MONITORING BLACK-TAILED PRAIRIE DOG TOWNS IN EASTERN NEW MEXICO USING REMOTE SENSING

2010 FINAL REPORT

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ABSTRACT

Using 2005 natural color orthophotography, we surveyed 503 digital orthophoto quadrangles (DOQQs) of eastern New Mexico for black-tailed prairie dog (BTPD) disturbance. Interpreters detected 43,404.69 ha of apparent BTPD disturbance. Field checking indicated that only 66% of polygons, amounting to 68.9% of polygon area, was actually BTPD disturbance, which gives an estimate of the actual area of disturbance over the study area of 29,949 ha. Of this, we estimated that 53.9% of interpreted town area or 16,142.5 ha, was covered in active BTPD towns. The center of the distribution of BTPD disturbance apparently shifted 17 km north between the 1996-97 and 2005 surveys. The DOQQ survey method is useful for surveying and monitoring the distribution of prairie dog disturbance over large landscapes. Used in combination with field data, it can also be used to estimate the area of active and inactive towns. However, area estimates are prone to inaccuracy due to variation among interpreters and improvements in image quality over time.

INTRODUCTION

In 2002, Natural Heritage New Mexico (NHNM) completed a remote sensing survey for black-tailed prairie dog colonies (BTPD, *Cynomys ludovicianus*) across the species' historical range in New Mexico. For that survey, we used digital orthophoto quarter quadrangle (DOQQ) panchromatic (black and white) air photos collected in 1996 and 1997. This 17.9 million ha survey revealed 24,400 ha of disturbance attributable to BTPDs. Sixteen of the 23 counties in the historical range showed disturbance attributable to BTPDs, but the greatest concentrations of towns occurred in Lea, Roosevelt, Curry, Union, Colfax, and Quay Counties (Johnson et al. 2003). Field checking in 2003 revealed that 89% of towns identified on the 1996-1997 imagery were still identifiable in 2003 as prairie dog disturbance on the ground (Johnson et al. 2003). Considering the six-to-seven years elapsed between the image creation and the DOQQ survey, and in light of the dynamic nature of prairie dog towns, 89% is a surprisingly high accuracy/persistence rate.

In 2004, new, natural color DOQQs became available for the southeastern part of the state. We re-surveyed a 200-quad area in the six southeastern NM counties, an area of 3.2 million hectares. This survey revealed that between the 1996-97 imagery and the 2004 imagery, the area of towns in the sampled quads decreased by 46%, and the distribution of towns shifted markedly to the north (Johnson et al. 2006). Our investigation of several hypotheses for the shift and decline suggested that plague was responsible for town losses in the south; however, plague could not account for gains in the north.

In 2007, natural color DOQQs created from 2005 images became available for the entire state. This imagery offers several opportunities to: 1. re-survey towns across the entire range of BTPDs in New Mexico, to detect longer-term changes, 2. analyze changes in the spatial distribution of BTPD towns over both time periods, 3. ground truth town data four years after they were collected, to obtain an assessment of the accuracy of the photo interpretive method over more towns than were visited in the original survey, and 4. determine if the northern shift in BTPD distribution suggested by the 2004 subset survey is apparent in the larger sample of images surveyed in 2005.

For this project, we surveyed for BTPD towns within the historical range, using the 2005 DOQQs. For the most efficient use of resources, we included for survey those 472 quarter-quads that we found contained probable and field-validated towns on the 1996-97 and 2004 imagery. We added to that sample an additional 31 DOQQs that were adjacent to or connecting quads found to contain BTPD disturbance in our previous survey (Johnson et al. 2003). Although it is possible that this approach missed a few new towns that have arisen outside these quads, surveying the areas that previously contained BTPD disturbance should detect changes in all old towns and reveal new towns in those areas, while avoiding unproductive survey of quads in the west central and southwestern parts of the historical range that contain few or no BTPD towns.

Field checking is an important component of remote sensing prairie dog surveys, for several reasons. Although the method previously has proven to be quite accurate, some level of error will always be inherent. To make reasonable estimates of the actual area of BTPD towns, it is necessary to have information about error rates. In addition, as imagery improves, error rates are expected to decrease, and these changes should be incorporated into area estimates. Finally, when working with a species of conservation concern, both positive and negative errors potentially have unwanted consequences. For example, an overly conservative population estimate could lead to extensive and unnecessary investment in listing and protecting a secure species. An overly liberal assessment of population health could result in failure to protect a species actually in trouble and ultimately require drastic protective measures. For these reasons, this project allotted more resources to field checking than the 2002-2003 survey.

STUDY AREA

The highest concentrations of black-tailed prairie dog towns in New Mexico lie within the eastern plains of the state. The statewide distribution is split roughly by the Canadian River, into a northern and southern group. The current range of the BTPD is now mainly confined to the Western High Plains and Southwestern Tablelands Ecoregions of New Mexico (Omernick 1987, Figure 1). The northern group falls within the High Plains section of the Great Plains, principally north and east of the Canadian River, with a few isolated colonies to the west of the Canadian. The southern group falls within the Llano Estacado, marking the southernmost extent of the Great Plains. These two regions differ in physiography and climate.

Within the northern section above the Canadian River, elevations range from 1180 to 2219 m (3871 to 7280 ft), with a mean elevation of 1597 m (5239 ft). In the south, elevations range from 1098 to 1521 (3602 to 4990 ft), with a mean elevation of 1304 m (4278 ft). Temperatures vary from north to south. Roy has the lowest average minimum temperature and Hobbs the highest average maximum temperature (Figure 2). However, average annual precipitation differs little from north to south (393.19 to 454.15 mm, 15.4 to 17.87 in), with the southern stations of Clovis and Hobbs receiving greater precipitation than the northern stations (Figure 2). All stations experience early summer convective showers and late summer monsoons (WRCC 2009).

Over 65% of the study area is covered by Western Great Plains Shortgrass Prairie, followed by agriculture (15%). Approximately 10% falls within the Great Plains Sandhill Shrubland and Apacherian-Chihuahuan Mesquite Upland Scrub. The remaining area is scattered through several map units (National Land Cover Gap Analysis Project, http://www.nbii.gov/portal/server.pt/community/gap_home/1482). Throughout the eastern plains, particularly within the sandhill shrubland and mesquite upland scrub, inclusions of shortgrass occur on relatively shallow, calcareous alluvial and lacustrine sediments that provide habitat for the black-tailed prairie dog (Neville et al. 2005).

Figure 1. Study area within the Southwestern Tablelands and Western High Plains ecoregions (Omernik 1987).

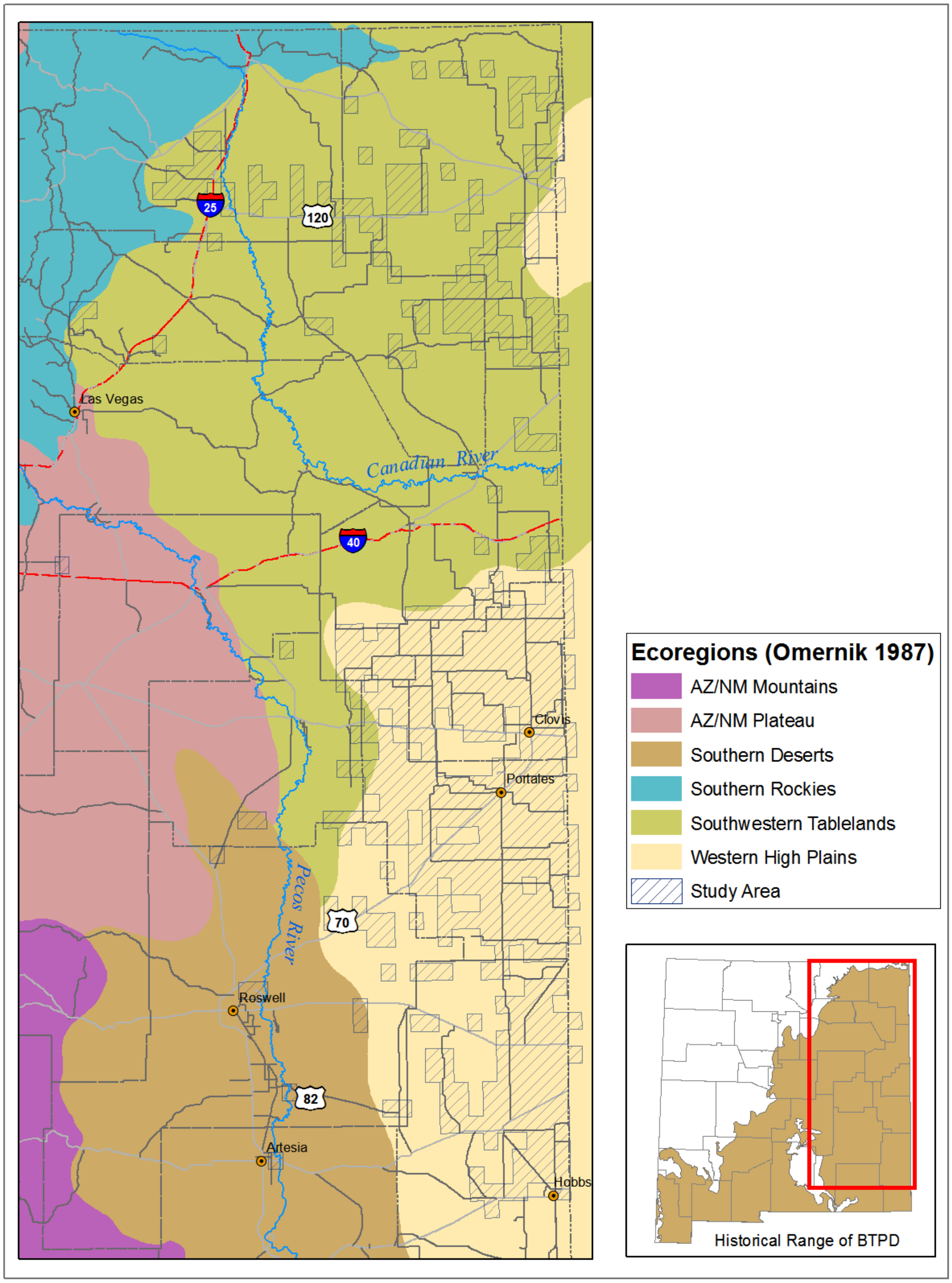


Figure 2. Temperature gradient along the eastern plains within the study area.

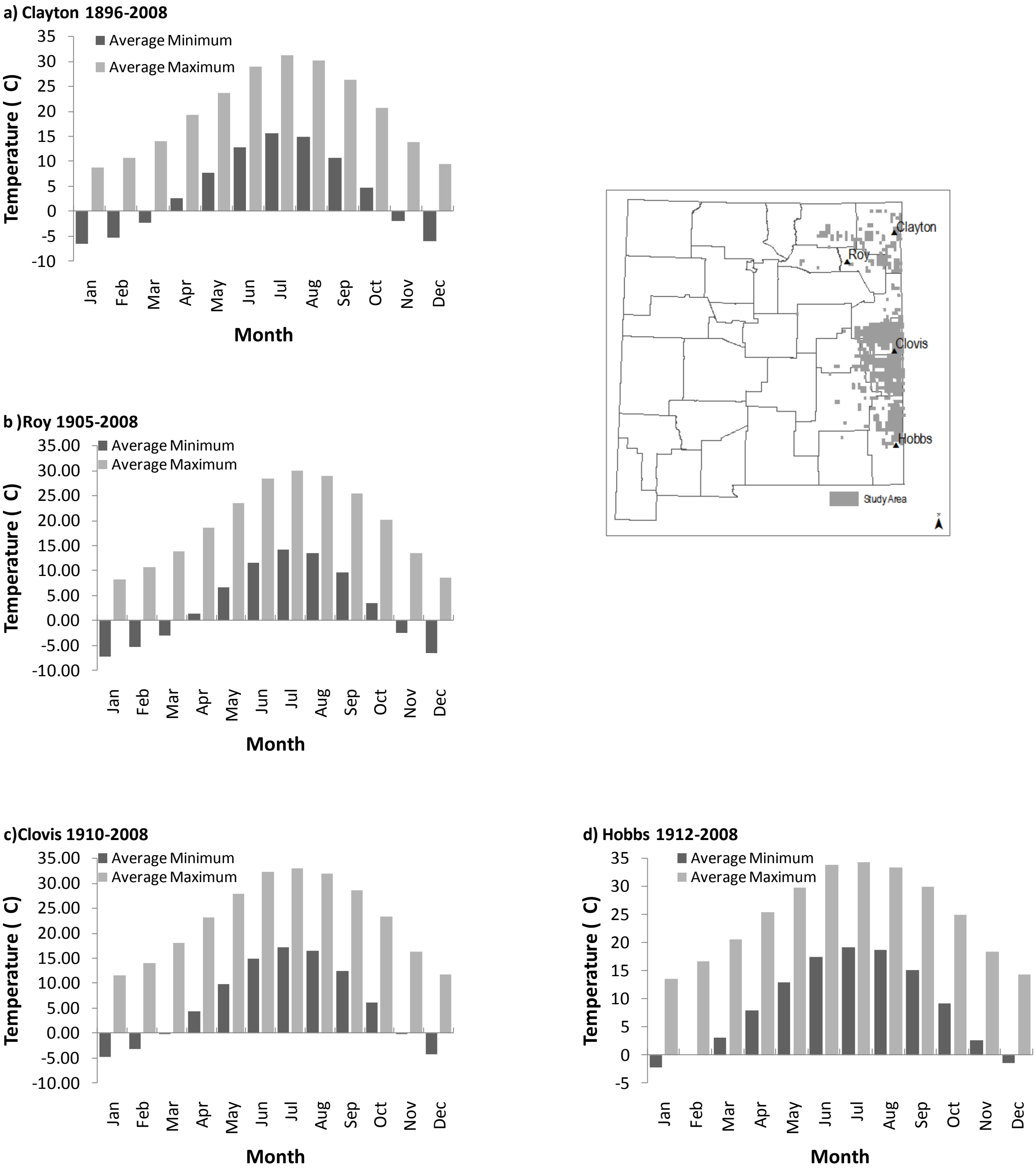
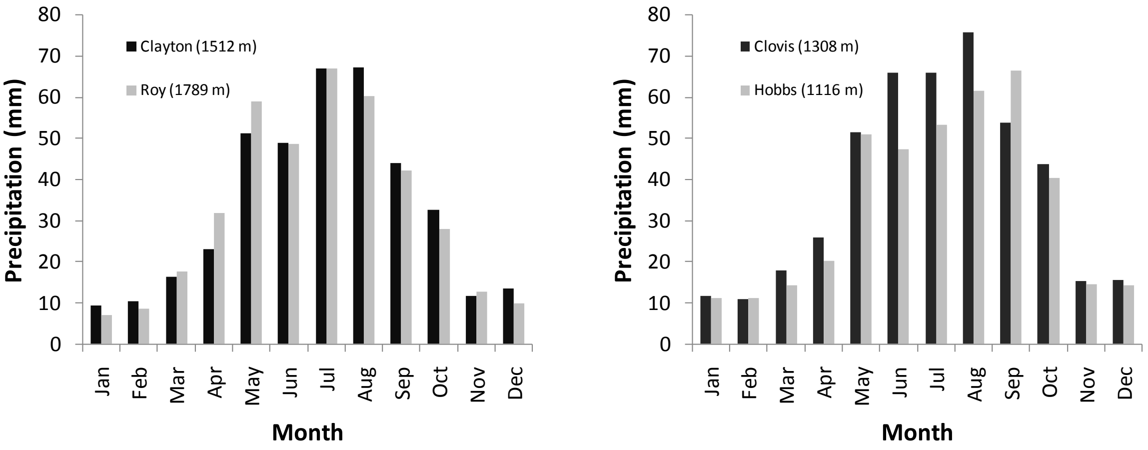


Figure 3. Precipitation from north to south within the study area.



METHODS

DOQQ SURVEY

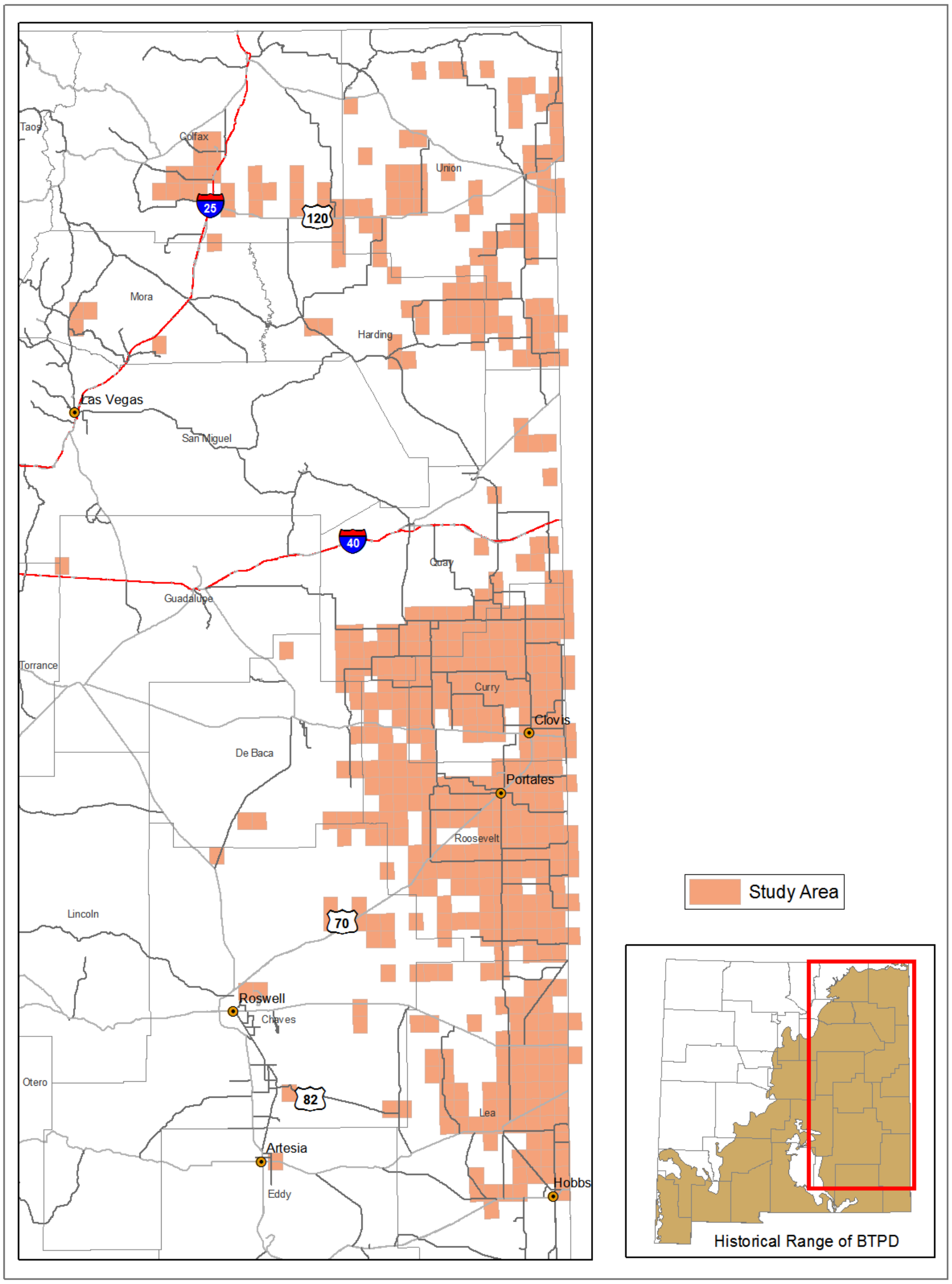
The mounds created by black-tailed prairie dogs at burrow entrances show up as bright, roughly circular spots on DOQQs. Mounds are typically spatially clumped and are often surrounded by a lighter halo on the image, indicative of vegetation clipped by the prairie dogs. A DOQQ prairie dog survey consists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

The digital orthophoto quarter quadrangle (DOQQ) collection was flown and processed by Bohannan-Huston, Inc., as a partnership of federal, state, local, and tribal governments coordinated by the New Mexico Geospatial Data Acquisition Committee. The orthophoto images are in natural 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 one-meter ground sample distance from source imagery flown at 10,668 m (35,000 ft) above ground in July 2005. The survey area covered 1,994,789 ha in 503 DOQQs from eastern NM (Figure 4).

DOQQ SURVEY 2005

We brought each DOQQ image into Environmental Systems Research Institute, Inc. (ESRI) ArcMap™ software and viewed it at multiple scales, including 1:3,780 (essentially the default raster resolution of the image) to 1:20,000. Often the smaller scale viewing provided a clearer picture of the halo (clipped) area. 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 DOQQs in the analysis area were viewed. We included the GIS layer delineating prairie dog disturbance from the 1996-97 image survey and the 2004 image survey in the map while we viewed the 2005 images. The 1996-97 and the 2004 layer provided locations of previously- identified polygons and their interpretation and (for some polygons) ground-truthing history.

Figure 4. Study area DOQQs.



When we identified a potential new town, we drew a polygon around the boundary by tracing the clipped-vegetation halo surrounding the mounds (Figure 5). Each site was given an alphanumeric identifier beginning with the interpreter's initials and was attributed with the number of the DOQQ in which it was identified, the initials of the interpreter, and the assigned status (town or questionable town), and, when applicable, the reason polygons were classified as towns or questionable. Only 45 of 1230 (3.6%) polygons were classified as questionable, 16 of these were field checked, and half of the field-checked questionable towns were actually old or active towns. These results suggest that eliminating towns classed as questionable could be eliminating actual towns from the data set. We therefore included all questionable towns in the data set with those classified as towns. Using ArcMap, we created a GIS layer of all polygons representing the potential towns observed in the 2005 imagery.

We designated as towns those 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 or the 2004 layer, we sometimes consulted the previous attributes of the polygon when making our decision about the 2005 polygon.

A different observer quality-checked all polygons delineated by the first interpreter. Discrepancies were then reviewed by the original observer and revisions made where necessary.

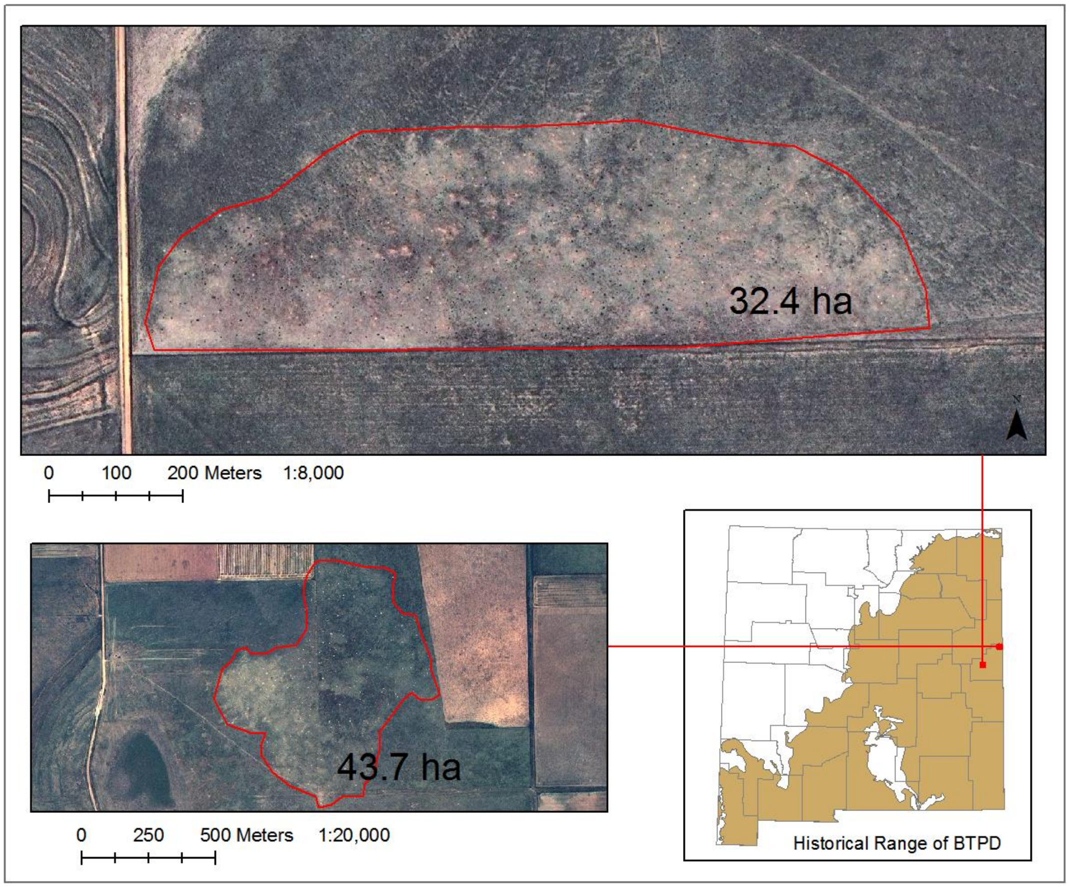
FIELD VALIDATION

We provided a field technician with 1:100,000 maps of all 2009 interpreted polygons along with an associated spreadsheet that included the unique site identification number and UTM location. Using a GPS unit, the technician traveled to the nearest position possible relative to the targeted polygon to observe prairie dog activity or evidence of active or inactive mounds. We were only able to access the interior of polygons that fell within federal lands, as we had no permission to enter private or state lands. The technician would often climb on the vehicle and use 10 X binoculars to scan for prairie dog activity and/or evidence of prairie dog mounds. He entered his results and GPS coordinates of his position into an excel spreadsheet.

SPATIAL ANALYSIS

Using the field results in a GIS we determined the distance between the observer and the targeted disturbance polygon. This distance was used as a check of the field observer's location relative to the target polygon and to determine if observation distance influenced the field classification. Distances were calculated using ArcGIS tools.

Figure 5. Examples of black-tailed prairie dog disturbance at two scales.



The field check showed 337 (66%) of the 507 towns and 68.9% of the polygon area checked to be either active or inactive BTPD towns. This 66% (or 68.9%) ability to identify BTPD towns in the imagery represented a higher error/change rate than we had experienced in previous BTPD DOQQ surveys (89% of polygons were determined to be BTPD activity by Johnson et al. 2003). We therefore reviewed the field-negative polygons in the 2005 imagery and (recently acquired) 2009 imagery and checked previous field checking data from our studies or others' reports.

For each polygon where the field observer found no evidence of an active or inactive prairie dog town (n=170), we reviewed the 2005 imagery and compared it to the (newly acquired) 2009 imagery. We classified these field-negative polygons to identify potential (1) photo interpretation errors, (2) field observation errors, or (3) on-ground changes between the creation of the imagery and the field observation.

To determine changes between 1996-97 and 2005, we identified gains and losses within the study area. For example, if a 2005 interpreted polygon was not represented in the 1996-97 GIS, this was considered a gain. If there was no 2005 polygon overlapping a 1996-97 polygon, this was considered a loss. Using these results, we used Kriging surfaces to create regions of loss, gain, and relative stasis. When we tested other methods offered within the ArcGIS tools, we saw no compelling change in the spread of data points in the semivariogram or covariance graph. We therefore used a spherical prediction model.

To determine any major shifts in the overall spatial distribution between the two surveys, we used the interpreted polygons of both surveys and separately generated one-standard-deviation ellipses.

RESULTS

SURVEY OF 2005 DOQQS

We had performed the previous survey over the entire BTPD historical New Mexico range using imagery from 1996 and 1997 (Johnson et al. 2003). Considering only the 503 DOQQs examined in both surveys, the previous survey detected 26,474.83 ha of apparent BTPD disturbance in 710 polygons. For that survey, mean polygon size was 37.28 ha (range 0.16-954.88 ha). For the current survey of 503 DOQQs from the 2005 imagery, we detected 1230 polygons covering 43,404.69 ha (Figure 6). The mean polygon area was 35.28 ha (range= 0.15-1154.73 ha). Thus, more polygons were detected in the 2005 than in the 1996-97 imagery, but the average size of polygons was similar in the two surveys.

Town size, shape, and direction can fluctuate over time. A spatial analysis of polygon area in the two surveys shows that 15,448 ha of polygon area detected in 1997 were no longer detectable by the 2005 imagery, while 32,383 ha of new disturbance were interpreted in 2005. Polygon area evident in both surveys; i.e., area unchanged between the two surveys, was 11,026 ha (Figure 7).

Here we compare gains and losses in the north and south areas, keeping in mind that the north survey area, north of the Canadian River, was only about one-third the size of the south survey area (Figure 8). In the north, 2649.7 ha (0.53% of the north surveyed area) was lost, while in the south, 12,798.5 ha (0.85%) was lost. In the north, 11972.1 ha (2.4% of the area) was gained, while 20,411 ha (1.36%) was gained in the south. In the north, 3464.2 ha (0.69%) remained unchanged, while in the south, 7562.4 ha (0.5%) remained unchanged. Thus, relatively more area was lost in the south, while relatively more area was gained in the north (Figure 8a).

More whole towns were lost in the south than the north (n=170 and 33, respectively), resulting in a loss of 4,631 ha (0.31%) in the south compared to 571 ha (0.11%) in the north. More towns were also gained in the south (532 vs. 168 towns). Larger gains in the south 9668.7 ha (0.64%) than the north 5937.2 ha (1.19%) offset these whole town losses (Figure 8b).

Considering whole towns, both the north and south experienced area gains overall, with the north showing slightly more (5366.2 ha) than the south (5037.8 ha). The source of the differences occurs in average town sizes. The average size of a town lost in the north was smaller than that lost in the south (16 vs. 27 ha), and average size of towns gained was larger in the north than in the south (35 vs. 18, respectively).

Thus, the majority of area gains occurred through expansion of existing towns; i.e., 21,979 ha vs. 10,404 ha of whole towns gained. Likewise, the majority of area losses occurred to existing towns; i.e., 15,448 ha vs. 10,246 ha of whole towns lost.

Figure 6. Photo interpreted BTPD disturbance using 2005 digital orthophotography.

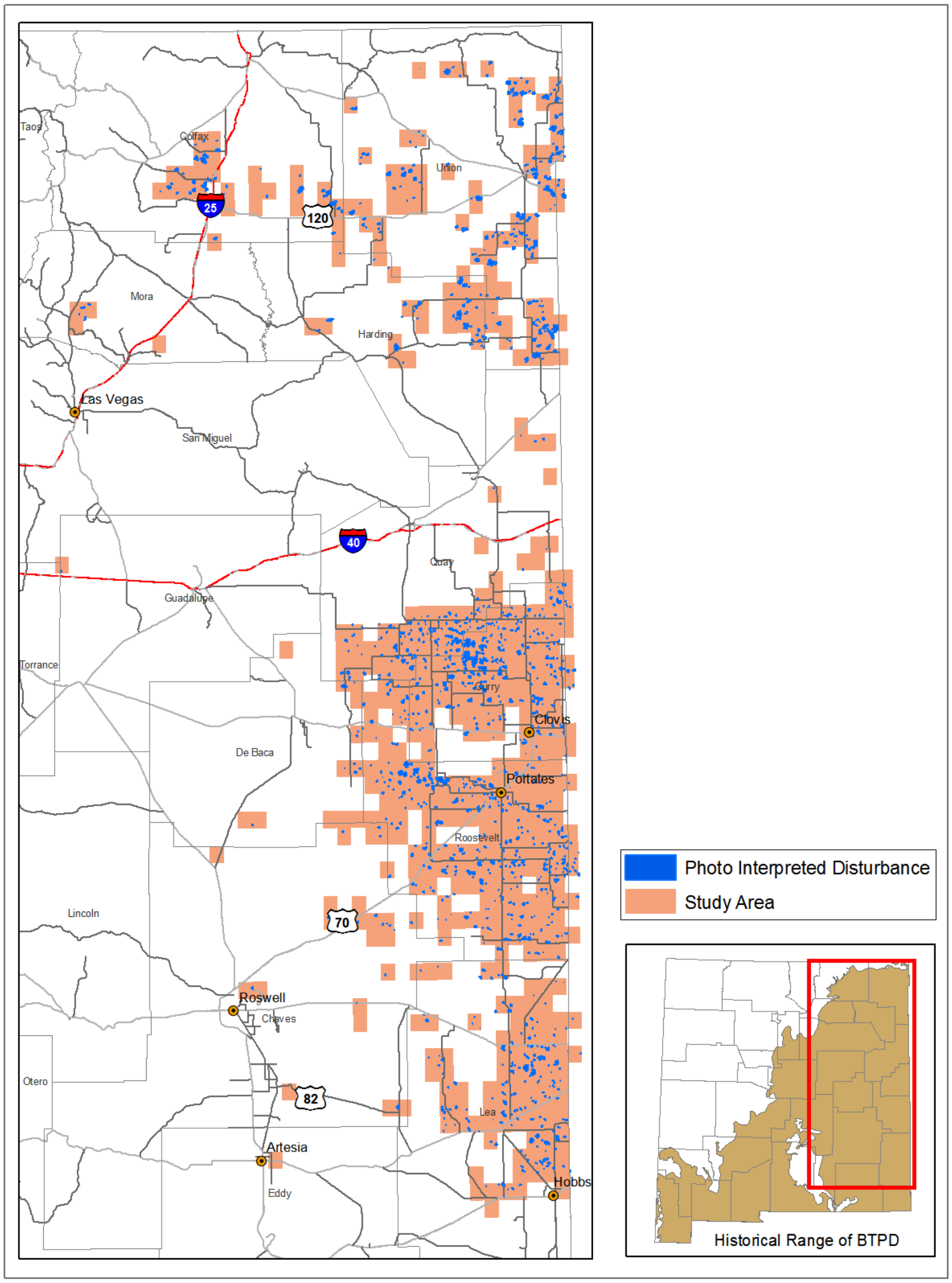


Figure 7. Change in BTPD disturbance from 1996-97 to 2005.

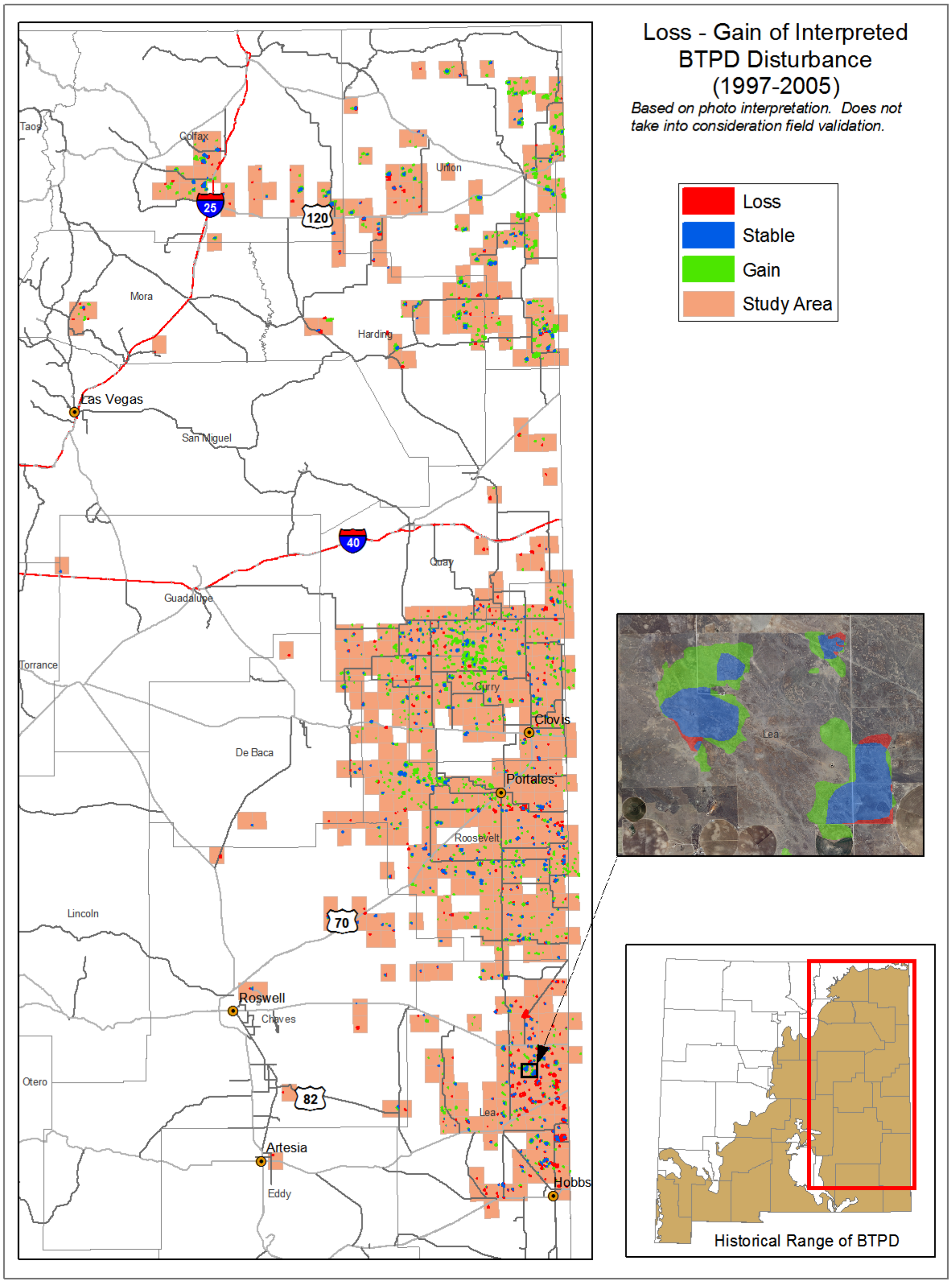


Figure 8. Change in the north and south regions between 1996-97 and 2005. a) uses all polygons to determine overall loss, gain, and no change; b) uses a subset of towns that entirely disappeared or were entirely new between the two dates.

SOURCES OF VARIATION BETWEEN 1996-97 AND 2005 SURVEYS

In addition to actual changes on the ground, two additional sources of variation could have contributed to the apparent increase in area between the 1996-97 and 2005 imagery. First, the new imagery is apparently clearer than the older imagery, and more towns may be detected. The initial imagery was panchromatic with a single-band file, while the more recent imagery was a three-band file containing visible blue, green, and red. Humans can discriminate more shades of color than we can tones of gray (Lillesand et al. 2008). We were able to adjust the contrast of the 3-band file to see greater variation among surface objects.

Interpreter differences are an additional potential source of variation between the two surveys. Our evidence for this is based on a comparison of two interpretations of the same 200 DOQQs from 2004, first interpreted in 2005 (Johnson et al. 2006) and re-interpreted by a different interpreter in 2009. The first interpreter consistently interpreted smaller areas (total area 41% smaller) in the same imagery, primarily due to delineating BTPD disturbance more tightly. This difference was approved by the PI and Jim Stuart of NM Department of Game and Fish for the 2005 survey, but it likely created apparent differences in area that in fact resulted from a change in methods between surveys. The same interpreter also was more conservative in identifying fewer towns. In addition, a third interpreter disagreed with 27% of a sample of the second interpreter's 2005 towns.

SPATIAL DISTRIBUTION OF POLYGONS

More polygons and polygon area were lost in the southern part of the BTPD range than in the north, as evident in Figure 7. Likewise, more polygon area was gained in the central and northern areas of the survey. A kriging surface analysis built on hectares gained, lost, or stable between 1996-97 and 2005 depicts these shifts, with purple areas representing BTPD disturbance area increases between the two surveys, and brown areas representing areas where BTPD disturbance was lost (Figure 9). The inset standard error map shows in brown the areas of higher confidence in the model, with errors ranging from 50.6 to 57.4 ha.

The kriging analysis was based on the DOQQ survey only and did not include information from the field survey. Including field results would improve accuracy of the kriging surface map at specific field-checked sites but not in areas that were not field checked. Hence, to avoid confusion and the mixing of field and image analysis results, we use the imagery only for this analysis.

A directional distribution analysis of interpreted polygons indicates that the entire distribution of BTPD disturbance shifted between the 1996-97 and 2005 DOQQ surveys (Figure 10). The center of the polygon distribution shifted 17 km to the north between the 1996-97 and 2005 surveys, with a moderate shift of 2.5 km to the east. This shift in polygon distribution suggests that variation due to imagery and interpreter cannot explain all of the increase between the two surveys, because these two factors would not be expected to vary from north to south. Thus, the distributional analysis suggests that actual losses occurred in the south and gains in the north between 1996-97 and 2005.

Figure 9. Kriging surface based on interpreted differences between 1996-97 and 2005. 2009 field validation results overlay the model.

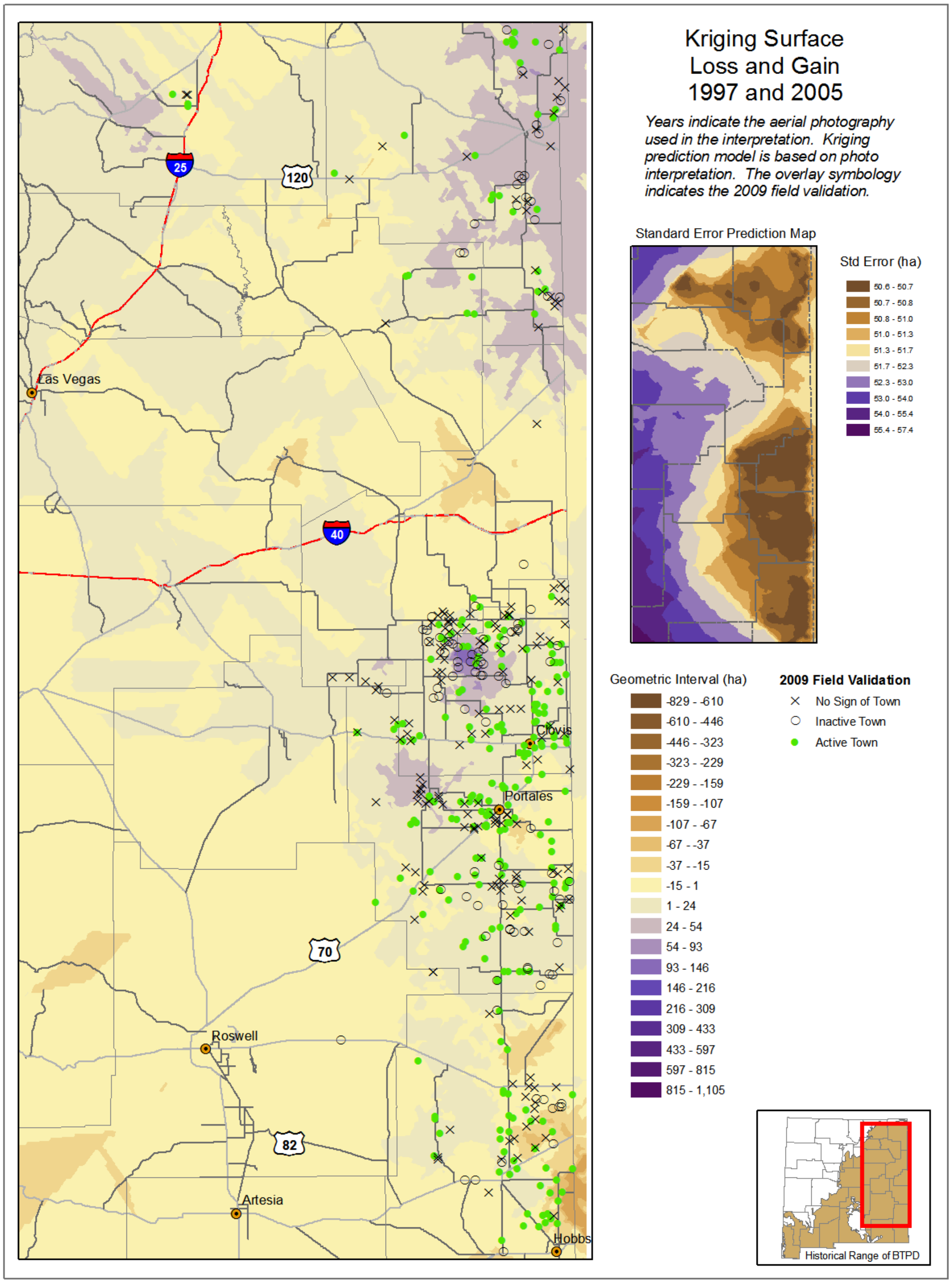
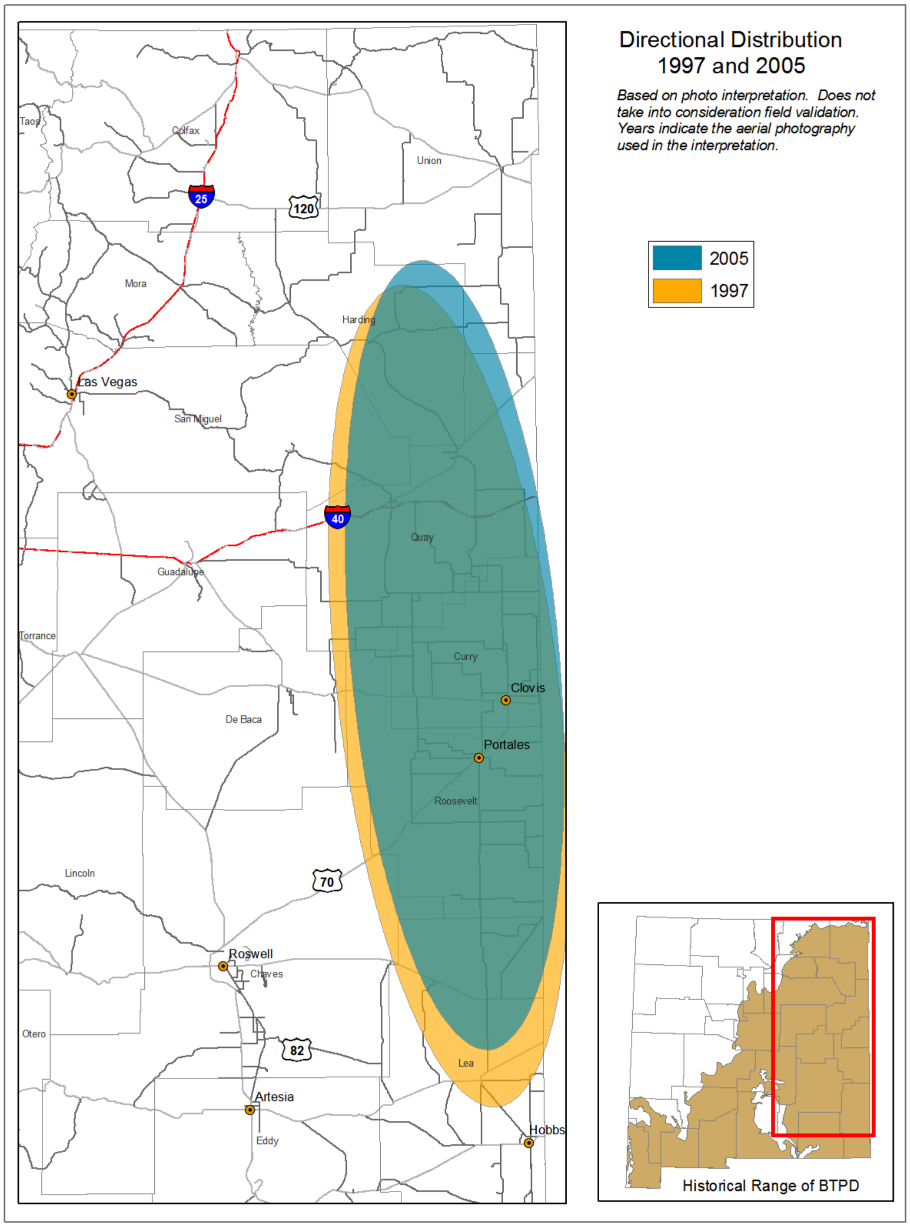


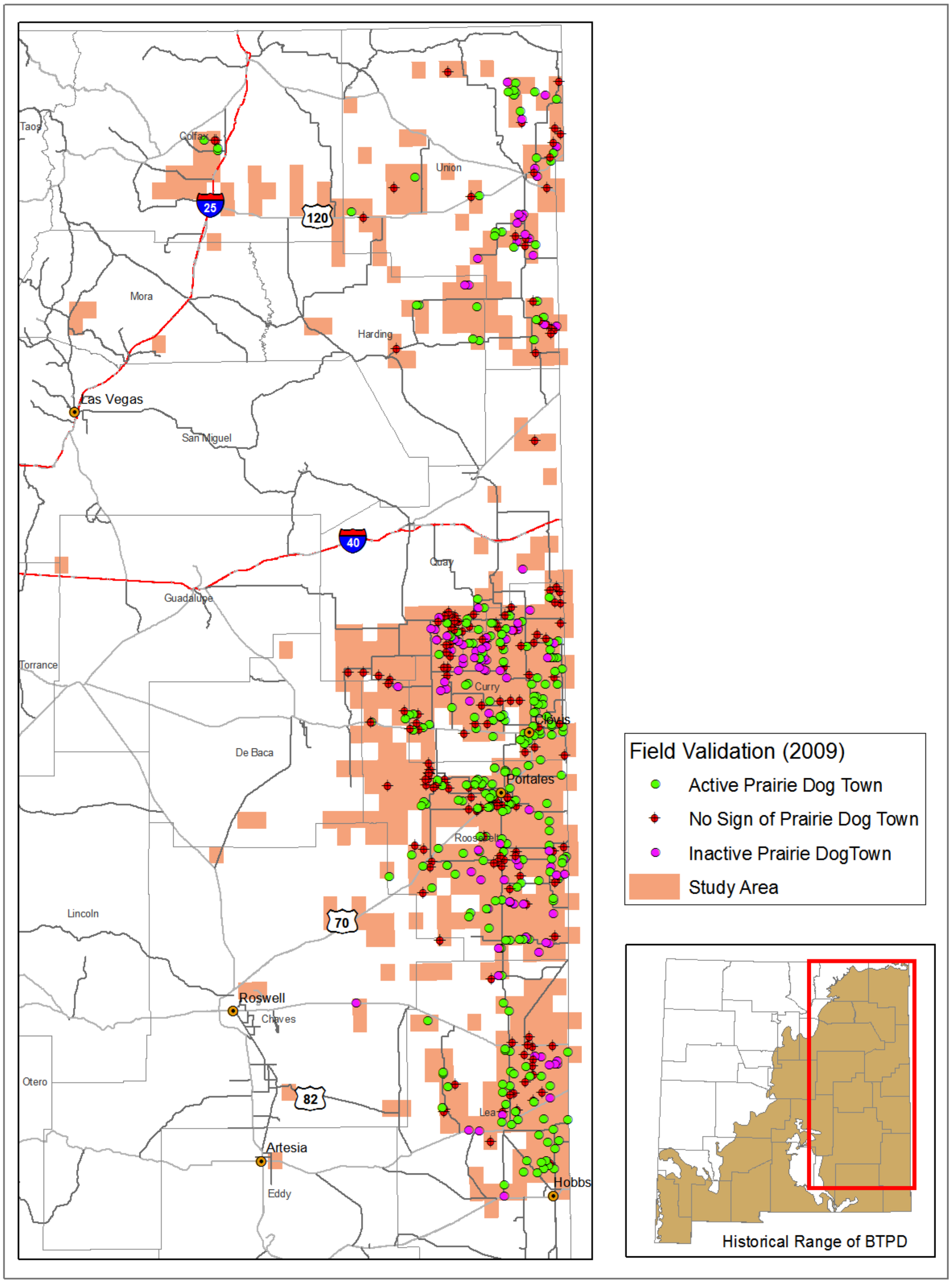
Figure 10. Directional distribution ellipse for 1996-97 and 2005.



Field Check of DOQQ Survey Results

A surveyor visited 507 polygons detected in the DOQQs to check the accuracy of the interpretation. Field checked towns were distributed throughout the study area. They were concentrated in the center of the study area, in accordance with the distribution of the DOQQs surveyed and BTPD towns identified (Figure 11).

Figure 11. Field validation results for the 2005 orthophoto interpretation conducted in 2009.



The field check found 45% of town polygons and 37.2% of town area to be active towns, while 20% of town polygons and 31.3% of polygon area were inactive. Two percent of polygons and 0.5% of polygon area were towns where activity was undetermined. The field check found that 34% of towns representing 31% of town area were not BTPD towns (Table 1).

Table 1. Summary of field check results.

	Active Towns	**Inactive Towns**	**Unknown Towns**	**All Towns**	**Not Towns**	**TOTAL**
Number of Towns	230	99	8	337	170	507
% of Towns	45%	20%	2%	66%	34%	100%
Area (ha)	8312.2	6989.7	106.2	15408	6949.3	22357.3
% of Area	37.2%	31.3%	0.5%	68.9%	31%	

Of the 170 field-negative polygons that we re-assessed, 25 (14.5% of polygons, 11.3% of area) were converted to agriculture by 2009. A second look at the 2005 imagery suggested that the original interpretation could have been in error for 46 (27% of polygons, 12.4% of area) of the 170 field negative polygons. We had field data indicating that 27 polygons (15.9%, of polygons, 32.8% of area) had been active towns prior to 2009. On the 2009 imagery we found 72 polygons (42.4% of polygons, 43.4% of area) that appeared to be BTPD disturbance (Table 2).

Table 2. Summary of office review of negative field polygons.

	Agricultural Field	**Possible Interpreter Error**	**Previously Active**	**Town/Possible Town in 2009**	**TOTAL**
Towns	25	46	27	72	170
% Towns	14.7%	27%	15.9%	42.4%	100%
Area	783.2	859.3	2281.9	3024.9	6949.3
% Area	11.3%	12.4%	32.8%	43.4%	100%

We can approach the field data in several ways. Most simply, we can assume that the field technician was able to detect BTPD disturbance on the ground and that his data provide a reliable estimate of actual BTPD disturbance across the entire study area in 2009. Using this approach, our estimate of actual disturbance on the ground in 2009 would be 69% of the total polygon area or 29,949 ha of BTPD disturbance on the 503 surveyed DOQQs. This accords fairly well with our estimate for the same 503 1996-97 DOQQs reviewed previously, 26,475 ha.

This estimate does not include false negatives; i.e., new towns or towns missed on the imagery. The field interpreter found 22 towns not identified in the imagery, which represents a 4.3% increase in the number of polygons in the field check and 0.28% of the field-checked polygon area. Given that we do not know what proportion of new towns was missed, we elected not to include this small area adjustment in our estimate of BTPD disturbance and active area.

It is possible that active area in the field was smaller than interpreted area because the field technician missed some active towns. Towns move between years and could have been too far away from access points by 2009 to allow for accurate assessment. In addition, we were not permitted to walk to some towns managed by the New Mexico State Land Office. We therefore field checked only those towns on state and private land that we judged to be near roads. These we viewed from the nearest road access point. To determine whether distance from the observer was associated with the ability to detect BTPDs or their burrows, we looked at the distance from apparent town edge (derived from 2005 interpreted polygons) to the point where the observer was standing when he checked the town. There was no significant difference between observer distance to active towns vs. distance to polygons designated as "no town" (Table 3). There was also no significant difference in distance to observer between all towns combined (active, inactive, and activity unknown) and polygons designated as "no town" (Table 4). Thus, we reject the hypothesis that the field technician systematically failed to classify the more distant polygons as towns.

Table 3. Results of two-sample t-test comparing distance from observer to active towns vs. no towns, assuming equal variances.

	Dogs Observed	***No Town***
Mean	92.23699651	88.20512146
Variance	12790.92258	14426.03093
Observations	212	169
Pooled Variance	13515.71995	
Hypothesized Mean Difference	0	
df	379	
t Stat	0.33630728	
P(T<=t) one-tail	0.368412641	

t Critical one-tail	1.648884032	
P(T<=t) two-tail	0.736825282	
t Critical two-tail	1.966242898	

Table 4. Results of two-sample t-test comparing distance from observer to all towns vs. no towns, assuming equal variances.

	All Towns	*No Town*
Mean	74.40045674	88.20512146
Variance	10030.3177	14426.03093
Observations	328	169
Pooled Variance	11522.19613	
Hypothesized Mean Difference	0	
df	495	
t Stat	-1.35818932	
P(T<=t) one-tail	0.087511159	
t Critical one-tail	1.647937753	
P(T<=t) two-tail	0.175022318	
t Critical two-tail	1.964767909	

Another approach to estimating actual BTPD disturbance on the ground would be to adjust the interpreted area based on the office re-interpretation of field-negative polygons, informed by the new 2009 imagery. In that review, 23.6% of the re-interpreted area was determined not to be BTPD disturbance in 2009, either because it had been converted to agriculture or because it had been initially mis-interpreted. Removing this proportion from the interpreted area gives an estimated actual disturbance area of 33,161.4 ha, not including false negatives. This estimate is based on a smaller number of polygons than the 29,949 ha estimate above, and it is also based on review of imagery and not field data. Therefore, the most reasonable approach appears to be to accept the estimate based on the field results.

Hence, in the absence of reliable information on false negatives (towns missed in the 2005 analysis or new towns since 2005), our best estimate of the town area on the ground is

29,949 ha. The number of missed and new towns is likely small relative to the area of interpreted polygons (<3%, Johnson et al. 2003). An estimate of new towns appearing between 2005 and 2009 could be acquired by surveying the same 503 DOQQs in the 2009 imagery. Alternatively, a sample of these new DOQQs could provide a factor to allow estimation of new town area.

ACTIVE TOWNS

Of the field-checked towns where activity could be determined, 230 of 329 towns (69.9%) were determined to be active. In area, this translates to 53.9% of interpreted town area. Using this factor, we estimate 16,142.5 ha of active BTPD towns in the study area (29,949 ha x 53.9%) in 2009. Based on our 2003 survey (Johnson et al. 2003), we estimated 12,687 ha of active BTPD towns in the study area. The current estimate is a 27% increase from the estimate based on 1996-97 imagery. The increase may have come in part from the northward distributional shift, which included gains in the northern part of the distribution. However, these area estimates should be considered approximate only and could have been inflated by improved image quality and interpreter differences (see Discussion, below).

DISCUSSION

CHANGES IN BTPD TOWNS OVER TIME

This study has identified two types of changes in BTPD disturbance in eastern New Mexico between 1996-97 and 2005. The first is an increase in the total area of estimated BTPD disturbance from 26,474.83 to 29,949 ha within the 503 DOQQs examined for both surveys. This translates into an increase in active area from 12,687 ha to 16,142.5 ha. We consider the magnitude of this increase to be approximate only. Although spatial analyses indicate that more disturbance area was gained than lost, increased image quality and/or differences in interpretation could have inflated the apparent increase in BTPD area.

We have more confidence in the change in distribution of towns across the state because north-south variation in gain and loss rates would not be expected to be influenced by either image quality or interpreter. In addition, a survey of a subset of DOQQs created in 2004 (interpreted by a different observer) showed a similar northward shift in the BTPD distribution in New Mexico (Johnson et al. 2006). The imagery for this study is now five years old. Just after this DOQQ survey was completed, 2009 imagery became available. Leaving aside the unfortunate timing in image availability, the 2009 imagery provides an opportunity to assess the stability of this distributional shift, in addition to the opportunity to evaluate the area either missed in the DOQQ survey or added since 2005. When we first detected the northward shift in BTPD disturbance, we examined several hypotheses for the change. The most reasonable hypothesis, given our limited data on any of them, was that a plague event had decimated towns at the southern end of the distribution in New Mexico (Johnson et al. 2006). Plague may still be prevalent in the area, or BTPD populations may not have recovered from earlier plague events. However, if the northward trend continues, a rigorous look at a hypothesis of climate change would be warranted.

SURVEY METHOD

It seems the more DOQQ surveys we do, the more we understand the method's limits. On the one hand, it is encouraging that the BTPD disturbance and active areas do not differ widely between our surveys of the 1996-97 imagery and the 2005 imagery. It is also encouraging that the northward distribution shift we detected in 2004 imagery was borne out on a larger scale with new 2005 imagery. Detection, depiction, and the potential for spatial analysis of the distribution of towns over large landscapes is a clear strength of the DOQQ survey method over other methods. The method can also be productively used to focus field studies.

The precision of area estimates is a weakness of the method. It is impossible to distinguish active from inactive towns in the imagery, and interpreter variability can bias estimates. Ground truthing serves as a check against these weaknesses, but area estimates are necessarily just that. However, the same weaknesses apply even to ground surveys. We have found it extremely difficult to delineate the edges of prairie dog towns in the field, even using GPS technology. It is not possible to see the edge of a town and is even more difficult to distinguish inactive portions of an otherwise active town.

To address these weaknesses of the DOQQ method, we first recommend that as much field checking as feasible be conducted and as much as possible field workers should make their determinations at the polygon site rather than from a distance. Second, in spite of our efforts to train interpreters thoroughly and standardize their interpretation, we have detected some differences among interpreters, and in fairness to the interpreters, our view of how best to draw polygons has changed through time.

We believe the method used in the 2005 survey is more biologically meaningful than that used in the 2004 surveys. In the earlier survey, the interpreter drew the polygon tightly around evident disturbance, which resulted in projections from the center of disturbance that were close enough to easily be traversed by a prairie dog. Areas that did not show signs of disturbance in the imagery were not previously included in the polygon, even though these areas were clearly within the probable town area used by the animals. There are advantages of both approaches. Drawing the polygons tightly around the most obvious disturbance probably allows for greater consistency among observers. Drawing polygons more broadly to include inlets that were highly likely to be used, albeit less heavily, by the animals is more biologically accurate. In future studies we will explore these two approaches to determine the best way to train interpreters for consistency and accuracy.

In conclusion, this study has indicated a possible increase in the area of BTPD disturbance and active BTPD towns between 1996-97 and 2005. It has indicated a more reliable distributional shift toward the north over the study area. Finally, this study has detected new sources of potential error in interpretation that, when addressed, should help to increase interpreter accuracy in the future.

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