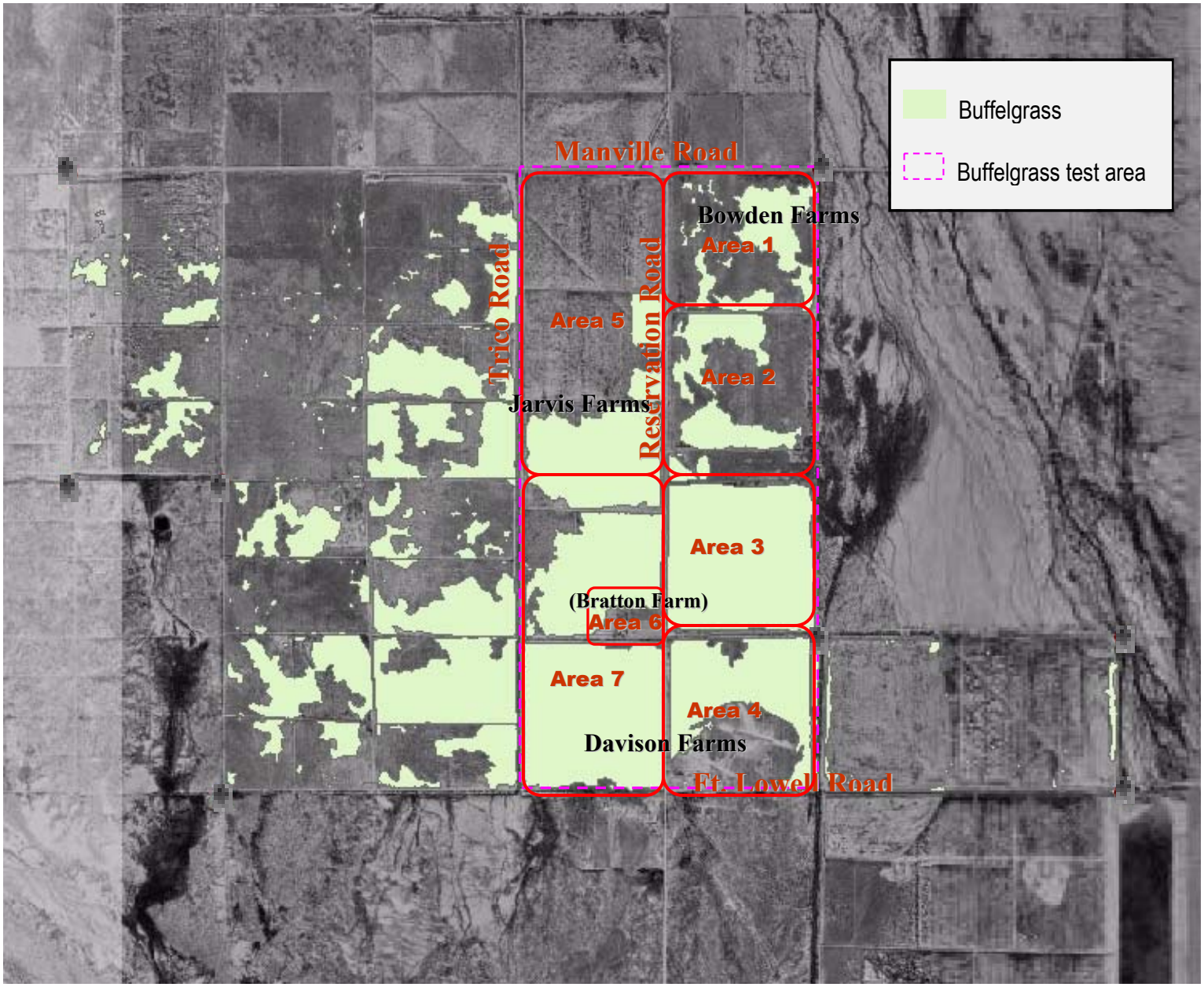


Table 1. History of treatments within portions of the study area in Avra Valley (compiled by Pat Quest, Tucson Water Department, September 2007).

Treatment	**Date**	**Area in Map 2**	**Comments**	**Details**	**Result**
Fencing	29 Jun 2002	1-7			Once cattle no longer had access to graze, buffelgrass quickly invaded.
Controlled burn	29 Mar 2007	1	The burn was patchy due to shifting winds. The east side of Area 1 received less fire.	A 9.14-m perimeter was bladed to create a firebreak.	Approximately 75% of the area burned.
Herbicide applied via tractor	1–10 May 2007	1	Approximately 32.4 ha sprayed.	Used 75.7 liters of Kleenup® diluted solution per 0.40 ha sprayed. 0.44 liters of unmixed product per 0.40 ha.	
Herbicide applied via tractor	31 Jul–8 Aug 2007	1	Second round of herbicide application. The west side of area was not sprayed because it contained mostly native grasses with isolated patches of buffelgrass, pigweed and tumbleweed.	Used 2.5% Kleenup® solution; approximately 2.07–2.23 liters per 0.40 ha; 69.48 liters of mixed chemical per 0.40 ha.	Pigweed still growing. This was the first area sprayed after the monsoon started, when buffelgrass was approx. 0.46 m high. The pigweed was not mature at this time. New growth of buffelgrass appeared after the application. Patchy areas of buffelgrass dieback.

Treatment	Date	Area in Map 2	Comments	Details	Result
Controlled burn	29 Mar 2007	2	The burn was patchy due to shifting winds. The east side of Area 2 received less fire.	A 9.14-m perimeter was bladed to create a firebreak.	Approximately 50% of this area burned.
Herbicide applied via tractor	9–17 Aug 2007	2	First round of herbicide application.	Used 2.5% Kleenup® solution; approximately 2.07 liters per 0.40 ha.	
Controlled burn	29 Mar 2007	3	The burn was patchy due to shifting winds. The east side of Area 3 received less fire. The burn was increasingly patchy at the south end of Area 3.	A 9.14-m perimeter was bladed to create a firebreak.	Approximately 25% of this area burned.
Herbicide applied via tractor	20–27 Aug 2007	3		Used 2.5% Kleenup® solution; approximately 2.07 liters per 0.40 ha. Raised the sprayer booms[1] because the buffelgrass was too high to be sprayed with the booms lowered.	

Treatment	Date	Area in Map 2	Comments	Details	Result
Controlled burn	29 Mar 2007	4	The burn was patchy due to shifting winds. The east side of Area 4 received less fire. The burn was increasingly patchy at the south end of Area 4.	A 9.14-m perimeter was bladed to create a firebreak together with a 9.14-m perimeter surrounding Tucson International Modelplex Park Association (TIMPA).	Approximately 25% of this area burned.
Herbicide applied via tractor	28 Aug–5 Sep 2007	4		Used 2.5% Kleenup® solution; approximately 2.07 liters per 0.40 ha. Sprayer booms raised[1].	
Mowed	Aug 2006	5		A 9.14-m perimeter was bladed to the north of the farmhouse fence to create a firebreak.	
Mowed	Jan 2007	5			

Treatment	Date	Area in Map 2	Comments	Details	Result
Herbicide applied via airplane	2–4 Sep 2007	5	Aerial spray notes: Area to be sprayed is programmed into the flight plan using a GPS. Plane holds 757 liters of diluted solution per load. Able to spray slightly more than 2 passes each load. Sprayed for 10 hours. Sprayed a little less than 242.8 ha.	5% Kleenup® solution. For comparison purposes, plane averages 18.9 liters of diluted solution per 0.40 ha, tractor averages 64.3 liters of diluted solution per 0.40 ha.	
Bladed	27 Feb 2006	6	Area surrounding the Bratton Farm.	A 61-m perimeter was bladed to create a firebreak.	
Herbicide applied via tractor	10 Sep 2007	6	Area surrounding the Bratton Farm.	Used 2.5% Kleenup® solution; approximately 2.07 liters per 0.40 ha. Sprayer booms raised[1].	

Treatment	Date	Area in Map 2	Comments	Details	Result
Mowed	Jul 2007	7	Approx 45.7 m in Area 7 were accidentally mowed parallel to Reservation Rd on the west side. Area 7 otherwise has not been treated to date. Burrowing owls appear to move to different burrows in Area 7. Burrows, perhaps occupied by owls, parallel the eastern fence line and western berm.		
Herbicide applied via airplane	2–4 Sep 2007	7	Aerial spray notes: Area to be sprayed is programmed into the flight plan using a GPS. Plane holds 757 liters of diluted solution per load. Able to spray slightly more than 2 passes each load. Sprayed for 10 hours. Sprayed a little less than 242.8 ha.	5% Kleenup® solution. For comparison purposes, plane averages 18.9 liters of diluted solution per 0.40 ha, tractor averages 64.3 liters of diluted solution per 0.40 ha.	

Treatment	Date	Area in Map 2	Comments	Details	Result
Herbicide applied via tractor	10 Sep 2007	7	Burrowing owls appear to move to different burrows in Area 7. Burrows, perhaps occupied by owls, parallel the eastern fence line and western berm. Ground was sprayed 15.2 m west of fence line to avoid burrowing owls.	Used 2.5% Kleenup® solution; approximately 2.07 liters per 0.40 ha. Sprayer booms raised[1].	

[1] Sprayer booms are mounted on the back of the tank that contains the chemical, on the tractor. The booms are stiff hoses that distribute the chemical. The booms can be lowered to spray short vegetation, or raised for higher vegetation.

METHODS

Burrow visits in 2006 prior to treating areas for buffelgrass

On 17 Aug 2006, City of Tucson requested that we visit burrows that had been marked as occupied in June 2006 (Grandmaison and Urreiztieta 2006). We visited those burrows on 19 Aug 2006 and checked them for signs of occupancy that day. The City was planning to spray portions of the buffelgrass test area (Map 2) on 20 Aug 2006 and wanted to know the location of any burrows that were still active. However, spraying was subsequently delayed because the vegetation was thought to be too high and needed to be mowed first.

Locating burrowing owls

We surveyed the Avra Valley properties using standardized passive driving surveys (Conway and Simon 2003) on 19–22 Aug 2006 and 4 Jan–10 Apr 2007. We also surveyed Simpson Farms in Marana on 21 Feb 2007 and from 4 May–5 Jul 2007. In Tucson, we did not survey for burrowing owls and instead checked all burrows and nearby burrows (excluding those at Davis-Monthan Air Force Base) that have been occupied in one or more of the previous four years (2002-2006; Conway and Ellis 2004, Ellis et al. 2004, Conway and Ogonowski 2005, Ogonowski and Conway 2006) to look for current signs of occupancy.

Post-treatment nest checks and surveys

Areas 1–4 (Map 2) were burned on 29 Mar 2007, but shifting winds caused only the northern half of the area to burn substantially (only 25% of Areas 3 and 4 burned).

On 2 Apr 2007, we checked the one occupied burrow in the burned area (in Area 1) to determine whether burning had any immediate negative effects. We conducted a standardized survey throughout the burned areas (primarily Areas 1–2) on 10 Apr 2007 to examine the effects of the burn. Herbicide was applied to Areas 1–4 beginning 1 May 2007. Two more burrows in Area 1 became occupied in late May 2007. We visited all the occupied burrows throughout the rest of the 2007 breeding season to look for evidence of any immediate negative effects from the herbicide application. We also used an infrared video probe during these visits to look inside all occupied burrows for any dead or sick owls.

Monitoring burrowing owls during the 2007 breeding season

When we found burrowing owls in Avra Valley, we marked the burrow which the owl was using by placing 5 short stakes surrounding the burrow (at a 5-m radius from the burrow) and tying pink or orange flagging tape to the stakes so that the burrow was encircled by tape. The tape was placed 0.5 m from the ground. We did not mark burrows in Tucson.

In both Avra Valley and Tucson, we visited occupied burrows every 7–14 days. Prior to approaching each burrow, we observed burrowing owls from ≥100 m away using a spotting scope to re-sight banded owls, determine if either of the adults had disappeared or been replaced (indicating mortality or abandonment), and observe the owls prior to disturbing them. We then approached the burrow and recorded the presence of the following: signs of occupancy (pellets or feces); signs of nesting (shredded material); prey remains; number, age and sex of owls; evidence of depredation; and any unusual

observations or behaviors. We also used an infrared video probe to inspect each occupied burrow during nest visits and recorded the presence and number of eggs, adults, and juveniles. We also looked for any burrowing owl remains (mortality) both inside and outside the burrow.

Banding and morphological measurements

We attempted to trap and band as many of the unbanded adults and juveniles as possible. Banding allowed us to identify each individual owl so that we could determine when an adult had disappeared or been replaced, determine where any dead burrowing owls came from, more accurately determine the number of offspring produced, and determine site fidelity, annual return rates, and natal recruitment. We placed a U.S. Geological Survey band on one leg and a uniquely-numbered aluminum color band (Acraft Bird Bands, Edmonton, Alberta, Canada) on the other leg of each owl. We measured lengths of wing chord and metatarsus for all adult owls, and used a Pesola scale to weigh both adult and juvenile owls. We compared whether any of these morphological measurements differed between treatment and control areas.

Burrow re-occupancy and abandonment

We determined whether burrows that were occupied in August of 2006 in the treatment area were still occupied during the winter or breeding season in 2007. We also compared whether burrows that were occupied in March (before the controlled burn) and early May (before the herbicide application) 2007 continued to be occupied after each of the treatments. Finally, we compared the number of burrows newly occupied in late May

between the treatment and control areas to determine whether treatments influenced burrow occupancy.

Buffelgrass surveys

Just prior to the start of treatments (on 24 Mar 2007) we estimated buffelgrass density in Areas 1–4. These areas can be resampled in the future to determine whether the buffelgrass eradication treatments performed by the City of Tucson were effective and whether the different treatments yielded different results. We established 3 equidistant transects within the 4 areas, and used the Nearest Individual Method (Barbour et al. 1999) to measure buffelgrass density.

RESULTS

Burrow visits in 2006 prior to treating areas for buffelgrass

Only one of the burrows that had been marked in Jun 2006 was occupied by burrowing owls on 19 Aug 2006 (Table 2). That burrow (Avra2006-11) was occupied by an owl of unknown age and sex, and may have been a secondary (satellite) burrow used by burrowing owls occupying a new burrow we found nearby (Bowfm2). At Bowfm2, we found one female, one male, and two juvenile burrowing owls. We marked the occupied burrows in Area 1 with flagging tape. Both these burrows were on the east side of Reservation Road within Area 1 (Map 2).

Table 2. Results of 19 Aug 2006 visits to burrows that were occupied in Jun 2006 (Grandmaison and Urreiztieta 2006). One previously occupied burrow and one new burrow were found to be occupied on 19 Aug 2006.

Burrow	UTMs	Active	Notes	Sex and # of BUOWs	New active burrows nearby	Name of new burrow	UTMs of new burrow	Signs of activity
Avra2006-01	12 S 471884 3572373	N			N			
Avra2006-02	12 S 471898 3572319	N			N			
Avra2006-03	12 S 471871 3572267	N			N			
Avra2006-04	12 S 471839 3571031	N	Coordinates were off by 13 m but the burrow was well-marked.		N			
Avra2006-05	12 S 471999 3571815	N			N			
Avra2006-06	12 S 471977 3572262	N			N			
Avra2006-07	12 S 471979 3572202	N	Collapsed, unmarked.		N			
Avra2006-08	12 S 471933 3571698	N	Collapsed.		N			
Avra2006-09	12 S 473687 3571562	N			N			
Avra2006-10	12 S 473621 3572114	N			N			
Avra2006-11	12 S 474141 3572446	Y	BUOW footprints, 1 BUOW observed. This is probably a satellite burrow being used by the owls at Bowfm2.	1 UK	N			
Avra2006-12	12 S 474052 3572358	N			Y	Bowfm2	12 S 0474128 3572338	4 BUOWs: M, F, 2J, prints, feathers. Probed but could not see beyond 0.75 m.
Avra2006-13	12 S 474044 3572111	N			N			
Avra2006-14	12 S 474046 3572350	N			N			
Avra2006-15	12 S 474047 3572360	N			N			
Avra2006-16	12 S 473973 3571683	N			N			

Locating burrowing owls

We did not find any burrowing owls during the standardized passive driving survey we conducted on 19–22 Aug 2006. We found 5 occupied burrows during surveys conducted from 4 Jan–5 Jul 2007 in several Avra Valley properties (Map 3, Table 3). We also found 2 burrows with signs of occupancy at the Simpson Farms property in Marana. Additionally, we found other occupied burrows incidentally during the course of fieldwork. Table 4 lists all the burrows that we monitored on City of Tucson properties.

Map 3. Areas surveyed from 4 Jan to 5 Jul 2007.

Table 3. Burrows found that had signs of burrowing owl occupancy during surveys from 4 Jan–5 Jul 2007 on City of Tucson properties in Avra Valley and Marana.

Date found	Burrow name	Location	UTMs (NAD 27 Conus)	Notes
4 Jan 07	Cacfm1	Cactus Farms	0471834 3571783	Pellets
4 Jan 07	Cacfm2	Cactus Farms	0472483 3572211	Sign, probed: saw 2 owls
17 Jan 07	Bowfm1	Bowden Farms	0473942 3572380	Male owl observed
28 Mar 07	Tucfm1	Tucker Farms	0468526 3577293	Feces, bones
28 Mar 07	Tucfm2	Tucker Farms	0468612 3576474	Pellets, feces, prey, lining
21 Feb 07	Marana1	Simpson Farms	0469178 3593430	Old sign
4 May 07	Simfm16	Simpson Farms	0470437 3592471	Old sign

Post-treatment nest checks and surveys

The City of Tucson burned Areas 1–4 on 29 Mar 2007, but only Areas 1 and 2 burned thoroughly. On 2 Apr 2007, we checked the only known occupied burrow in the burned area (Bowfm2 in Area 1; Map 2, Table 2) to determine whether burning had any immediate negative effects. Despite the charred ground, both adult burrowing owls were visible at the entrance to the burrow and did not appear to have been negatively affected. Neither owl had been banded as of this date, and no eggs or juveniles were thought to have been present yet. We did not find any evidence that burrowing owls were injured or killed due to the controlled burn during our survey on 10 Apr 2007. Neither did we find any newly-occupied burrows. However, two more burrows in the burned area were subsequently occupied by burrowing owls.

2007 monitoring season

We monitored 39 burrows in Avra Valley that had some evidence of burrowing owl use since Jun 2006 (Table 4, Maps 4 and 5). We marked 14 of these burrows that were in the designated treatment areas and were being used as nests, satellites, or had been occupied as a wintering burrow since Jan 2007. Burrows were occupied on Jarvis Farms, Cactus Farms, and Bowden Farms during the winter (Table 4). We documented nesting attempts at four occupied burrows in Avra Valley in 2007. We defined a nesting attempt as a pair seen once or a single male seen twice at a burrow between 1 Apr and 15 Jun, excluding owls known to be nesting elsewhere (i.e., excluding satellite burrows)(Garcia and Conway, in press). Three of the four nesting attempts in Avra Valley were within the treatment area on the northern end of Bowden Farms (Area 1; Map 2), and the other nesting attempt was on Tucker Farms, outside of the treatment area. In Avra Valley, only one of the three nesting attempts in the treatment area was successful (i.e., ≥1 juvenile reaching 30 days of age; 33% apparent nesting success in the treatment area). The one nesting attempt in the control area was not successful.

In Avra Valley, we did not find any dead or ill burrowing owls that could be attributed to the treatments. Both nest failures in the treatment area appear to have been caused by predators. In one case (Bowfm4), we found burrowing owl feathers and skin on 22 Jun, indicating depredation of the female (the male was still present) by an avian predator (Todd 2001). In the second case (Bowfm3), a snake of unknown species was seen inside the burrow on 5 Jul, 10 days after the adults were seen for the last time at that burrow. We saw a pair of unbanded owls at another burrow (Bowfm5) on 5 Jul, which we assumed was the pair from Bowfm3. The nest in the control area (Tucfm2) failed for

unknown reasons (the male disappeared, leaving the female and young juveniles, then all the owls disappeared).

We also surveyed Simpson Farms in Marana, and found two burrows that were potentially occupied by burrowing owls. However, we did not see any owls at either burrow. One of the burrows (Simfm16) had an egg in the tunnel indicating a previous nesting attempt, but the attempt had apparently already failed by the time of our first visit. The other burrow had no fresh signs of use after we cleared away the original signs of use (white wash, pellets).

In Tucson, we monitored 142 burrows (Map 6). We documented nesting attempts at 25 of these burrows. Nine of the 25 nesting attempts in Tucson were successful (36% apparent nesting success). Combining the Tucson and Avra Valley control areas, 9 of 26 nesting attempts were successful, resulting in apparent nesting success of 35%. Therefore, we did not detect a difference between treatment and control areas in nesting success (33% vs. 35%).

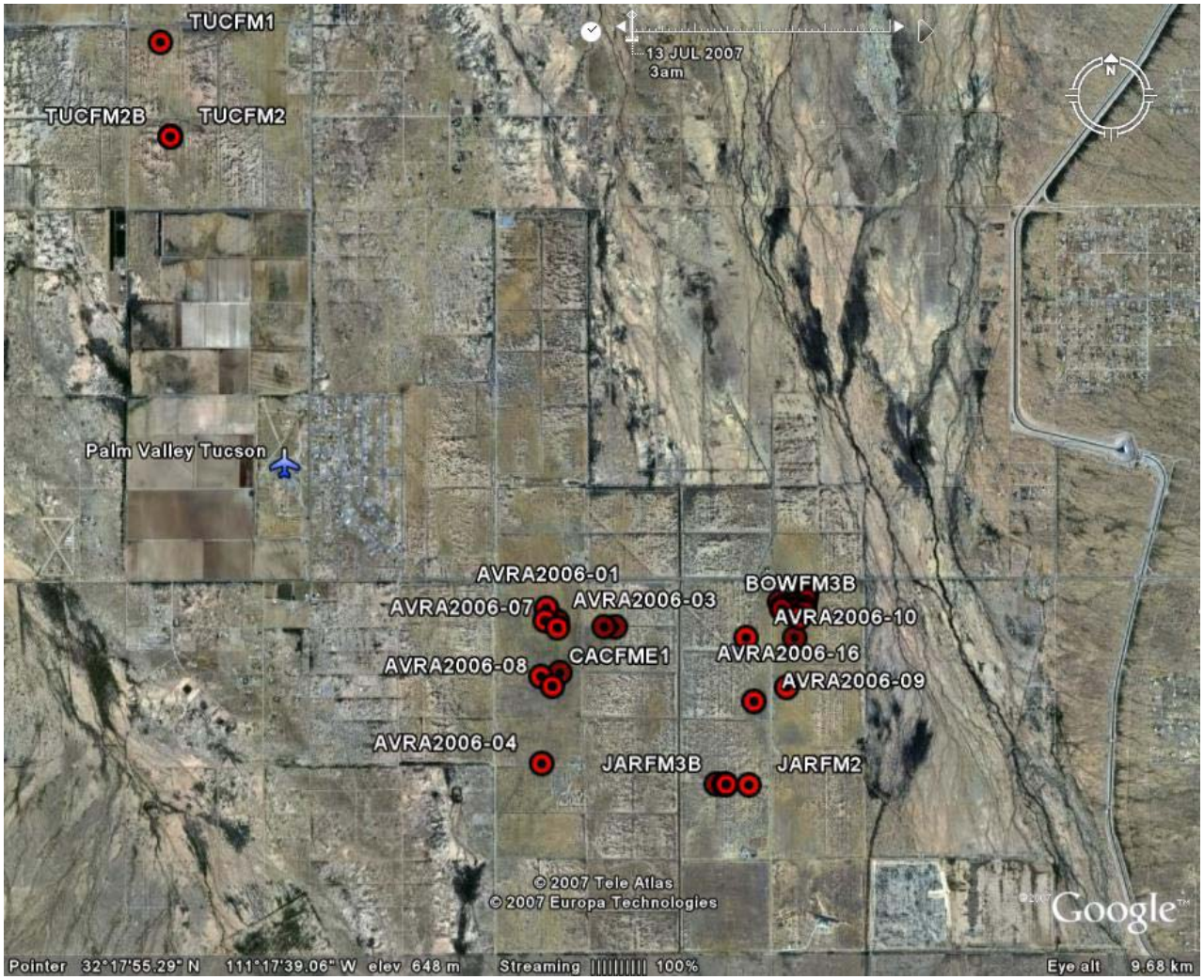
We observed an average of 3 (±0.3) juveniles (30 days old) per successful nest in Tucson. We also observed 3 juveniles (30 days old) at the successful nest in the treatment area (although the inferences that can be drawn from just one nest are very limited).

Table 4. Location and status of 39 burrows on City of Tucson properties in Avra Valley in 2007.

Burrow name	UTMs (NAD27CONUS)	Status in 2007	Flagged
Avra2006-01	12 S 471884 3572373	Inactive	N
Avra2006-02	12 S 471898 3572319	Collapsed	N
Avra2006-03	12 S 471871 3572267	Inactive	Y

Avra2006-04	12 S 471839 3571031	Inactive	N
Avra2006-05	12 S 471999 3571815	Inactive	Y
Avra2006-06	12 S 471977 3572262	Inactive	Y
Avra2006-07	12 S 471979 3572202	Collapsed	N
Avra2006-08	12 S 471933 3571698	Inactive	Y
Avra2006-09	12 S 473687 3571562	Inactive	Y
Avra2006-10	12 S 473621 3572114	Collapsed	N
Avra2006-11	12 S 474141 3572446	Inactive	N
Avra2006-12	12 S 474052 3572358	Satellite	Y
Avra2006-13	12 S 474044 3572111	Inactive	N
Avra2006-14	12 S 474046 3572350	Collapsed	N
Avra2006-15	12 S 474047 3572360	Active in winter	Y
Avra2006-16	12 S 473973 3571683	Inactive	N
Bowfm1	12 S 473942 3572380	Active in winter, satellite during breeding	Y
Bowfm1b	12 S 473934 3572361	Nest, succeeded	Y
Bowfm1c	12 S 474036 3572400	Satellite	Y
Bowfm2	12 S 474128 3572338	Satellite	Y
Bowfm3	12 S 474132 3572370	Nest, failed	Y
Bowfm3b	12 S 474082 3572284	Satellite	Y
Bowfm4	12 S 473915 3572424	Nest, failed	Y
Bowfm5	12 S 474149 3572493	Satellite	Y
Bowfm5b	12 S 474125 3572494	Satellite	N
Cacfm2	12 S 472483 3572211	Active in winter	Y
Cacfme1	12 S 471834 3571783	Satellite in winter	Y
Cacfme3	12 S 472385 3572212	Satellite in winter	N
Jarfm1	12 S 473356 3570848	Satellite in winter	Y
Jarfm2	12 S 473641 3570840	Satellite in winter	Y
Jarfm3	12 S 473426 3570846	Active in winter	Y
Jarfm3b	12 S 473444 3570845	Satellite in winter	N

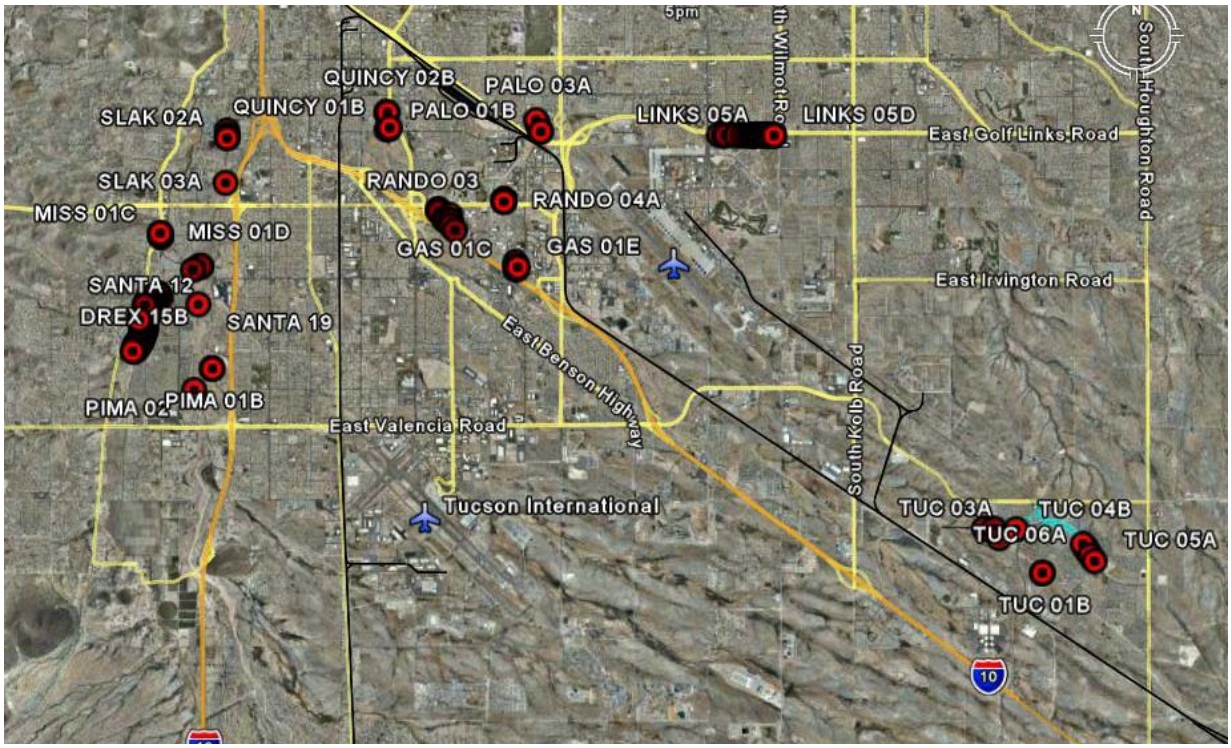
Simfm14	12 S 471182 3593131	Inactive	N
Simfm16	12 S 470437 3592471	Inactive	N
Simfm16b	12 S 470429 3592463	Inactive	N
Simfm17	12 S 469837 3592660	Inactive	N
Tucfm1	12 S 468526 3577293	Active in winter?	N
Tucfm2	12 S 468612 3576474	Nest, failed	N
Tucfm2b	12 S 468612 3576470	Satellite	N



Map 4. Location of burrows monitored in Avra Valley during the 2007 breeding season.

Map 5. Burrows monitored in the buffelgrass treatment area during the 2007 breeding season.

Map 6. Burrows monitored in Tucson during the 2007 breeding season.



Banding and morphological comparisons

We trapped 74 burrowing owls in Tucson (control area) between 28 Mar and 26 Jul including 16 recaptures (owls captured and processed twice within the same year). We also trapped 1 burrowing owl in the control area in Avra Valley on 23 May 2007. In the treatment area in Avra Valley, we trapped 14 burrowing owls (1 in Aug 2006 and 13 from 17 May–12 Jul 2007). Four of the 13 owls trapped in 2007 were recaptures. All the owls captured in the treatment area in 2007 were captured after the area had been burned and sprayed. We excluded the owl captured in 2006 in Avra Valley from the following comparisons. We did not detect a difference between the treatment and control areas in metatarsus or wing chord length of adult burrowing owls ($P > 0.300$ in all cases). We also did not detect a difference between the treatment and control areas in body mass of adult burrowing owls ($t = -0.9$, df = 31, $P = 0.375$ from partial comparisons test; Fig. 1) after controlling for recaptures.

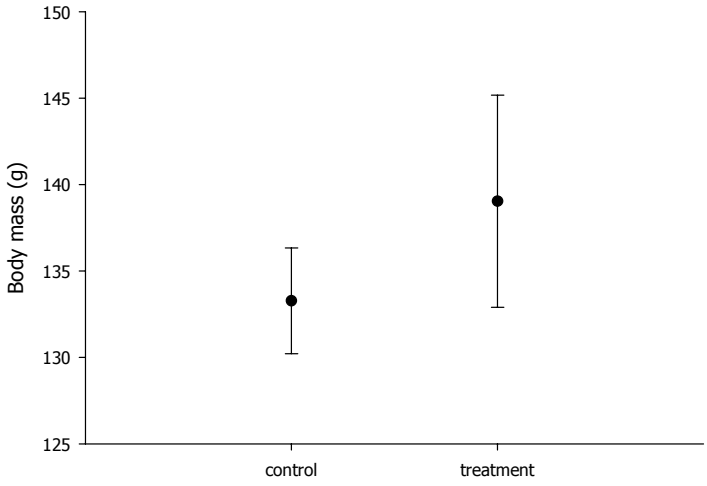


Figure 1. Adult burrowing owls in areas treated for buffelgrass did not differ in mass compared to adult burrowing owls in control areas.

Only one nest within the treatment area produced juveniles. Therefore, rigorous statistical analysis is not possible. To deal with this, we looked only at juveniles in the control area that were trapped within 2 days of the age that the juveniles from the treatment area were trapped. Younger juveniles trapped in the treatment areas were not as heavy compared to juveniles trapped in the control areas (Table 5). Even when the juveniles in the treatment area were older than those in the control area, such as at 22.5 days, the treatment juveniles were not as heavy as the control juveniles although the difference was not statistically significant. This effect disappeared by the time juveniles reached 40 days of age. However, because these results were based on one nest in the treatment area, the analysis presented in Table 5 has limited inference. Indeed, even if these differences in body mass are real (juveniles at the same nest needed to be treated as independent for this analysis), they may not be due to the treatments but rather they may be nest-specific or even specific to Avra Valley.

Table 5. Differences in body mass between juveniles trapped in treatment and control areas in southern Arizona. All juveniles from the treatment area were from the same nest, precluding strong inferences.

Age of juveniles (d)		**N**					
treatment	**control**	**treatment**	**control**	**Mean difference (g)**	**SE (g)**	***t***	***P***
12	n/a	1	0	n/a	n/a	n/a	n/a
15.5	14.5–17	1	6	-30.0	8.9	-3.4	0.020
22.5	20.5–21.5	4	3	-8.8	6.9	-1.3	0.261
41.5	40–41	3	9	3.6	6.0	0.6	0.282

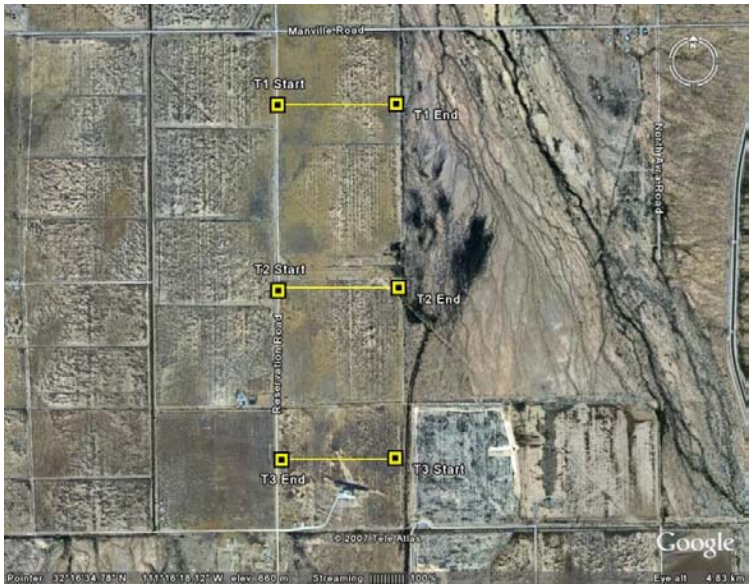
Burrow re-occupancy and abandonment

Two burrows were occupied in Avra Valley when we surveyed the area in Aug 2006 (Avra2006-11 and Bowfm2), both of which were in the treatment area. Neither of these burrows was used during the 2007 breeding season, although Bowfm2 was used as a satellite burrow in Aug 2007. Bowfm1 was the only burrow within the treatment area that was occupied by owls in March (before the controlled burn) and early May (before the herbicide application) 2007. Bowfm1 continued to be occupied after each of the treatments were applied, and two more burrows in the treatment area became occupied in late May 2007. Therefore, two of the three occupied burrows in the treatment area became occupied after the treatments were applied in late May. In contrast, none of the 26 burrows occupied in the control area became occupied in late May or later (i.e., all were occupied prior to late May).

Buffelgrass surveys

Buffelgrass density within the surveyed area was 200 plants/hectare (Map 7). Average distance to the nearest buffelgrass plant was as follows: transect 1 = 7.8 m, transect 2 = 6.4 m, and transect 3 = 1.7 m. Repeating these transects in Mar 2008 (and future years) and comparing the change in distance to the nearest buffelgrass at each point would allow the City of Tucson to evaluate the effectiveness of their buffelgrass control efforts.

Map 7. Transects within the buffelgrass treatment area that we surveyed for buffelgrass density on 24 Mar 2007.



DISCUSSION

Treating areas for buffelgrass does not appear to negatively impact burrowing owls, but our power to detect differences was limited due to the few number of burrowing owls found to be occupying the treatment areas (and Avra Valley in general) in 2007. Treating the areas surrounding one burrowing owl nest with herbicide did not cause abandonment and burrowing owls in the treatment and control areas did not differ in apparent nesting success, number of offspring per successful nest, and adult morphological measurements. We did detect a possible difference in body mass of young juveniles between the treatment and control areas. However, because only one nest in the treatment area produced juveniles, we have no way of determining whether this possible

difference is real and if so, whether it is associated with the treatments or with some other factor.

We did not find any direct or indirect effects of treating areas by burning then applying glyphosate on the ground. We cannot compare the effects of mowing versus burning or aerial versus ground application of glyphosate on burrowing owls because no burrowing owls were present in the areas that were mowed or sprayed aerially. To our knowledge, only one pair of owls (in Area 1) was present in any of the areas at the time any treatment was applied (although more owls occupied Area 1 later). Nevertheless, direct observations of the owls present during treatments did not indicate any negative effects that were immediately obvious.

This year, we marked all the occupied burrows to ensure that any treatments applied by large machinery would not collapse burrows. The burrows in Avra Valley were especially fragile, and the ground surrounding burrows was prone to collapsing. Indeed, once the monsoons were underway, at least one burrow completely collapsed into a large sinkhole. Therefore, indirect effects of applying glyphosate (such as the possibility of collapsing active nests) must also be considered when determining which methods will be used to treat a given area for buffelgrass.

The burrowing owl breeding season extends from 15 Mar to 15 Sep. Our surveys and those conducted in 2006 (Grandmaison and Urreiztieta 2006) indicate that burrowing owls also overwinter in Avra Valley. As areas are cleared of buffelgrass, more burrowing owls may occupy burrows during both winter and summer. Therefore, re-applications of treatments to eradicate buffelgrass must take into account the dynamic occupancy patterns of burrowing owls both across seasons and within a season.

RECOMMENDATIONS

- Standardized burrowing owl surveys should be conducted in areas that are scheduled for buffelgrass treatment no more than 30 days prior to applying the treatments.
- Occupied burrows should be circumvented by machinery to avoid collapsing burrows when applying treatments on the ground.
- Occupied burrows should be flagged at a 5-m radius from the burrow so that the burrows will not be run over (Grandmaison and Urreiztieta 2006). Treatments within the 5-m radius should be applied by hand while taking care not to collapse the ground when walking within the 5-m radius.
- Aerial spraying should proceed with caution until its effects can be evaluated. We recommend that burrowing owls not be sprayed directly and that spraying near burrows occupied by owls be done manually.
- We recommend that burrowing owls in treatment areas continue to be monitored to increase the statistical power of comparisons between owls in treatment and control areas, especially in terms of differences in juvenile body mass.
- We recommend that buffelgrass density be estimated on an ongoing basis to determine the effectiveness of different treatment strategies.
- From the perspective of the burrowing owl, the best times to treat areas for buffelgrass are 15 Feb–15 Mar and 1 Sep–15 Oct. These times fall between breeding and overwintering, and would minimize impact and disturbance to owls.

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