Monitoring Black-Tailed Prairie Dog Towns in Southeastern New Mexico Using Remote Sensing

Final Report

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Abstract

Remote sensing using digital orthophoto quadrangles (DOQs) has shown promise as a tool for landscape-scale survey of black-tailed prairie dogs. In this study, we investigated the usefulness of DOQs as a monitoring tool. We re-surveyed an area of 200 quads, encompassing 3,228,357.45 ha in southeastern New Mexico. Our original survey was performed in 2002, using imagery acquired between 1996 and 1997 (Johnson et al. 2003). For the second survey we used 2004 imagery, which has a higher spatial resolution than the 1996-1997 imagery and is of natural color rather than panchromatic. The method was useful for detecting change in town number, size, and distribution.

The area of black-tailed prairie dog disturbance in the study area declined between 1996-97 and 2004, particularly in the southern half of the study area, on the Caprock of northern Lea County. We investigated four hypotheses for the cause of the decline: drought, land use changes, prairie dog control, and plague. Average minimum temperatures were notably higher between 1996-97 and 2005 than for the period of record from the early 1900s-2005, and average precipitation was slightly lower than average. However, weather in the northern and southern halves of the study area did not differ enough to explain the greater town losses in the south. There was no notable land use change or modification to the land surfaces between the two surveys. Toxicant sales and assistance by USDA Wildlife Services in Lea County were not high enough to explain the dramatic declines we observed in the south. Wildlife Services reported a significant plague event three years ago in northern Lea County, from which populations have yet to recover. We believe plague is the primary cause of the prairie dog town losses we observed in this survey. However, encroaching human disturbance and climate changes could provide obstacles to re-population of the impacted area.

Introduction

In 2002, Natural Heritage New Mexico completed a remote sensing survey of black-tailed prairie dogs (*Cynomys ludovicianus*) over the species' historical New Mexico range (Johnson et al. 2003). The 2002 survey was based on digital orthophoto quadrangles (DOQs) from 1996-97 panchromatic aerial photos. Field verification of these results was completed in 2003 (Johnson et al. 2004). Color DOQ imagery acquired in 2004 recently became available for the southeastern corner of New Mexico. The purpose of this project was to use the new imagery to re-survey a portion of the historical range first surveyed in 2002, to detect changes in town size, number, and distribution since the first survey.

Methods

The DOQ collection, Southeast New Mexico, was created by the US Geological Survey. The orthophoto images are in standard color and meet the National Map Accuracy Standard for 1:12,000 scale maps. The geographic extent of each image is approximately one quarter of a 7.5 minute quad. The images were produced with a 1-meter ground sample distance from source imagery flown at 20,000 ft above ground in November 2004. We surveyed 200 quads, covering an area of 3,228,357.45 ha (Figure 1).

DOQ Survey

The mounds created by black-tailed prairie dogs at burrow entrances show up as bright, roughly circular spots on DOQs. Mounds are typically spatially clumped and are often surrounded by a lighter "halo" on the image, indicative of vegetation clipped by the prairie dogs. A DOQ prairie dog survey consists of searching DOQ images for these two indications of disturbance (Figure 2).

We brought each DOQ image into Environmental Systems Research Institute, Inc. (ESRI) ArcMap™ software and viewed it at a scale of 1:3,780, essentially the default raster resolution of the image. Each image was examined, one screen at a time, moving left to right, then down and right to left until the entire image had been reviewed. The process continued until all DOQs in the analysis area were viewed. We included the GIS layer delineating prairie dog disturbance from the 1996-97 image survey in the map while we viewed the 2004 image. The 1996-97 layer provided locations of previously-identified polygons and their interpretation and (for some polygons) ground-truthing history.

When we identified a potential town (T), we drew a polygon around the boundary by tracing the clipped-vegetation halo surrounding the mounds (Figure 2). Each site was given an alphanumeric identifier beginning with the interpreter's initials and was attributed with the number of the DOQ in which it was identified, the initials of the interpreter, the assigned status (town or questionable), and the reason polygons were considered questionable. Using ArcMap, we created a GIS layer of all polygons representing the potential towns observed in the 2004 imagery.

We designated as towns polygons that had well-defined mounds and a definite contrast between the site and the surrounding landscape. When a site was identified in the same general place as a ground-truthed polygon from the 1996-97 layer, we considered the attributes of the 1996-97 polygon when making our decision about the 2004 polygon (e.g., if a 1996-97 site was found to be extirpated after ground-truthing, it would be unlikely to be currently active).

If a site did not meet the mound and halo criteria, but the site still appeared noteworthy, we designated the site as questionable (Q, Figures 3, 4). For all questionable sites, one of four reasons was given:

> agriculture: the questionable site was located in a field, and the disturbance could be agricultural disturbance or ants (Figure 3),
>
> grazing: if grazing activity was apparent, the town was questionable because it was unclear whether the disturbance was caused by prairie dogs or cattle,
>
> shrubland: the site was questionable because it was found in an area with dense vegetation where no clipping was evident (Figure 4),
>
> burrow configuration: the appearance and arrangement of the mounds were atypical, or
>
> other: no specific reason was noted, but the site appeared questionable.

A different observer quality-checked a subset of towns using the same survey technique explained above. We chose four quads comprising 16 DOQs, spread throughout the study area. These areas were chosen to represent various abundances of old and new towns: high and low numbers of both old and new towns, high numbers of old towns in an area where low numbers of new towns were found, and vice versa. In each of the four quads, the new observer checked every new town delineated in this study and independently assessed its status. She also checked the entire quad and delineated additional new potential towns. Discrepancies were then reviewed by the original observer and revisions made of the entire dataset where necessary.

Spatial Analysis

We created an overlay of the statewide 1996-97 polygons that occurred within the 2004 survey area. We converted the ArcMap-calculated areas of the polygons into hectares for all layers and used hectares for all area analyses. For both years we used ArcMap to calculate polygon count and minimum, maximum, sum, mean, and standard deviation of polygon areas, and we made the same calculations for each area analysis.

We used the Intersect tool in ESRI ArcToolbox™ for the 1996-97 and 2004 polygon layers to create a third polygon layer of the overlapping area of the two GIS datasets. We determined the total area of 1996-97 polygons that intersected 2004 polygons, and the total area of 2004 polygons that intersect 1996-97 polygons, as well as the area of polygons that were unique to the 2004 survey.

To assess town movement, we selected all 1996-97 polygons designated as towns that came within 200 meters of 2004 polygons designated as towns (we defined the nearest two towns within 200 meters as the same town). We exported a layer for 1996-97 and for 2004 that contained the center point locations of the selected towns and used the near function to calculate the distance between the center points. We also compared the total hectares of the selected polygons from each year.

We used the Identity function in ArcMap to assign county and ownership type for each polygon in the 2004 layer. Where the polygon covered more than one county or ownership type, the polygon was split into separate records. We used the results of the identity to calculate total areas of sites and towns within each county and ownership type.

To compare the distributions of towns between the two survey years, we used the Directional Distribution tool in ArcToolbox. Results are displayed as a one-standard-deviation ellipse, which covers more than 60% of the features (towns) and shows the general distance and direction of all of the polygons in the layer from the calculated center of the distribution. We used town plus questionable polygons for 1996-97 and 2004 to create ellipses. We also ran the tool on only polygons designated as towns and found the difference between the results to be insignificant, so we do not include those results. We used the Near tool to calculate the distance between the center points.

A visual inspection of 2004 polygons indicated apparent differences in the density of towns north to south; therefore, to compare north and south groups of polygons, we divided the 1996-97 polygons into two groups with equal numbers of polygons (202 in each half). We divided the 2004 polygons along the same north-south line, which allowed us to detect changes in the number of towns north versus south of the dividing line. We then compared the northern and southern distributions of the 1996-97 and 2004 towns, by area and number of towns.

To investigate land use changes between surveys, we compared land use in 1996-97 and 2004 at prairie dog town sites that were present in both surveys to town sites that disappeared between the two surveys. We checked towns in two samples of five quads (20 DOQs) each and recorded the presence of agriculture, oil and gas, or other land uses. For information on plague and toxicant use, we consulted Ken Podborny of USDA Wildlife Services. We derived temperature and rainfall information from datasets downloaded from the Western Regional Climate Center (2006). We used data for Portales, in the northern sector and Tatum, in the south (Figure 1).

Results

We identified 435 sites, covering 9771.49 ha from the 2004 images. Of these, we designated 286 sites, covering 8208.59 ha, as towns. The largest site designated a town covered 393.98 ha, the smallest 0.36 ha. Mean town size was 28.70 ha (SD=45.93ha). Sites were identified in 5 counties, with the highest percentage, 66%, in Roosevelt

County (Table 1.) The majority of sites (85% of area) were located on private land, followed by state land, with 10% (Table 2).

Total area of town plus questionable sites decreased by 41% between 1996-97 and 2004, but the number of sites increased by 31 (Table 3), which suggests that the size of sites decreased in the intervening seven years. While town plus questionable count increased by 31 between the two surveys, town count decreased by 47 (14%). Thus, many more questionable towns were detected in the second survey. Mean town size was reduced between 1996-97 and 2004 by 36.85% (from 45.45 ha in 1996-97 to 28.70 ha in 2004). Mean questionable site size was reduced by 47.47% (from 19.97 ha in 1996-97 to 10.49 ha in 2004.)

County	Count (T&Q)	Total Hectares by County (T&Q)	% of Total Area (T&Q)
CHAVES	8	115.77	1.18%
CURRY	54	551.49	5.64%
DE BACA	6	67.94	0.70%
LEA	82	2531.38	25.91%
ROOSEVELT	287	6504.92	66.57%
Total	437*	9771.49	100.00%

County	Count (T)	Total Hectares by County (T)	% of Total Area (T)
CHAVES	5	86.32	1.05%
CURRY	28	476.02	5.80%
DE BACA	6	67.94	0.83%
LEA	53	2122.80	25.86%
ROOSEVELT	195	5455.52	66.46%
Total	287*	8208.59	100.00%

T=town, Q=questionable

Table 1. Summary of photo-interpreted sites by county. Polygons were divided when they fell into more than one county, to reflect the exact area in each county. *Polygons were counted in each county in which they fell, resulting in a polygon count rather than actual town count.

Owner	Count (T&Q)	Total Hectares by Owner (T&Q)	% of Total Area (T&Q)
BLM	1	25.91	0.27%
DOD	8	452.49	4.63%
Private	405	8342.27	85.37%
State	63	950.82	9.73%
Total	477*	9771.49	100.00%

Owner	Count (T)	Total Hectares by Owner (T)	% of Total Area (T)
BLM	1	25.91	0.32%
DOD	6	432.41	5.27%
Private	270	6965.74	84.86%
State	40	784.53	9.56%
Total	317*	8208.59	100.00%

T=town, Q=questionable

Table 2. Summary of photo-interpreted sites by ownership. Polygons were divided when they fell into more than one ownership area, to reflect the exact area by ownership. *Polygons were counted in each ownership area in which they fell, resulting in a polygon count rather than actual town count.

Polygons	1996-97 (ha)	2004 (ha)	1996-97 - 2004 (ha)	% Difference	1996-97 Count	2004 Count	1996-97 - 2004 Count
T + Q	16554	9771	6783	41	404	435	-31
T	15136	8209	6928	46	333	286	47
Ground-truthed T	3439				63		
Intersecting T + Q	9442	6894	2548	27	176	187	-11
Intersecting T	9027	5859	3168	35	155	128	27
Intersecting Ground-truthed T	2765				37		

T=town, Q=questionable

Table 3. Total area of sites from each photo interpretation year and area of intersecting sites from each year.

We defined 1996-97 towns that fell within 200m of the nearest 2004 town as the same town. Those towns that persisted from the 1996-97 survey moved on average 330.03 m (range 12.09 – 2,080.06 m), measured from center points of polygons. The 1996-97 towns that intersected 2004 sites were larger than the 2004 sites they intersected, reflecting the decrease in town size mentioned above (Table 4).

Statistic	1996-97	2004
Mean	80.88	48.52
Variance	25090.01	3733.73
Observations	114	114
Hypothesized Mean Difference	0	
t	2.035	
P (two-tail)	0.043	
t Critical (two-tail)	1.976	

Table 4. Size comparison of towns present in 1996-97 and 2004. Test is two-sample t-test, assuming unequal variances.

We divided towns from 1996-97 into northern and southern halves having equal numbers of polygons. We compared them to the resulting 2004 sites in the same northern and southern areas. The number of towns south of the dividing line decreased by half, while the number of towns north of the dividing line increased enough to more than balance losses in the south (Figure 5). However, the total area of all towns declined dramatically. The total area of northern towns changed little, but the total area of southern towns declined by more than half and was not balanced by area increases in the north (Figure 5).

The directional distribution analysis indicated that the distribution of all towns moved 36.67 km (22.91 mi) to the north between the two surveys (Figure 6). This movement was caused primarily by the loss of towns on the Caprock (Figure 7).

Not surprisingly, for both the northern and southern areas, new towns were on average smaller than persistent towns (Table 5). New towns were also smaller than towns lost, which contributed to the overall loss of total town area.

Town Status	Mean Area North, ha (SD)	Mean Area South, ha (SD)
Persisted 1996-97 to 2004	45.20 (59.59)	50.11 (60.44)
Gained	15.43 (26.40)	17.15 (16.87)
Lost	23.22 (28.06)	50.52 (72.09)

Table 5. Mean sizes of remaining, new, and lost (1996-97 to 2004) towns in the northern versus southern areas.

In summary, between 1996-97 and 2004, total town area declined dramatically on the study area, primarily due to losses on the Caprock. These losses were not balanced by gains in the northern half of the study area. In addition, average town size decreased and the center of the distribution moved about 37 km to the north in seven years.

We investigated four hypotheses to explain the loss of towns in northern Lea County. First, above-average temperatures or below-average precipitation between 1996-97 and 2004 could have limited growth of forbs that prairie dogs depend on for food. We looked at precipitation and temperature at Portales, NM, in the north half of the study area, and Tatum, NM, in the south (Figure 1). The mean precipitation for the period recorded at Tatum was slightly lower than the mean annual precipitation from 1919-2005 (15.61” versus 16.13”, a 0.52” difference), but the average annual precipitation for Portales was 0.24” higher for the period than for the period 1914-2005. Both weather stations showed 2003 to be unusually dry and 2004 to be unusually wet.

The average annual temperature from 1919-2005 at Tatum was not higher, and in fact was slightly lower, than that from 1996-97 to 2005 (58.4^0 F versus 59.4^0 F). However, every year from 1998-2004, average *minimum* annual temperatures at Tatum were two degrees higher (mean = 44.19^0 F) than the average for 1919-2005 (42.1^0 F). Minimum monthly temperatures were similarly higher in Portales for the period in which prairie dogs declined. In 2003, Tatum and Portales received a fraction of the average precipitation (37.7% and 45.5% of average, respectively). This combination of very low precipitation and high minimum temperatures occurred at both the northern and southern sites in 2003. The months of October and November 2003 were especially warm. At Tatum, October was 5.65^0 F warmer than average, and November was 5.6^0 F warmer than average. At Portales, the highest average minimum monthly temperatures were 4.07^0 F and 4.97^0 F higher than normal in October and November.

Statewide toxicant use declined after 1996 (Appendix 1). No large-scale control projects were reported between 1997 and 2004, and control material sales for Lea County do not reflect enough control to make a noticeable difference in prairie dog populations (Ken Podborny, USDA APHIS Wildlife Services, personal communication). Note, however, that control information reported by Wildlife Services (WS) does not reflect a complete statewide summary but is based on information from individuals who received assistance from WS with prairie dog control.

We compared the images from both survey years and found no obvious change in land use between 1997 and 2004. The sample of lost towns contained 35 sites. Two (5.7%) were on agricultural fields, 13 (37.1%) were in agricultural areas, and seven (20%) were on oil and gas sites. The sample of persistent towns contained 28 sites. One (3.6%) was on an agricultural field, 15 (53.6%) were in agricultural areas, and two (7.1%) were on oil and gas sites. Thus, 62.9% of lost towns were near human disturbance, versus 64.3% of persistent towns potentially impacted by human disturbance.

The WS wildlife specialist for Lea County reports that a significant plague event occurred in northern Lea County about three years ago, and ranchers report that, at this writing, populations have not yet recovered (Ken Podborny, personal communication).

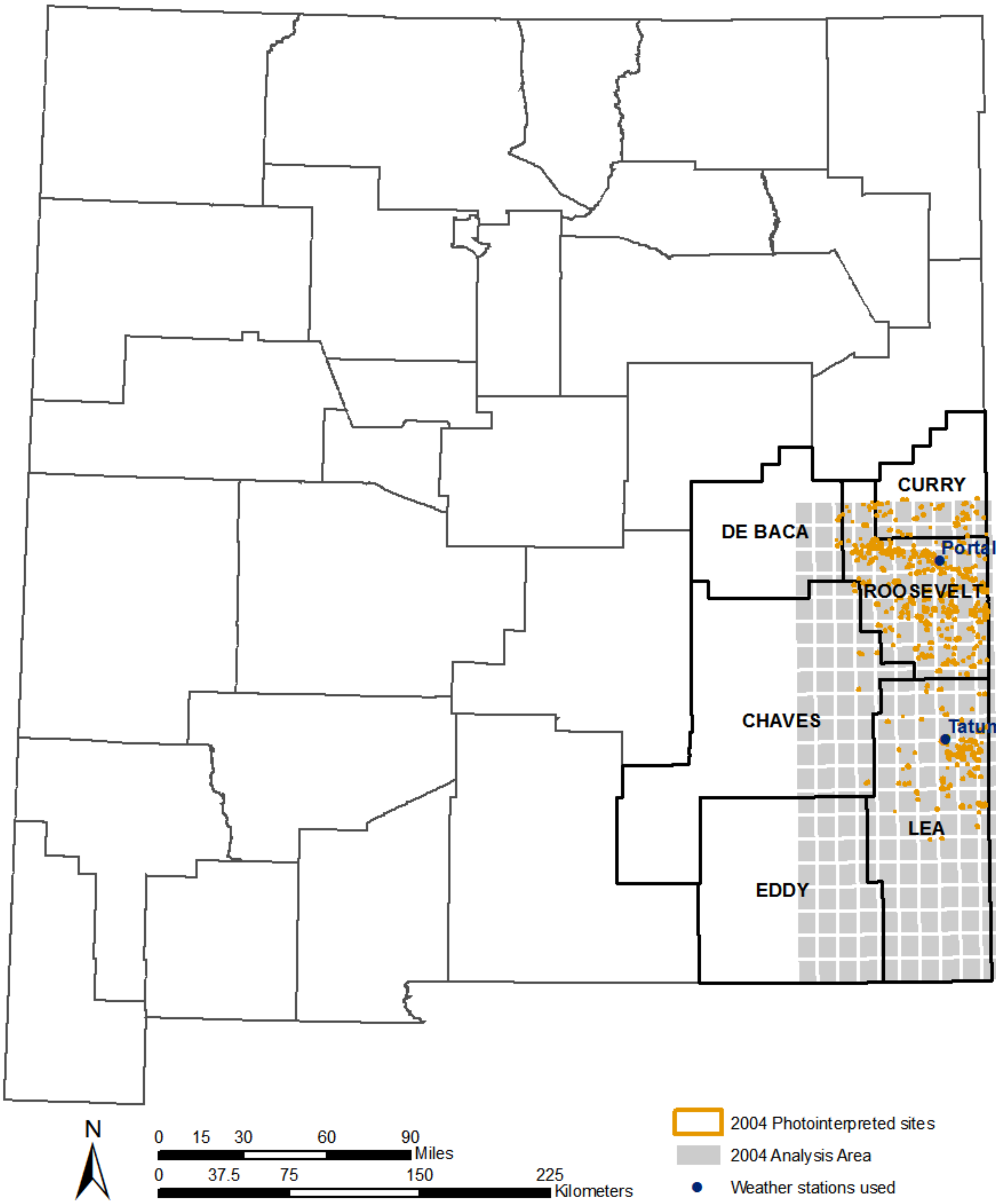


Figure 1. Area of comparison between 2004 and 1997 imagery.

Figure 2. 2004 interpreted town exhibits mounds (white dots) and clipping (haloing) typical of black-tailed prairie dog towns. The polygon from the 2004 image survey partially coincides with a polygon representing an interpreted town from the 1996-97 image survey.

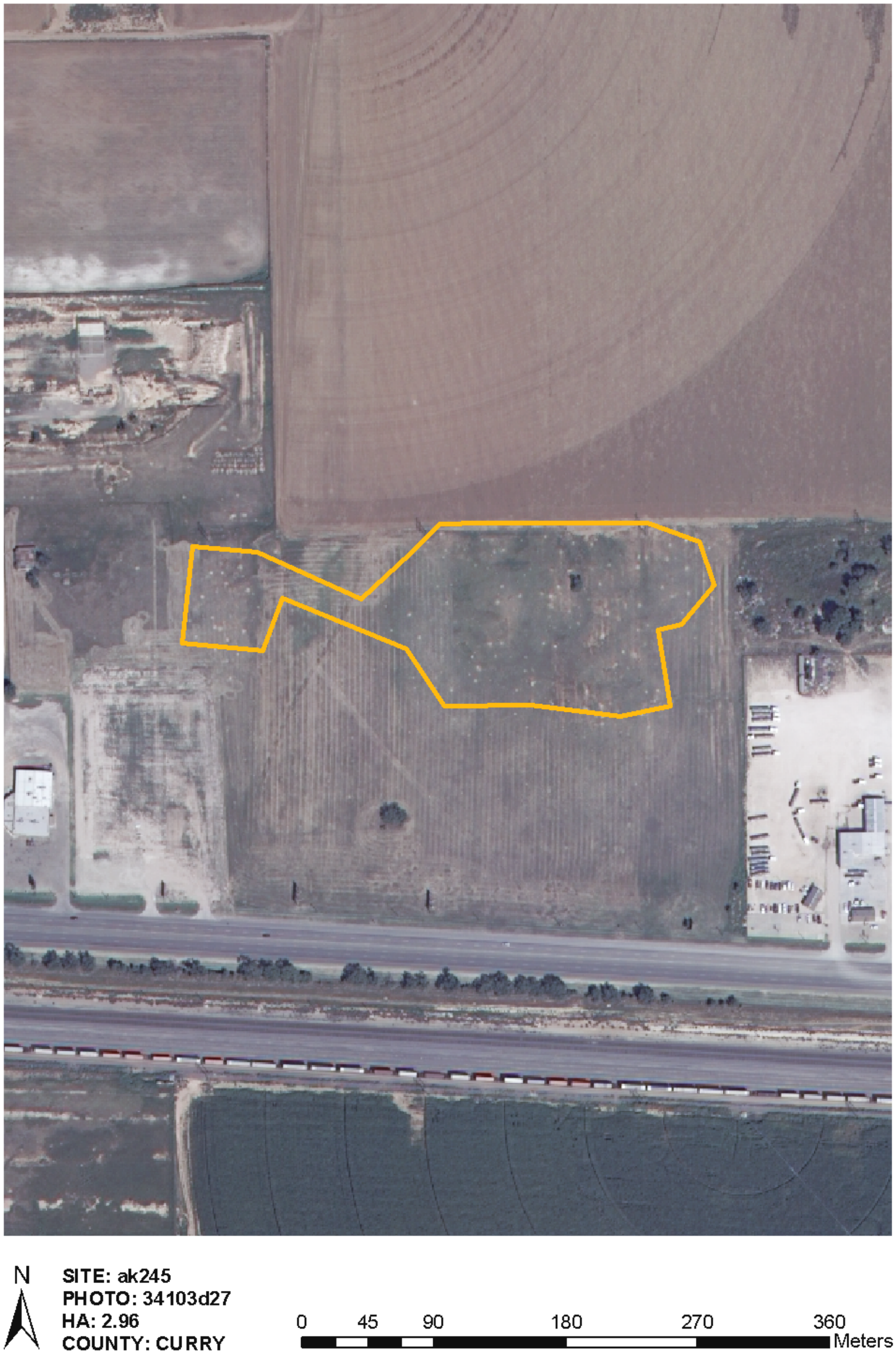


Figure 3. Site questionable due to location in agricultural field.

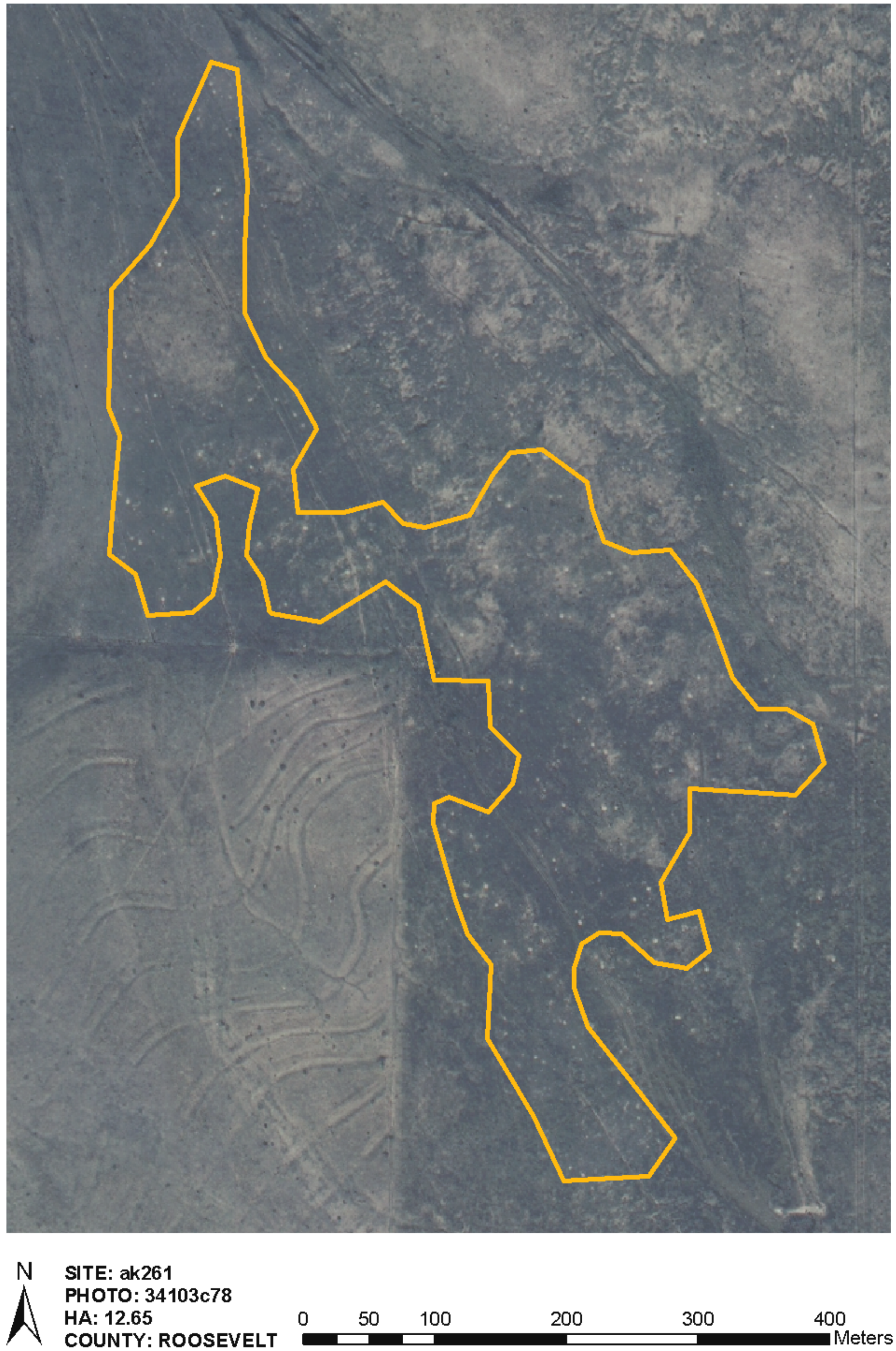
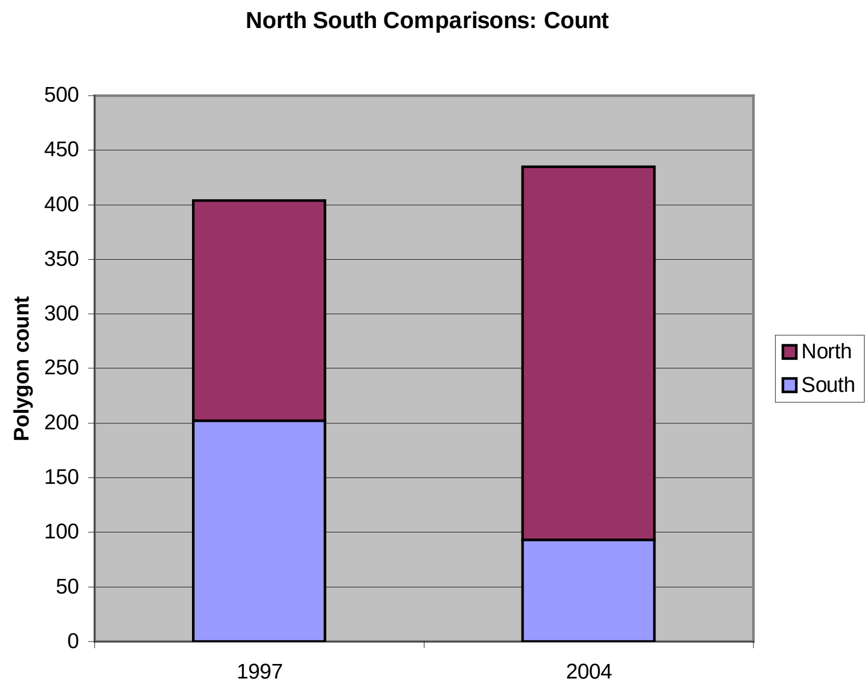


Figure 4. Site questionable due to location in densely vegetated area with very little clipping (haloing).



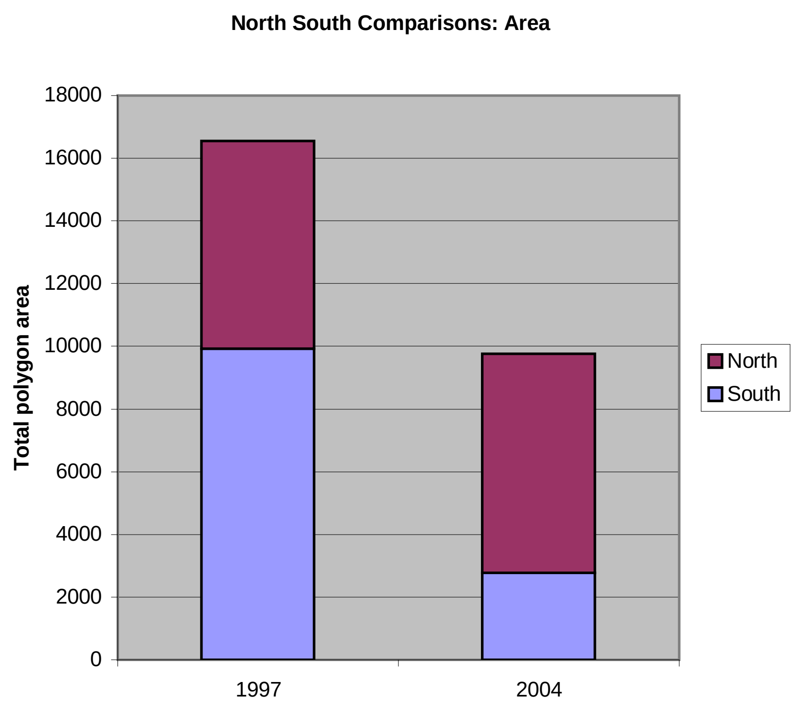


Figure 5. Numbers and areas of towns in north and south of study area, 1996-97 versus 2004.

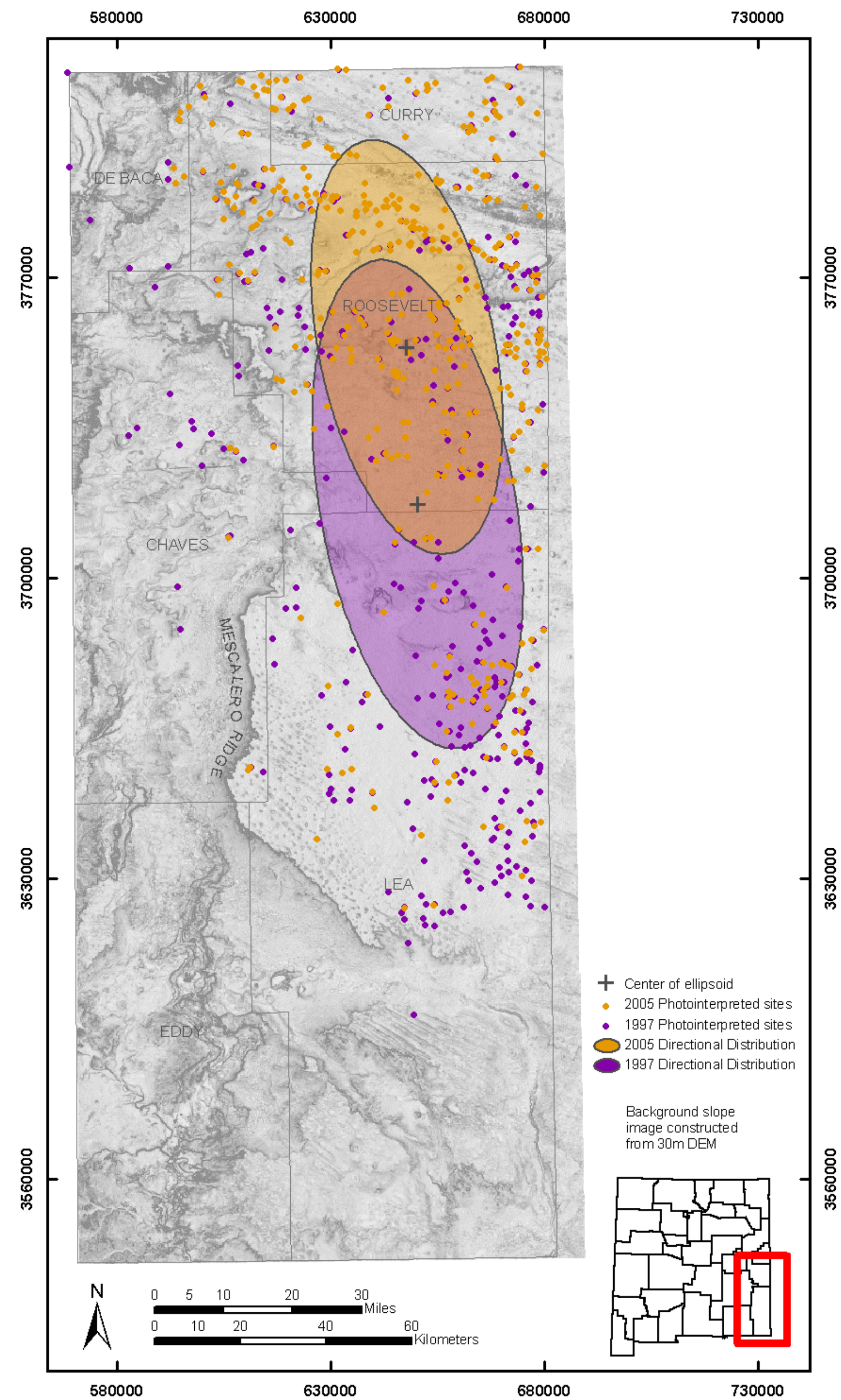


Figure 6. Directional distribution of prairie dog disturbance sites, 1996-97 and 2004. Center of distribution has shifted north by 36.67 km.

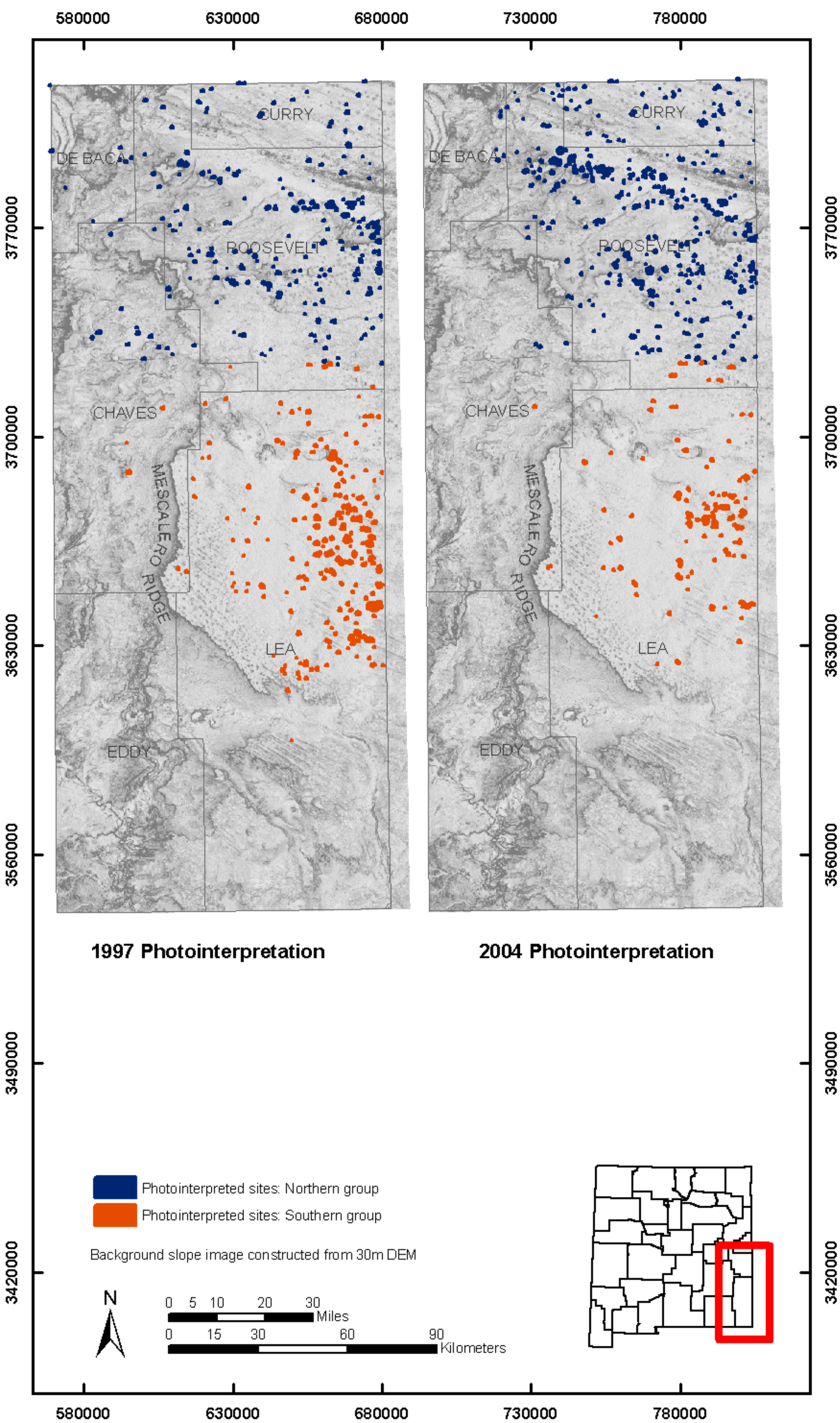


Figure 7. Prairie dog disturbance polygons from 1996-97 are divided into two equal groups (north and south). Using the same dividing line with 2004 imagery illustrates loss of towns in the southern part of the 1996-97 range.

Discussion

DOQ Survey Method

The first important conclusion from this study is that the DOQ survey method is useful for monitoring black-tailed prairie dog distribution and abundance. It is relatively easy to detect new towns, lost towns, and size changes over time using this method. With baseline GIS layers for comparison, it is easier to evaluate change than to perform the first DOQ survey in an area, and multiple images increase confidence in both surveys.

The new imagery appeared to be easier to read than the 1996-97 imagery, which may account for the increased number of small and questionable towns on the 2004 imagery. Smaller towns may be detectable on the new imagery. Ground-truthing will be necessary to evaluate this idea. If the new imagery resulted in an increase in false positives (e.g., kangaroo rat or ant disturbance being mistaken for small prairie dog towns), it would suggest even greater losses since 1996-97.

Changes in Prairie Dog Towns over Time

This re-survey indicates that the center of the distribution of black-tailed prairie dog towns in southeastern New Mexico has moved north over a seven-year period. This movement can be attributed to disappearance of towns in the southern part of the 1996-97 distribution, primarily from the Caprock in northern Lea County. The losses in the south were more than balanced by new towns in the north. However, new towns are on average smaller than old towns. Thus, even with an increase in overall town number, total town area decreased over a seven-year period.

The four most likely hypotheses to explain town loss in the south are weather, poisoning, land use change, and plague. Weather data from the northern and southern sections of the study area indicate that minimum daily temperatures averaged two degrees higher during the period of prairie dog decline than over the last 86 years (Western Regional Climate Center 2006). In 2003, the study area also received much less precipitation than average. Thus, the study area experienced weather conditions that could have impacted prairie dog forage. It is not clear, however, that weather differed sufficiently between the northern and southern areas to account for the differences in town loss. For the period, Portales (north) received on average 0.24” more annual precipitation than average, while Tatum (south) received 0.52” less than average. In 2003, an unusually dry year, minimum temperatures in October and November were unusually high at both sites, but departures from normal were only slightly higher at Tatum. These numbers do not appear sufficiently different to account for north-south differences in prairie dog persistence. However, a warming trend (minimum average increase for the study period: 1.6ºF Portales, 1.8ºF Tatum) in combination with a few dry years could impact prairie dog forage enough to provide an obstacle to re-population of the area.

WS records represent the most reliable data available on prairie dog control in the state. Available information suggests that poisoning impacts were not high enough in the impacted area to account for such high losses relative to surrounding areas. Although information on control is spotty, it is unlikely that large-scale toxicant use could have gone undetected, because WS keeps records of toxicants provided to landowners.

Agricultural and oil and gas development occurred on or near 62.9% of a sample of lost towns and 64.3% of a sample of persistent towns. Human impacts alone do not appear to explain the dramatic losses that occurred in Lea County, compared with areas that did not lose towns just to the north in Roosevelt County. Land use changes could, however, present an additional obstacle to population recovery.

The most plausible explanation for the majority of town losses we observed is plague. A significant plague event reportedly occurred in the area about three years ago (2002-2003). This report is consistent with the pattern of town losses, which was not randomly distributed, but rather clumped, as would be expected from disease.

Two or more factors could interact to impact prairie dog populations. Weather, for example, can affect plague incidence. In one Arizona and New Mexico study, one- and two-year time lagged precipitation for February and March was positively related to number of human plague cases (Enscore et al. 2002). Number of days above certain low maximum summer temperatures was positively related to number of cases, while number of days above certain high maximum summer temperatures was negatively related to plague incidence (Enscore et al. 2002). Thus, the generally drier, warmer temperatures observed in this study could have had negative effects on plague incidence. According to the models used in the Enscore et al. study, the impact of an especially dry 2003should not have been detectable for 1-2 years, and the plague event in the study area reportedly occurred in 2002-2003. Based on those models, dry weather in 2003 should have reduced plague impact in 2004-2005. It would be possible to test this hypothesis using imagery for 2005 that is slated to be available in early 2006. The Enscore et al. paper suggests that generally, we can expect increased incidence of plague after wetter, cooler years.

Unfortunately, plague, probably the primary cause of prairie dog decline in this study, is one of the most difficult impacts to manage. Human land use impacts, however, could be managed. A striking difference in oil well density in the northern and southern halves of the study area raises concern about the effects of continually-expanding oil and gas exploration on black-tailed prairie dog populations.

High-resolution 2005 DOQs are becoming available for the entire state. This imagery will make it possible to re-survey other areas of the state for changes in distribution of black-tailed prairie dogs. In addition, the 2004 imagery used in this study could be compared to the 2005 imagery to evaluate one-year changes. As digital aerial photo imagery becomes higher in quality and more-frequently available, ability to track prairie dog populations greatly increases.

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Appendix. 1. Estimated acres of black-tailed prairie dog towns treated in New Mexico, 1995-2004, based on control materials provided by APHIS Wildlife Services. Totals based on two assumptions: label use of products and that all products purchased were applied within that year. Number of acres are not necessarily unique each year and could represent re-colonized areas that were re-treated. From: NM Department of Game and Fish 2005.