Evaluation of High Resolution Digital Aerial Photos to Survey for Gunnison's Prairie Dogs

Final Report

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Introduction

Population declines of both black-tailed (*Cynomys ludovicianus*) and Gunnison's (*C. gunnisoni*) prairie dogs have resulted in proposals to list both species under the Endangered Species Act (US Fish and Wildlife Service 2002, http://www.fguardians.org/pdf/gunnison-pdog-petition.pdf). Although both species are known to have declined significantly during the last century, until recently the population sizes and distributions of neither were well known. To plan for the conservation and management of these species, it is necessary to conduct rangewide surveys to provide a basis for population monitoring. In 2000, Natural Heritage New Mexico began investigating the usefulness of remote sensing methods for detecting prairie dog disturbance (Johnson et al. 2000). After the initial investigation using satellite imagery proved marginally successful, we began photo interpretation of digital orthophoto quadrangles (DOQs), which allowed us to survey the entire historical New Mexico range of black-tailed prairie dogs (Johnson et al. 2003, 2004a). In 2003, we began evaluating the utility of surveying for Gunnison's prairie dogs using DOQs (Johnson et al. 2004b).

At the outset, we were skeptical of the potential for finding Gunnison's disturbance using photo interpretation of DOQs. Gunnison's prairie dogs occur in smaller colonies, create less ground disturbance, and use more habitats containing more vegetation than the habitats of black-tailed prairie dogs. We expected that these factors would make remote sensing surveys more difficult and less accurate than for black-tailed prairie dogs. For the most part, the study validated our concerns (Johnson et al. 2004b). However, a surprising amount of disturbance that appeared to have been created by prairie dogs was apparent on the images. Comparison of the DOQ survey results to known Gunnison's prairie dog locations provided by land managers and researchers indicated that the method, although less promising than for black-tailed prairie dogs, still yielded considerable area of potential new towns (Johnson et al. 2004b). For example, although our survey intersected only 51% of known towns, we searched a buffered area around known towns to account for town movement that could have occurred between the ~1997 and (mainly 2003) ground data. When current town sites were buffered by 250 m, the DOQ survey intersected 75% of known towns, and a 500m buffer intersected 84% of towns. The un-buffered result for Gunnison's (51%) is a lower success rate than we achieved with black-tailed prairie dogs (about 77% without buffering), but it suggests that it would be premature to rule the method out. We thought that higher resolution imagery, image enhancement, and/or field checking might improve accuracy.

The objective of this project was to evaluate new 2004 DOQ imagery from the New Mexico range of Gunnison's prairie dogs to determine 1) usefulness of the 1997 versus newer images in depicting Gunnison's prairie dog disturbance, 2) methods for image enhancement, and 3) changes in colony size, shape, and appearance between 1997 (as indicated by imagery) and 2003 (from field data) and 2004 (as seen in new DOQs). Field checking data from 2004 and 2005 helped us to assess the relative influence of town changes versus image inaccuracies on error rates.

Methods

Photo Interpretation

The Bureau of Land Management (BLM) acquired digital aerial orthophotography for portions of northwestern New Mexico in 2004, of which only San Juan County was served on the U.S. Geological Survey (USGS) website as a free download (http://seamless.usgs.gov/website/seamless/viewer.php). We used ESRI's ArcMap, Version 9.0, to record the envelope (minimum and maximum extent) for each polygon or polygon group of the field-verified data. The coordinate pairs were then used as extents to download imagery from the USGS website. The orthophoto images downloaded from the USGS website came in Tagged Image File (TIF) format. We downloaded 15 images of various sizes and extents.

We employed traditional aerial photo interpretive techniques (Lillesand and Kiefer 1987) to survey the subset of orthophoto images where field-verified polygon data were available from San Juan County, New Mexico. Each image was viewed in ArcMap and displayed at a resolution of 1:1,000 to 1:2,000, depending on the quality of the image. A large number of the images had a "grainy" appearance, making it difficult to identify prairie dog disturbance. To compensate for the varied quality of the images, we applied various raster enhancements to each image; for example, statistical contrast stretches or manual adjustments to contrast and brightness. Often a contrast stretch of three standard deviations was sufficient to reveal prairie dog disturbance patterns.

We used an iterative technique to examine the area in the image encompassed by the field-verified polygon and the area immediately surrounding it. Because the areas to be surveyed occupied more than one full screen, we systematically scanned the screen left to right, down, right to left, and so on, until the entire screen had been reviewed. We then moved one screen to the right (or down) and repeated the process until the entire image had been viewed. When we identified a characteristic disturbance as a potential prairie dog town, we digitized a polygon that connected the outermost mounds comprising the boundary of the town. Each polygon was assigned a unique site identification number and the site number for the original field verified polygon. This allowed us to establish a relationship to the original dataset.

As a first check of the photo-interpretation process, we compared photo-interpreted polygons to field-acquired polygons provided by various agencies. The field data were collected from 2002-2004. Because most were acquired in 2003, we refer to these data as "2003 field data."

Field Checking

A student intern field checked towns during the summers of 2004 and 2005. We provided the student with GPS locations and maps of possible towns, based on 2003 field locations acquired from land managers, our 2003 photo interpretation, and our photo interpretation of natural color images from 2004. The intern traveled to accessible towns having the GPS coordinates we provided (NAD 27). Using binoculars, he searched for prairie dogs and inactive burrows from the roof of a truck and, where towns were accessible, by walking several hundred meters in each direction from the GPS location provided. He recorded status as: active, active?, inactive, inactive?, or no town. He recorded GPS coordinates of new or moved towns. In 2004, using a GPS unit, he recorded the perimeters of a subset of towns, for comparison with photo-interpreted polygons. In our analyses, we assumed the nearest town within 200 m of the known or photo-interpreted locations to be the same town. For analysis, we sometimes lumped questionable towns or questionable inactive towns with towns.

Results

Photo Interpretation

We delineated 84 polygons of potential Gunnison's prairie dog disturbance on the 2004 digital aerial photos of San Juan County (Figure 1). The digitized polygons comprise a total of 187.75 ha (463.95 ac). The original dataset compiled by Johnson et al. (2004b) of 2003 field verified polygons for the same area covered 319.5 ha (789.50 ac), comprising 18 separate polygons. The difference in both area and polygon count between the two datasets may be due to differences in the two methods of polygon delineation, because they both cover the same approximate time frame (field = 2002-2004, photography 2004). The field verified polygons are more generalized and at times encompassed large areas that did not appear to be habitat, such as woodlands with no evidence of disturbance (Figure 2). For the current effort, the interpreter digitizing the disturbance in the imagery attempted to be exact by digitizing smaller, noncontiguous areas where disturbance was evident.

Physical characteristics of the landscape and radiometric problems inherent in the imagery confounded interpretation. Physical properties of the soil and disturbance by other species such as ants make photo interpretation difficult. Additionally, the Gunnison's prairie dog does not clip the vegetation as closely as does the black-tailed prairie dog, which creates more visible disturbance in aerial photos. The "haloing" effect (Johnson et al. 2003) with white spots is rarely evident in photos where Gunnison's prairie dogs are known to occur (Figure 3). The Gunnison's prairie dog is also found in a larger diversity of habitats than the black-tailed prairie dog, which is predominantly found in grasslands. The Gunnison's can be found in small openings among woodlands, shrublands, and grasslands (Johnson et al. 2004b). In addition, Gunnison's prairie dogs are much less social than black-taileds, and Gunnison's colonies are therefore smaller (Pizzimenti and Hoffmann 1973).

Radiometric problems included grainy images, making it challenging to distinguish burrow entrances from image graininess. Figure 4 compares a clear photo on the left with a degraded, grainy photo on the right. Due to the process inherent in downloading the images from the website, there were abrupt, artificial contrasts within an image caused by the mosaicking process. Because the images were not properly mosaicked prior to downloading, the contrast stretch to view the images had to be altered from one half of an image to the other half. For example, one side the image might be more grainy, a different color, or more blurry than the other side. The contrast problem created through the mosaic process could be avoided if the original dataset were available for interpretation.

We compared the size of 18 2003 field-verified polygons to the corresponding 2004 photo-interpreted polygons. The field-acquired polygons were larger, almost significantly so (paired t-test, t=1.8, p=0.044, n=18). The trend toward larger field-acquired polygons probably occurred because field-acquired polygons were outlined in less detail than those made from imagery, at times including areas that did not appear to be occupied or suitable habitat.

Field Checking

The intern visited 46 potential Gunnison's towns in 2004 and 66 in 2005 (Figures 5, 6, 7, and 8). In 2004, using a GPS unit, he collected perimeter data for a subset of 11 towns to look at changes in town size and location over time. One town was much larger on the 1997 image than in the 2004 field check. A second town was much larger at the time of the field check than on the imagery. The remaining nine towns were roughly the same size in 1997 and 2004, but only two showed substantial overlap in the 1997 and 2004 polygons (Figure 9). Thus, in this small sample of towns, most towns moved considerably over the seven-year period, but only a few changed dramatically in size.

The 46 towns visited in 2004 were derived from 1997 imagery that we photo-interpreted in 2003. Of these, 15 (33%) were active or inactive towns, and 67% were not towns (Figure 10). This was our lowest accuracy rate of this study, attributable to the length of time between photos and field checking (eight years), the quality of the imagery, and possibly other factors (see below).

Of the 66 towns visited in 2005, 49 locations were obtained from 2003 photo interpretation of 1997 imagery. Eleven were field-verified locations obtained from management agencies, and six came from 2004 color imagery. The percent of photo-interpreted towns from 2004 imagery found to be actual towns in 2005 was nearly comparable to the proportion of 2003 field-acquired towns that were found on field checks in 2005 (67% towns versus 73% towns, respectively), while only 39% of towns photo-interpreted on the 1997 imagery were still towns in 2005 (Figure 11). However, it should be noted that the 2003 field and 2004 image samples were small, increasing the chance of sampling error.

Unfortunately, it is usually not possible to distinguish accuracy effects due to image quality from those caused by the passage of time; however, towns clearly change considerably over time. The best comparison data set showed that field-acquired towns from 2003 had changed enough in two years that only 73% of towns were still identifiable in the field in 2005. No photo interpretation was involved in this loss, which strongly suggests that large numbers of towns disappeared (or moved > 200m) in the intervening two years. Because neither field effort was a census of the entire area, we do not know to what extent losses were balanced by large-scale town movement or undetected gains.

Compared to this change (73% towns remaining) in field-acquired data over a two-year period, photo-interpreted and field results acquired one year apart (2004 versus 2005, respectively) show only 67% of towns still present (Figure 12). In this comparison, time should have less of an effect on accuracy, but photo-interpretation appears to have added additional uncertainty, as might be expected. Photo-interpretation of the older (1997) imagery shows additional loss of accuracy, presumably due to the combined effects of photo-interpretation and increased time intervals (eight years). This sample was similar in accuracy to the 2004 field check of a sample taken from the same data set (2003 photo-interpretation of 1997 imagery). It is somewhat encouraging that 2004 and 2005 field checks of different sets of polygons from the original 1997 imagery revealed similar error rates (33% and 37% towns, respectively). Given several potential sources of error; i.e., different sampling areas and habitats, increased experience on the part of the intern, or sampling error due to town size or number, the similarity of these two error rates is encouraging. It suggests that town changes over time may contribute more to error rates than the above potential sources of error.

Discussion

Photo Interpretation

The higher spatial resolution of the 2004 imagery (0.5 m) did not provide a clear advantage over the previous imagery obtained at 1 m resolution. In addition, the enhanced spectral quality of the 3-band, natural color imagery used in this study did not provide an apparent advantage over the panchromatic (black and white, single-band) images used predominately in previous studies (Johnson et al. 2003, Johnson et al. 2004b). The interpreter agreed with our previous conclusion for black-tailed prairie dog disturbance that the natural color imagery is less interpretable than the panchromatic (Johnson et al. 2003).

It took more time to locate colonies on the 3-band images, due to the poorly processed quality of the imagery from the USGS site and the increased complexity of 3-band images. Incorrect mosaicking of the downloaded images resulted in the need for multiple contrast enhancements per image. If we could acquire the individual images, the contrast issue would be resolved. However, other enhancements require individual adjustments to the dynamic range of individual bands within an image, and adjusting a 3-band image is more time consuming and difficult than adjusting a single-band image. Because we have found that natural color does not appear to improve, and may even confound, interpretation, the additional time required is clearly not justified.

We cannot conclude that the higher spatial resolution (0.5 m) or enhanced spectral quality of the 3-band, natural color imagery used in this study appreciably improved our ability to detect Gunnison's prairie dog disturbance. If the imagery becomes available for a wider area, it would be adequate for re-survey, but we would expect accuracy to be similar to that for our previous efforts for Gunnison's prairie dogs (Johnson et al. 2004b).

Field Checking

How useful is this survey method for Gunnison's prairie dogs? Field checks show disappearance of as many as 27% of towns in two years. A look at longer intervals suggests it may not be unreasonable to assume an annual loss rate of 10-15%. Seven- and eight-year intervals between image creation and field checking revealed only 33% and 39% towns remaining in the 2004 and 2005 field checks (Figure 12).

Starting with 49 towns and assuming a 12% loss rate per year yields totals of 35.7% and 31.4% of the starting total, after seven and eight years, respectively. Considering the potential sources of error, these totals are surprisingly close to the actual totals. This "loss" rate does not take into account gains from new town establishment or expansion of existing towns, but it suggests that, for this data set, an increase in town number or area of about 12% per year could balance losses.

Based on the available data, we cannot create a rigorous model to correct for errors in remote sensing survey results. Additional field monitoring would provide a more accurate estimate of annual town losses and gains. Combined with annual imagery, this information would allow the creation of a model that might be able to distinguish town losses from method weaknesses and therefore be useful to estimate actual acreage from imagery. More field data would also allow use of new town acreage in a predictive model. In addition to the lack of accurate parameters for model construction, we still do not know how long disturbance persists after a Gunnison's town has been extirpated; i.e., it is not possible to distinguish active from recently active towns on digital orthophotos. More ground data could shed light on this question.

In conclusion, this study does not indicate that the new, 0.5 m color imagery is the answer to the challenges of large-scale Gunnison's prairie dog inventory. Several sources of error exist within and outside of the imagery. However, annual field monitoring data from a subset of towns and annual imagery should greatly improve accuracy and allow creation of predictive models. Otherwise, this method of survey for Gunnison's prairie dogs will continue to be imprecise at best. We recommend that future remote sensing surveys for Gunnison's prairie dogs be based on new imagery and be conducted in combination with ground truth data.

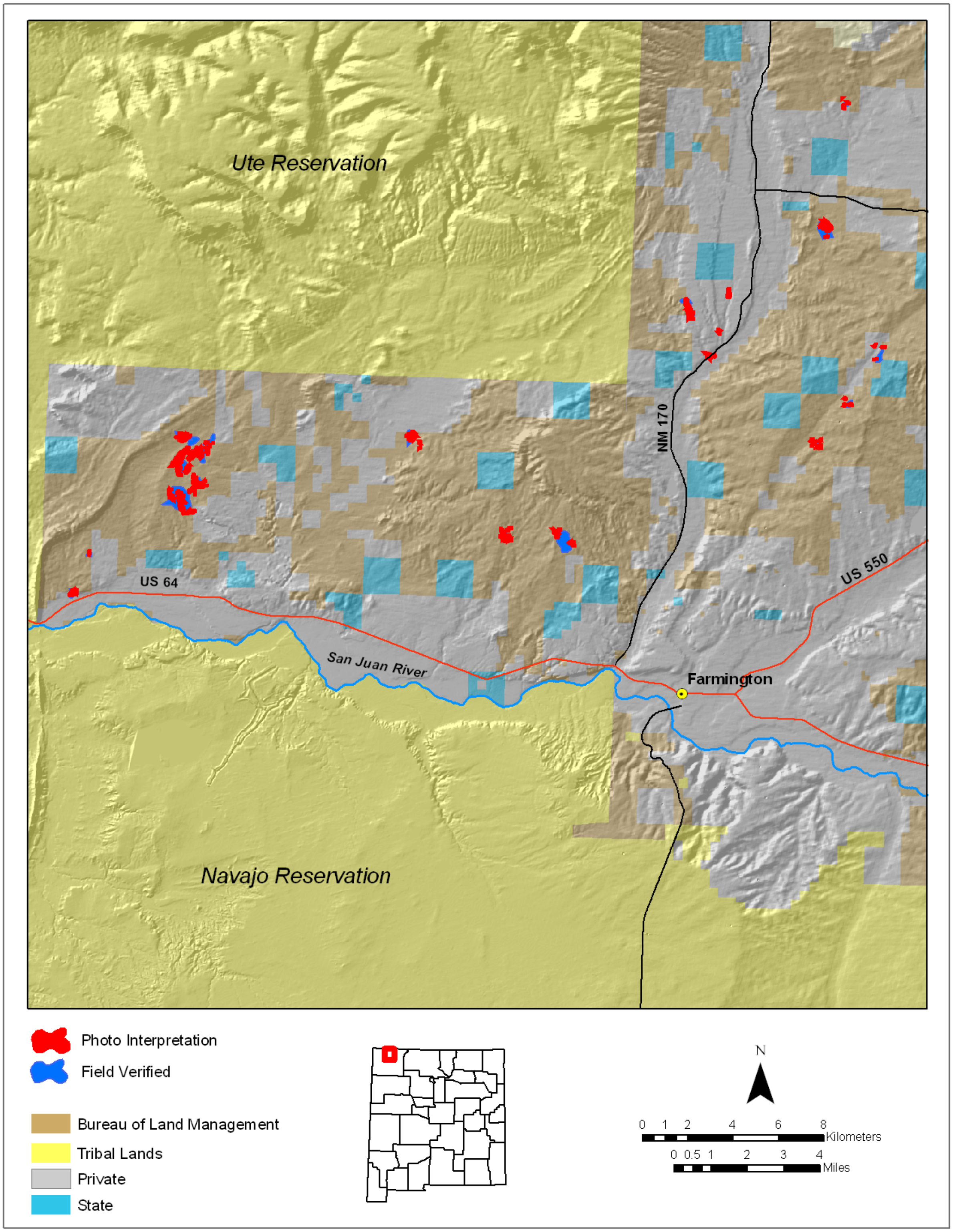

Figure 1. Photo interpreted (1997 imagery) and field verified (2003) polygons in San Juan County, NM for Gunnison's prairie dog.

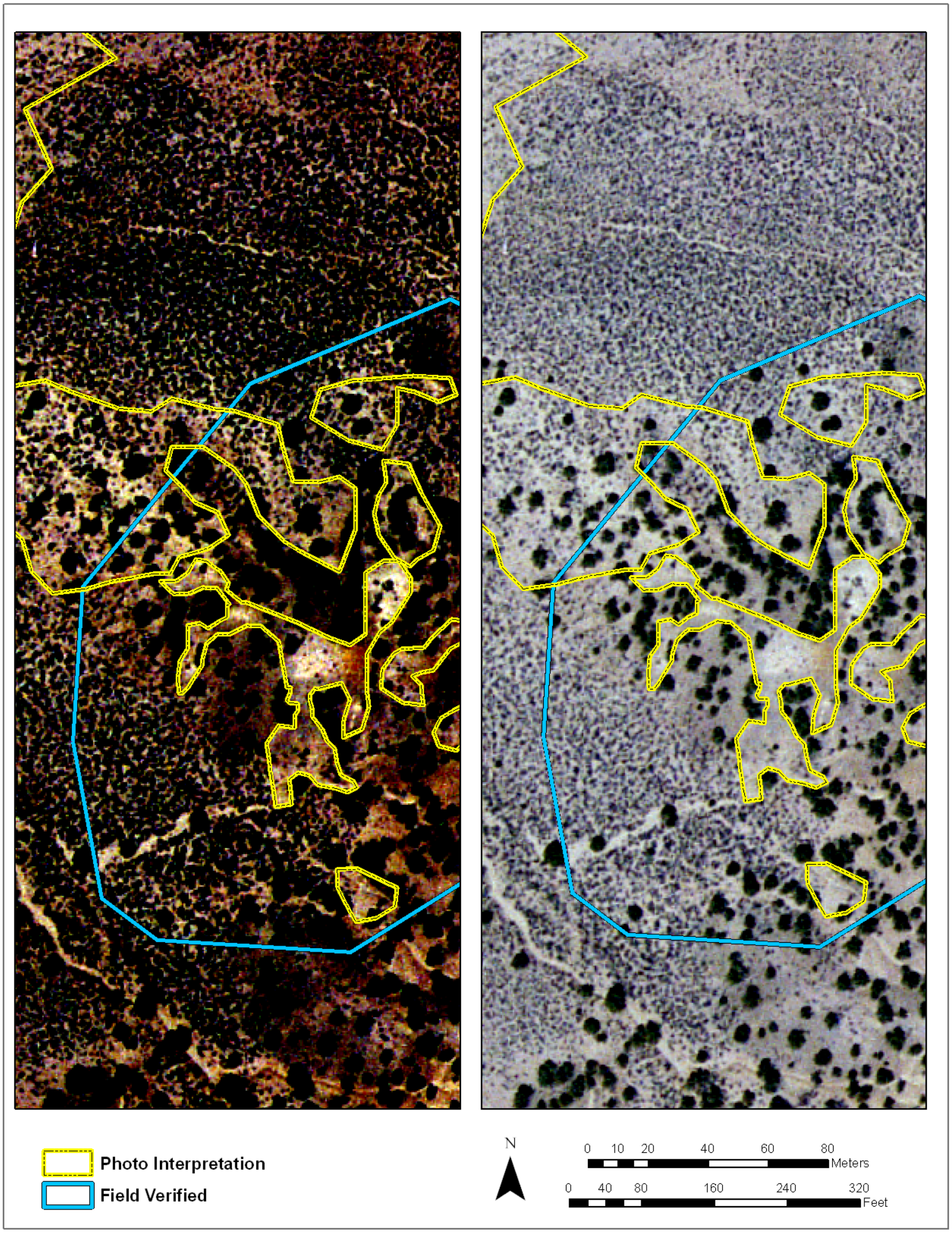

Figure 2. Gunnison's prairie dog colonies associated with woodlands. Contrast stretches (shown on left) enhance prairie dog disturbance.

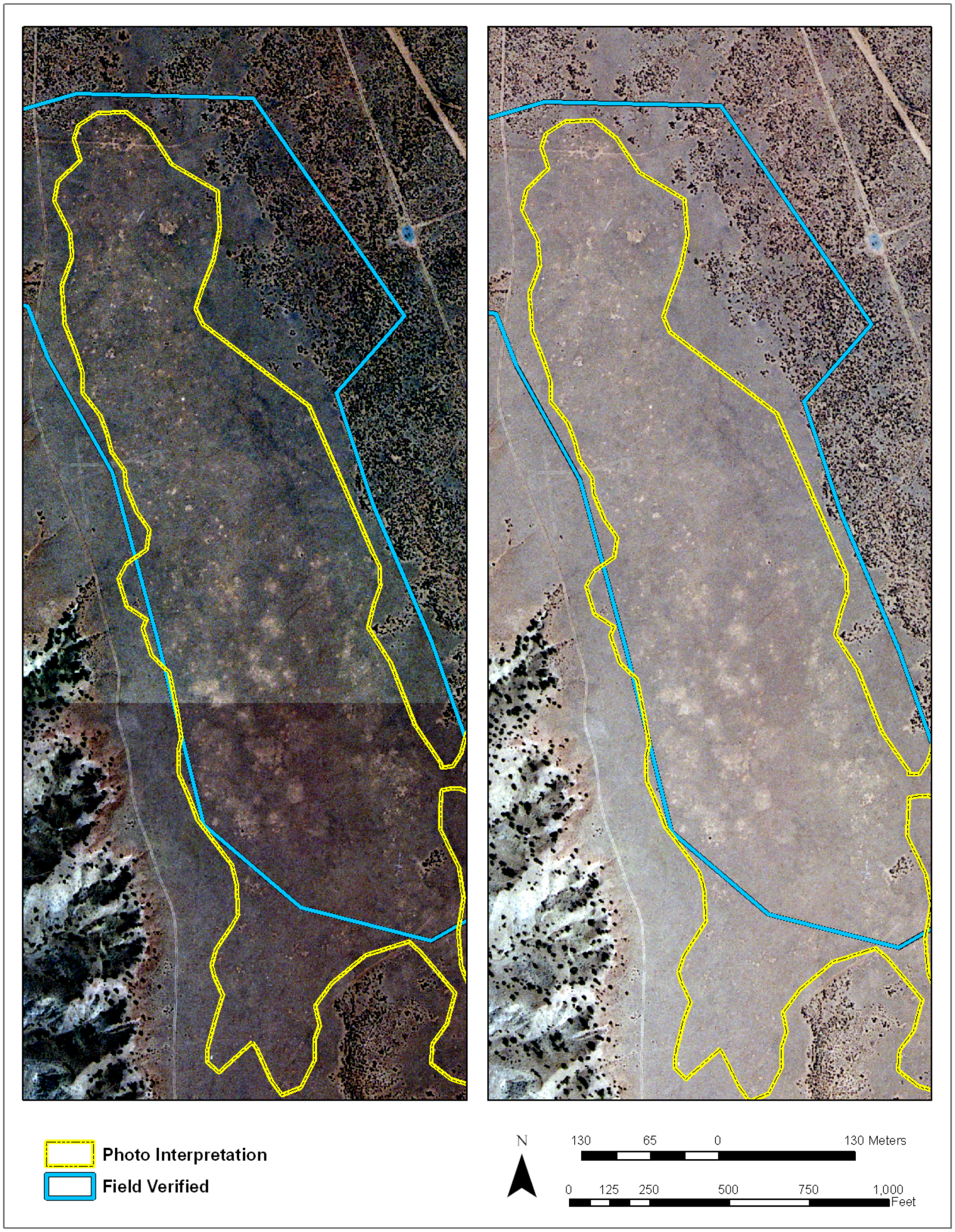

Figure 3. Gunnison's prairie dog colonies in grasslands. Contrast stretches (on left) enhance contrast between disturbed and undisturbed areas, but haloing and dots seen in images of black-tailed disturbance are not evident with Gunnison's.

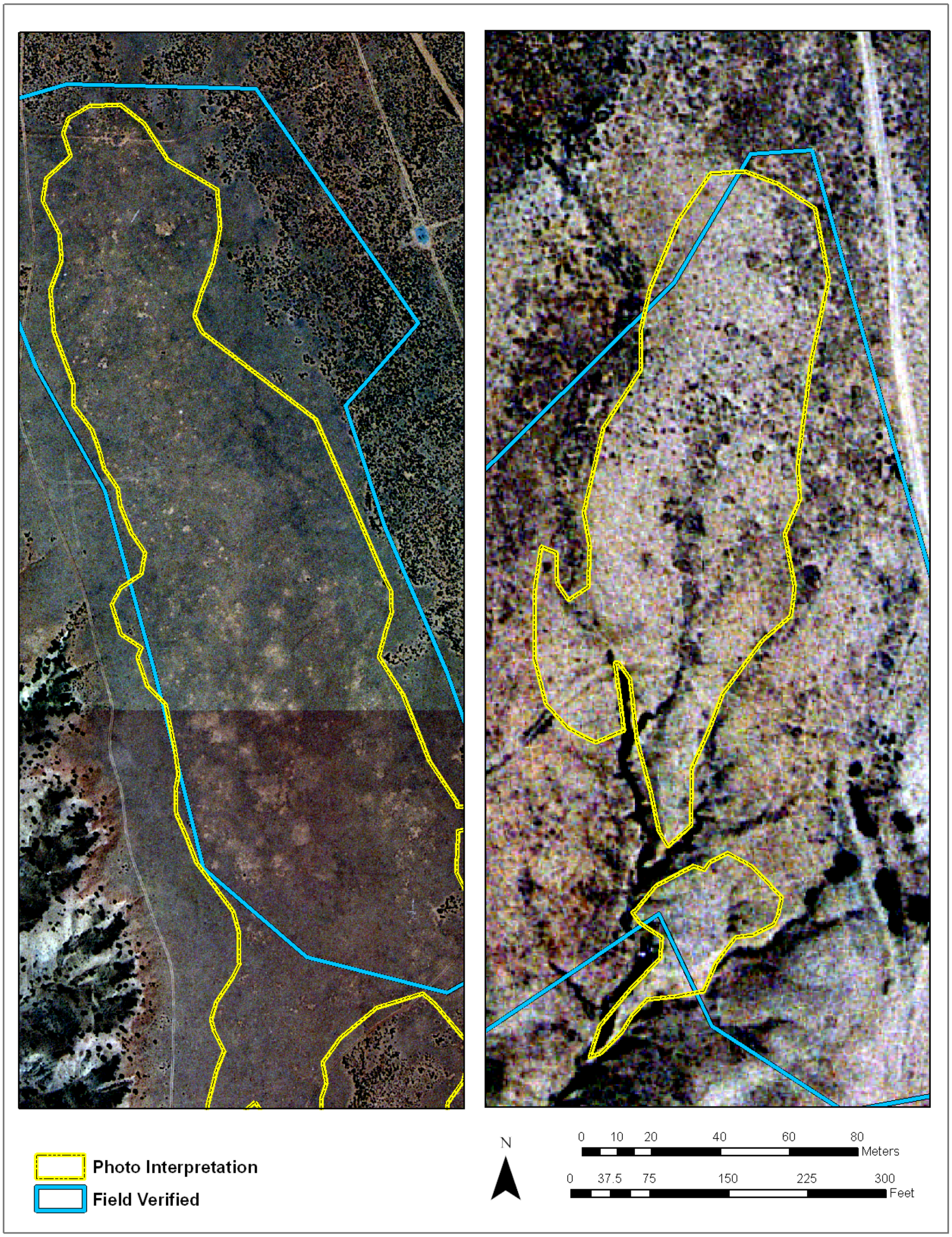

Figure 4. Comparison of photo quality. Left photo is of good quality, while graininess of right photo obscures prairie dog disturbance.

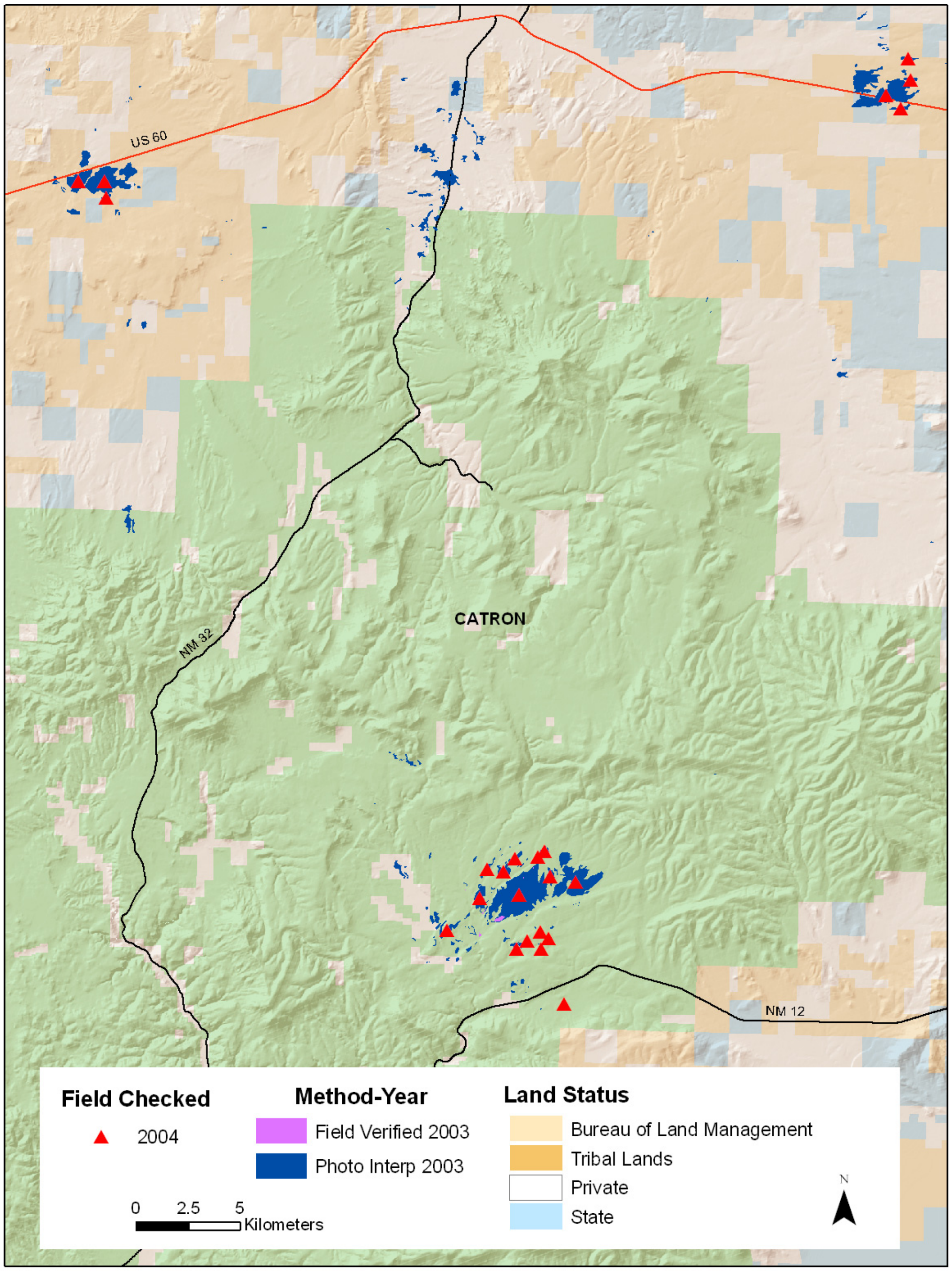

Figure 5. Field checked Gunnison's towns and sources of polygons, Catron County, 2004.

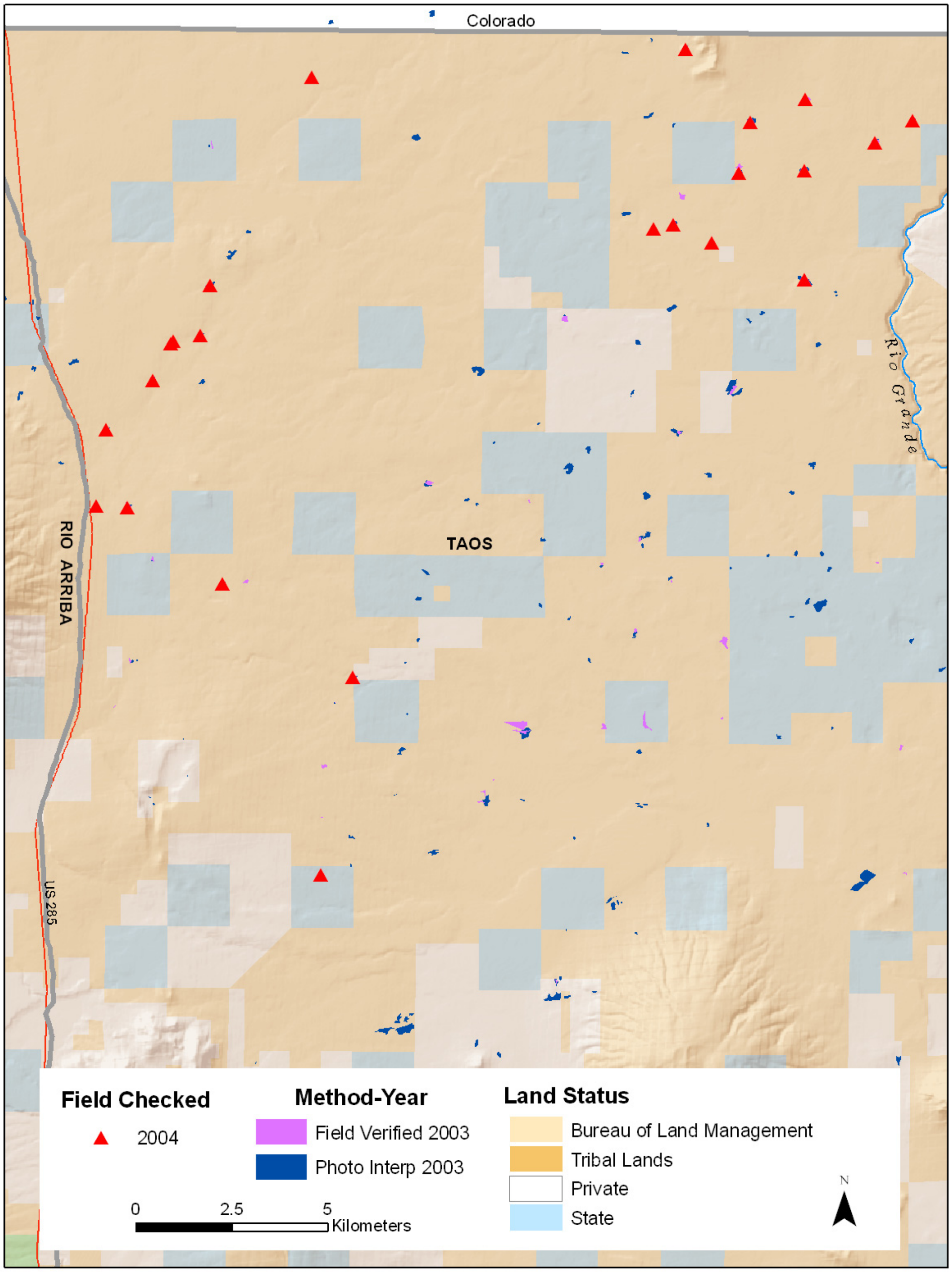

Figure 6. Field checked Gunnison's towns and sources of polygons, Taos County, 2004.

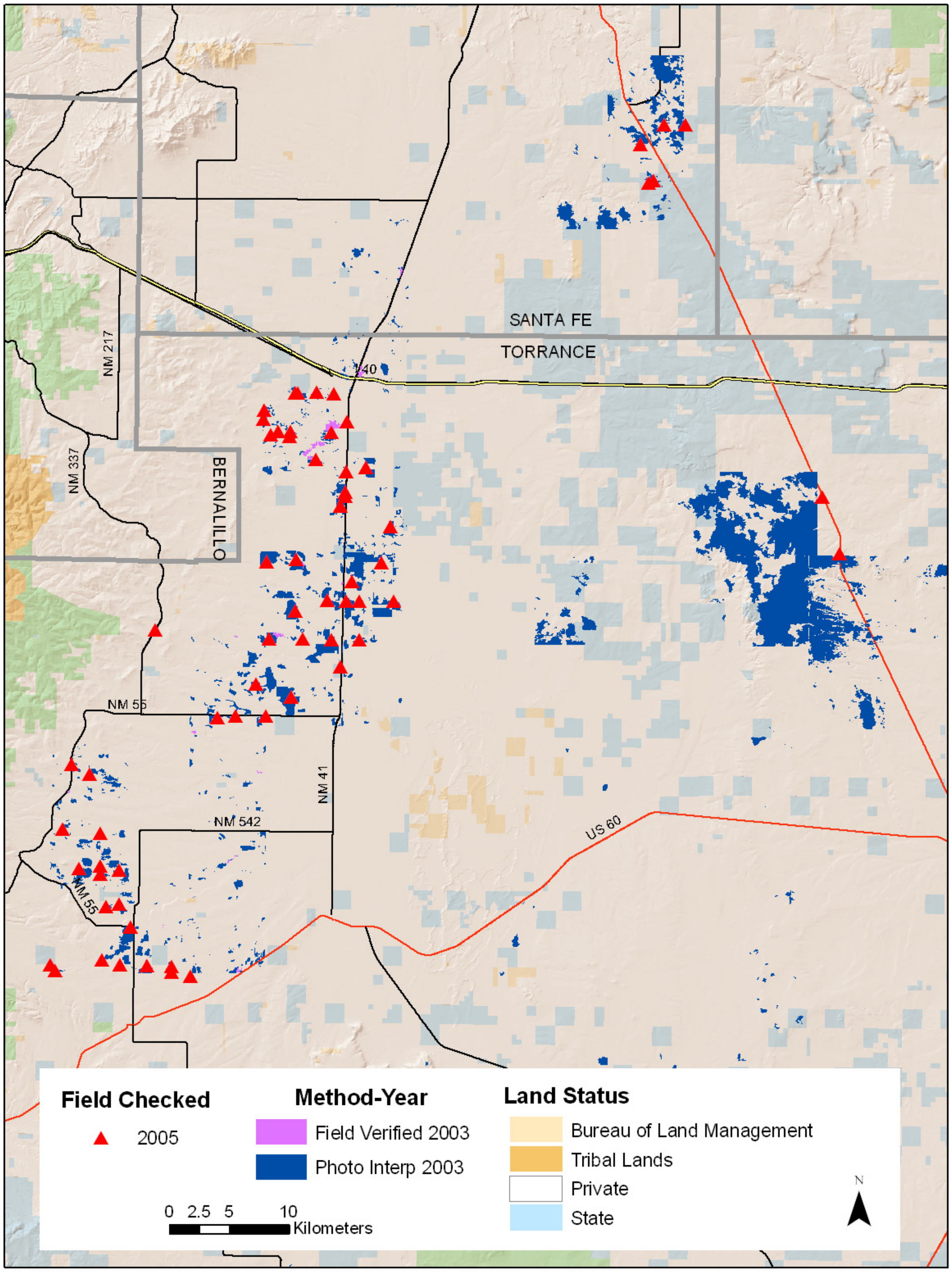

Figure 7. Field checked Gunnison's towns and sources of polygons, Torrance County, 2005.

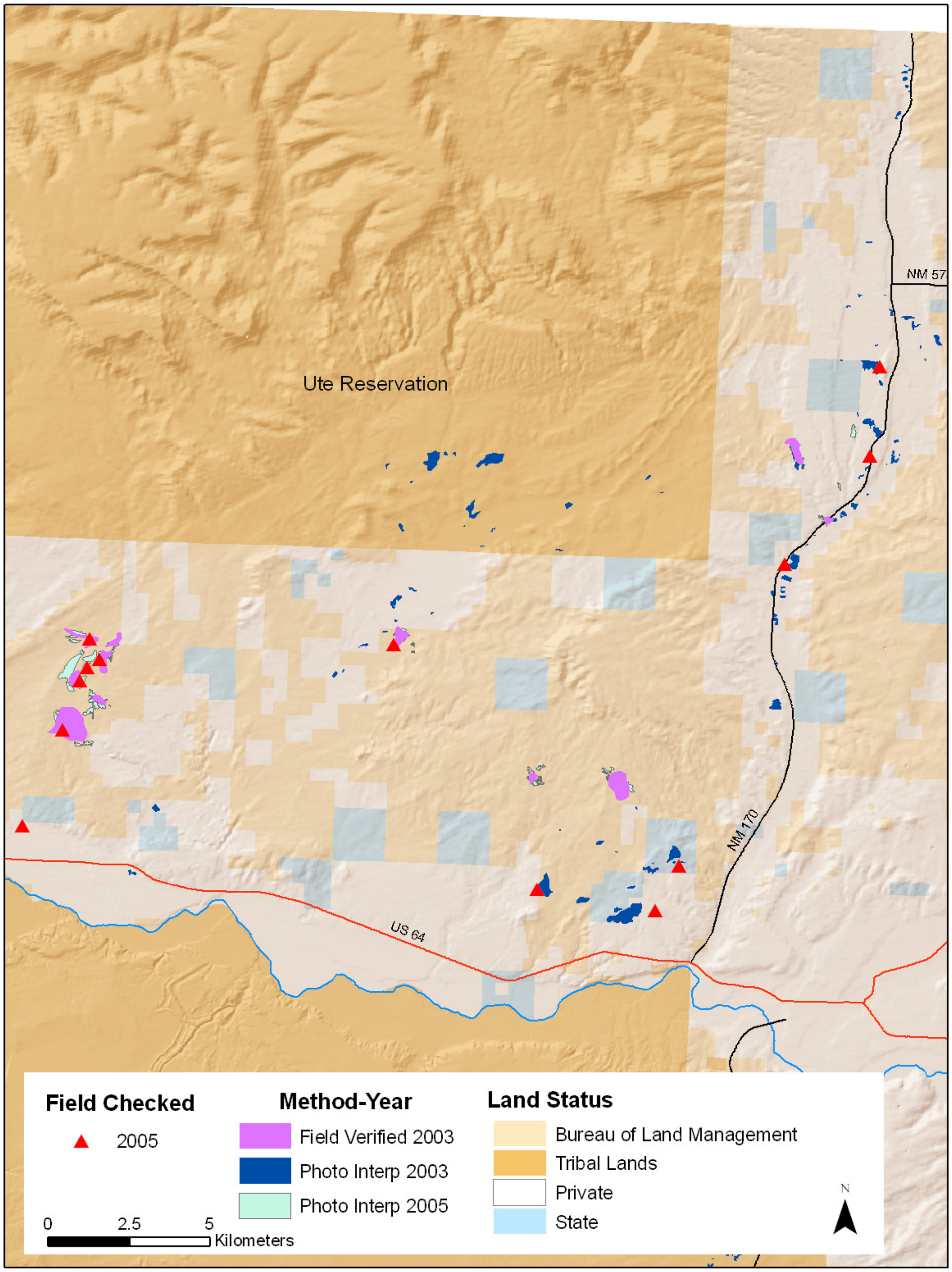

Figure 8. Field checked Gunnison's towns and sources of polygons, San Juan County, 2005.

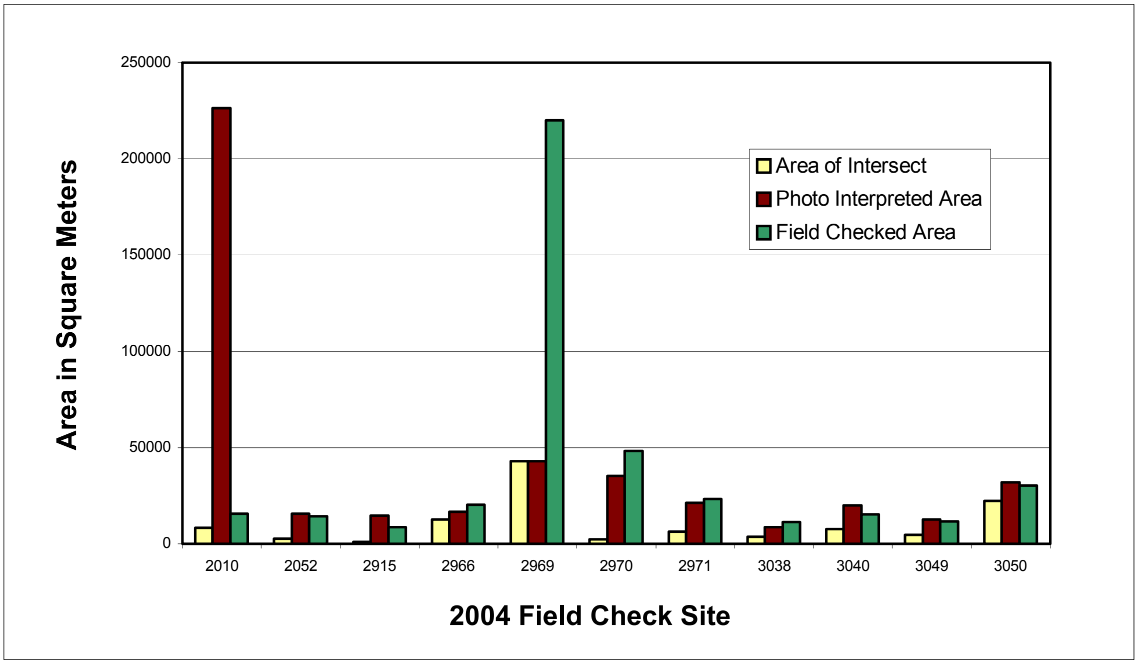

Figure 9. Area comparison of towns from 1997 imagery with 2004 field checks. Numbers are town identification numbers.

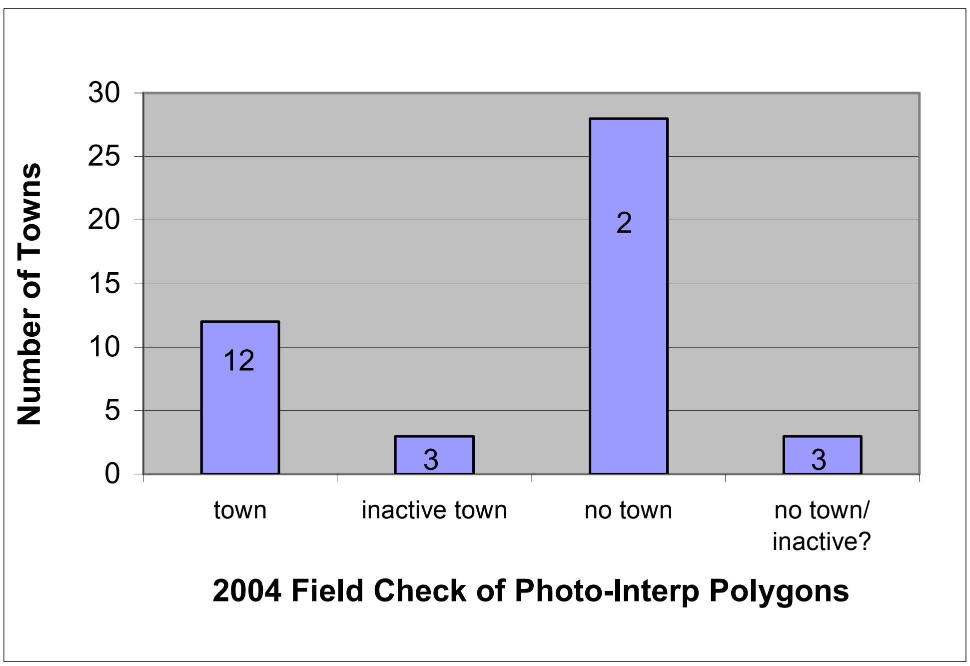

Figure 10. Results of 2004 field checks of 1997 imagery photo-interpreted in 2003.

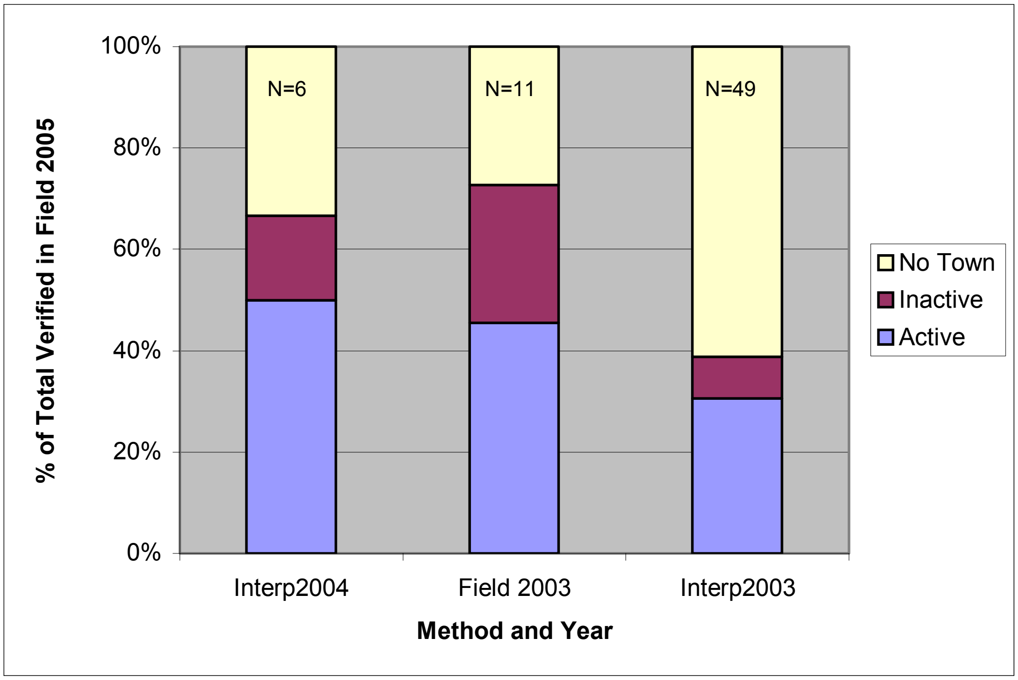

Figure 11. Results of 2005 field checks of towns from new 2004 imagery, 2003 field data, and 2003 interpretation of 1997 imagery.

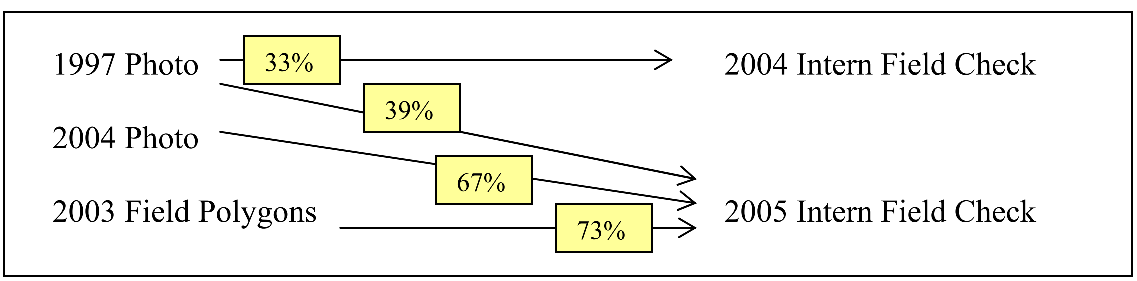

Figure 12. Comparisons of different survey methods/years. Percentages in boxes indicate percent of actual towns, as indicated by field checking in 2004 and 2005.

Acknowledgments

We thank NM Department of Game and Fish student intern, Ryland Hutchins, for providing field check data in 2004 and for field checking in 2005 as a NHNM volunteer. Information on known Gunnison's prairie dog towns was provided by Mike Bogan, Museum of Southwestern Biology; Bureau of Land Management, Albuquerque and Taos Field Offices; Ana Davidson, UNM Biology Department; Eagle Environmental, Inc.; Hawks Aloft, Inc.; Jicarilla Apache Reservation; Kirtland Air Force Base; Marron and Associates; Navajo Natural Heritage Program; Paul Neville, Earth Data Analysis Center; NPS Bandelier National Monument; Public Service Company of New Mexico; Lawry Sager; San Juan College, Farmington; Taschek Environmental; Turner Endangered Species Fund, Vermejo Park Ranch; USFS Jemez Ranger District; USFS Jicarilla Ranger District; USFS Mt. Taylor Ranger District; USFS Quemado Ranger District.

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