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ESTIMATING BLACK-TAILED PRAIRIE DOG (*CYNOMYS LUDOVICIANUS*) DISTRIBUTION IN TEXAS

Jason R. Singhurst, John H. Young, Greg Kerouac and Heather A. Whitlaw*
Texas Parks and Wildlife Department, Wildlife Diversity Program
4200 Smith School Road Austin, Texas 78744 and
*U.S. Fish and Wildlife Service, P.O. Box 42125
Texas Tech University, Lubbock, Texas 79409

Abstract–In response to petitions to list the black-tailed prairie dog (BTPD, *Cynomys ludovicianus* Ord) as threatened under the Endangered Species Act, an inventory of the BTPD in Texas was undertaken. The historical and current distributions of the species were estimated and compared, current complexes were identified, vegetative systems colonized by the species were characterized, and the effect of improved aerial imagery on current population estimates was estimated. Historical records of BTPDs were found in 114 Texas counties. Remote sensing and roadside ground-truthing were used to find current colonies in 73 counties. An estimate of 3,180 colonies of BTPDs in Texas occupying 59,300 ha was developed. The mean area occupied by a colony was 21.7 ha, and the mean rate of occupancy of a colony was 77.8%. Two to six complexes of colonies >2,023 ha were found, and 40–80% of the BTPDs in Texas were found living in complexes >404 ha. Current BTPD populations were concentrated on the Great Plains Shortgrass Prairies ecosystem, but colonies were also found on four other ecosystems and three anthropogenic systems. The population of BTPDs had receded from the southern and eastern boundaries of the historical range in Texas.

In 1998, under provisions of the Endangered Species Act, the National Wildlife Federation, the Biodiversity Legal Foundation, the Predator Project, and Jon C. Sharps petitioned the U. S. Fish and Wildlife Service (USFWS) to list the black-tailed prairie dog (*Cynomys ludovicianus*; BTPD) as threatened throughout its range (USFWS 1999, Van Putten & Miller 1999). Citing the effects of plague, habitat loss, poisoning, recreational shooting, and a lack of regulations to conserve the species, the USFWS classified the BTPD as a candidate for listing (Gober 2000). While the USFWS evaluated the petition, stakeholders from nine of 11 states within the historical range of the BTPD signed an interstate agreement establishing guidelines for the management and conservation of the species (Miller & Cully 2001). They recommended performing an inventory of the current BTPD population in each participating state (Van Pelt 1999, Luce 2003).

Methods used in the Texas inventory were developed from efforts to study BTPDs by remote sensing. Beginning more than 30 years ago, biologists used aerial photographs produced by government agencies to locate BTPDs on the landscape (Ernst 2001). Later, they used small aircraft to monitor BTPD towns and to produce new aerial imagery (Sidle 1999). Landsat satellite imagery allowed researchers to detect BTPD grazing patterns, or halos, on the landscape (Johnson et al. 2000). Digital Orthophoto Quadrangles allowed them to detect BTPD mounds and burrows, or pucks. A puck (circular) and halo (grazing) signature was ideal for remote sensing (Johnson et al. 2003).

Between 1999 and 2004, a GIS application was developed to conduct an inventory of BTPD in Texas. The objectives were to: 1) estimate the historical (pre-2000) distribution of the species in Texas, 2) estimate the current (2002-04) distribution using serial estimations and error analysis in Texas, 3) compare the historical and current distributions, and 4) identify metapopulations living in complexes >2,023 ha and complexes >404 ha.

STUDY AREA

The study area was the High Plains and Rolling Plains Ecoregions and portions of the Edwards Plateau, Trans-Pecos, Blackland Prairies, and Cross Timbers and Prairies Ecoregions in Texas (Gould 1975, Lyndon B. Johnson School of Public Affairs 1978).

METHODS

Defining prairie dog colonies.–The spatial definition of a colony was developed from diverse definitions and concepts. Two definitions of a colony were encountered. One was descriptive, defining a colony in terms of the presence of mounds, burrows, and modified vegetation (King 1955). The other was quantitative, defining a colony as a grouping of animals having a minimum density of 25 BTPD/ha (Luce 2003). A ward within a colony was used to designate disjunct subpopulations in a colony existing close enough to one another to communicate vocally (King 1955, Hoogland 1995), and an element occurrence used to describe disjunct populations of BTPDs occurring within 1,000 m of one another (NatureServe 2006).

Estimating historical distribution.–A historical record was defined as a record of a BTPD population that was recorded before 2000, when this inventory began. Mammalogy texts, journal articles, published and unpublished inventories, personal communications, and theses were used to accumulate historical records from 114 Texas counties (Bailey 1905; Hall & Kelson 1959; Cottam & Caroline 1965; U. S. Department of Agriculture Soil Conservation Service 1973; Pizzimenti 1975; Cheatheam 1977; Schmidly 1977; Flores 1985; Normand 1993; Davis & Schmidly 1994; Ernst 2001; Schmidly 2002; J. Wood pers. comm.). An exhaustive search of specimen collections, historical writings, and government records of BTPD poisoning programs was also considered, but those sources proved beyond the scope of the inventory.

Historical records of BTPDs in Tarrant, Smith, Fayette, and Bexar Counties were classified as relocations (Cottam & Caroline 1965: Fig. 3) and were not used in this study. Existing range maps for BTPDs in Texas were examined (Bailey 1905; Hall & Kelson 1959; Cheatheam 1977; Schmidly 1977; Davis & Schmidly 1994; Schmidly 2002). Maps delineating the North American range of the species were not utilized because of imprecision. Historical records in Bell and Lamar counties were treated as outliers rather than as part of the contiguous range (Fig. 3).

Estimating current distribution.–Current distribution was defined as the BTPD population in Texas between 2002 and 2004,

Fig. 1. The open polygons represent the prairie dog edit layer ground-truthed in the field using public roads (white lines).

when the data was ground-truthed (directly verified remotely sensed information). DOQs from 93 counties were remotely sensed to build that distribution. The DOQs came from aerial photography taken between 1994 and 1997. Leica Systems' ERDAS Imagine 8.x was used to search DOQs for BTPD puck and halo signatures and to digitize polygons around the signatures at a scale of 1:5000 with the county as the organizational unit.

After digitization, the set of polygons was saved as the raw layer for the county. Before ground-truthing, the raw layer atop of the DOQs was re-examined, and polygons representing the lowest probability signature were removed. The result was designated the edit layer (Fig. 1).

Using ESRI's ArcGIS 8.x, field maps were created for ground-truthing. The maps showed the edit layer (Fig. 1) and the roads atop a DOQ. Most ground-truthing was performed from roadsides, collecting data at sites with BTPDs and at sites with abandoned mounds. The ground-truth data was improved by

Fig. 2. The NA (not accessed) prairie dog colony polygon on the left is represented with stipple. The prairie dog colony polygon on the right with the diagonal hatch polygon represents the truthed layer with expansion to the northwest. The open polygons represent inactive areas within the truth layer in the northeast corner.

roadside searches between remotely sensed sites and via access to sites granted by landowners. Local expertise from biologists and residents was also considered. A Global Positioning System (GPS) point was taken at each site using either a Trimble or a Garmin GPS unit, and the date, presence or absence of BTPDs, and vegetation associated (visual dominance) with the site was recorded. The extent of edit layer (Fig. 1) polygons on the field map was compared to the extent of occupied areas on the landscape, and boundaries on the field maps were adjusted to match the actual colony on the landscape.

The truth layer (Fig. 2) was created by incorporating boundary adjustments made on field maps as a result of ground-truthing. County layers were merged into statewide edit and truth layers, and overlapping polygons along county boundaries were reconciled. The edit layer (Fig. 1) atop the DOQs was reviewed a final time, and polygons representing classes of signature variants that had not yielded BTPDs were removed.

The edit layer was split into two layers. The first, the calculation layer, contained edit layer polygons accessed during ground-truthing. Polygons in the calculation layer represented inactive sites with no field evidence of BTPDs, inactive sites with abandoned mounds, and active sites without boundary adjustments noted on the field maps. The second layer, the NA (not accessed) layer (Fig. 2), contained edit layer polygons not accessed during ground-truthing.

The current population of BTPDs in Texas was estimate using the following formula:

$$\text{best estimate} = \text{truth} + [(\text{truth} / \text{calculation}) \times (\text{NA})],$$

where truth, calculation, and NA represented the total area of polygons in the corresponding layers. The minimum aerial estimate was defined as the area of the truth layer, and the maximum aerial estimate was the sum of the areas of the truth and NA layers.

Polygons within 200 m of one another were defined as belonging to the same colony, using the formula above, where truth, calculation, and NA represented the total numbers of colonies in the corresponding layers. The minimum estimate was the number of colonies in the truth layer, and the maximum estimate was the sum of the number of colonies in the truth and NA layers.

The occupied areas of ground-truthed polygons were removed from corresponding edit-layer polygons to create a layer representing unoccupied areas of ground-truthed colonies adjacent to occupied areas. If a colony on the landscape had shifted outside of the edit-layer polygon, the polygon was re-examined atop the corresponding DOQ to determine whether the additional area should have been included in the edit layer (i.e. interpretation error). The edit layer was adjusted as needed, using the improving knowledge of BTPD signature variants as a guide. The resulting layer was used to estimate the mean rate of occupancy of colonies. The best and maximum aerial estimates were adjusted to reflect occupancy.

Colonies in the northern High Plains suffered an outbreak of sylvatic plague in 2003 and had lost an estimated 1,050 ha of BTPDs by May 2004. This loss was accounted for in the estimates, but no assumptions were made about losses beyond May.

Comparing historical and current distributions.–A layer of points was created from historical BTPD records, digitizing versions of historical range maps of the BTPD in Texas (Bailey 1905; Cottam & Caroline 1965; Cheatheam 1977) and merging the versions into one polygon. This historical range polygon encompassed all but two historical records, which were classified as outliers. Additionally, a description of the historical Rolling Plains megatown between Clarendon and San Angelo (Merriam 1902) was translated into a digital approximation of the town perimeter. This description was compared to the current population within this perimeter estimated in this study.

The current truth layer was converted into a layer of points representing the geographic centers, or centroids, of current BTPD colonies. This layer of points was translated into a polygon representing the current range of the BTPD in Texas, and the current point and polygon layers were compared to the historical layers.

Evaluating BTPD complexes.–Following Luce (2003), a complex of BTPDs was defined to be a group of disjunct colonies with perimeters ≤7 km apart. The truth layer was buffered by 3.5 km to create a minimum version of BTPD complexes, and the area of occupied colonies contained was calculated within each complex. The truth and NA layers were jointly buffered by 3.5 km to create a maximum version of BTPD complexes, and the area of occupied colonies contained was calculated within each complex. Following recommendations of the multi-state BTPD management plan (Luce 2003), the number of BTPD complexes was estimated >2,023 ha and the percentage of the current population occupying complexes >404 ha.

Characterizing vegetation.–Definitions of vegetative alliances and associations (NatureServe 2006) were defined to characterize the ecosystems colonized by the BTPD in Texas. Ecosystems included the Great Plains Shortgrass Prairies Ecosystem, the Great Plains Playa Lakes Ecosystem, the Southern Great Plains Mesquite Woodlands and Shrublands Ecosystem, the Southern Great Plains Deep Sand Shrublands Ecosystem, and the Great Plains Mixed Grass Prairies Ecosystem (NatureServe 2006). The following three anthropogenic systems were included: croplands, old fields, and conservation reserve program fields.

RESULTS

Estimating historical distribution.–Historical records of BTPDs were found in 114 Texas counties, four of which were classified as relocations (Fig. 3). Records were widely distributed throughout the High Plains, Rolling Plains, Edwards Plateau, and Trans-Pecos Ecoregions. Historical records also reached into the western Cross Timbers and Prairies Ecoregion. One outlying record was found in the northern Blackland Prairies Ecoregion.

Estimating current distribution.–Between 2000 and 2004, occupied BTPD colonies in 73 Texas counties were ground-truthed, and reports of occupied colonies in Reeves, Irion, and Tarrant Counties were received (Fig. 4). The edit layer was created from 6,408 digitized polygons around remotely sensed BTPD signatures; 56.7% (n = 3,632 of 6,408) of the polygons were ground-truthed to create the truth layer.

Polygons within 200 m of one another were defined as

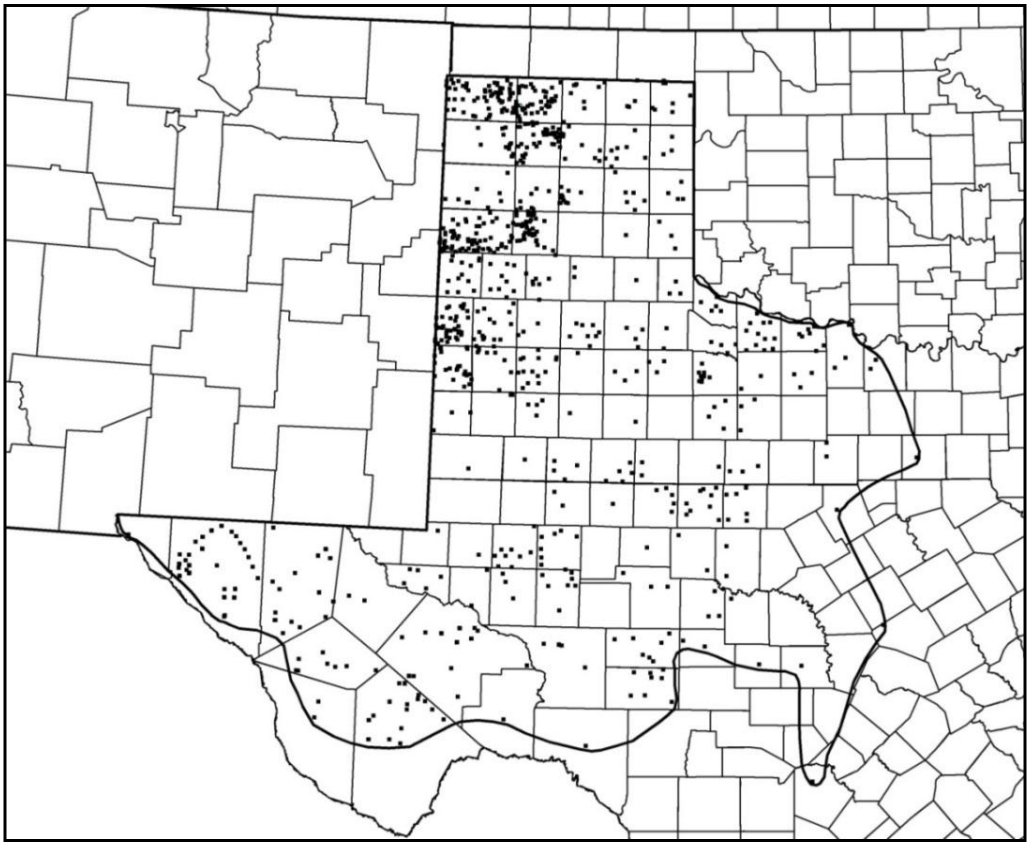

Fig. 3. Estimated historical (pre-2000) distribution of the black-tailed prairie dog in Texas.

belonging to the same colony, and 58.5% (n = 2,695 of 4,608) of the remotely sensed colony signatures were ground-truthed, finding 62.2% (n = 1,676 of 2,695) to represent occupied colonies. Between 1,676 - 3,590 colonies in Texas were found, with an estimate of 2,870 colonies. Of the total area of signatures remotely sensed, 62.7% (50,300 ha) were ground-truthed, with 72.4% (36,400 ha) to be occupied. Between 36,400–66,300 ha of occupied areas in colonies were found, with an estimate of 58,100 ha (Table 1, Raw Data).

Occupied portions of ground-truthed colonies varied from 0.03-1,420 ha with a mean occupied area of 21.7 ha. Seventeen colonies (1.34%, n = 1,676) that were >200 ha were ground-truthed, 43 colonies (2.68%) from 100-200 ha, 98 colonies (6.57%) from 50-100 ha, 550 colonies (35.2%) from 10-50 ha, 859 colonies (48.6%) from 1-10 ha, and 109 colonies (5.63%) <1 ha.

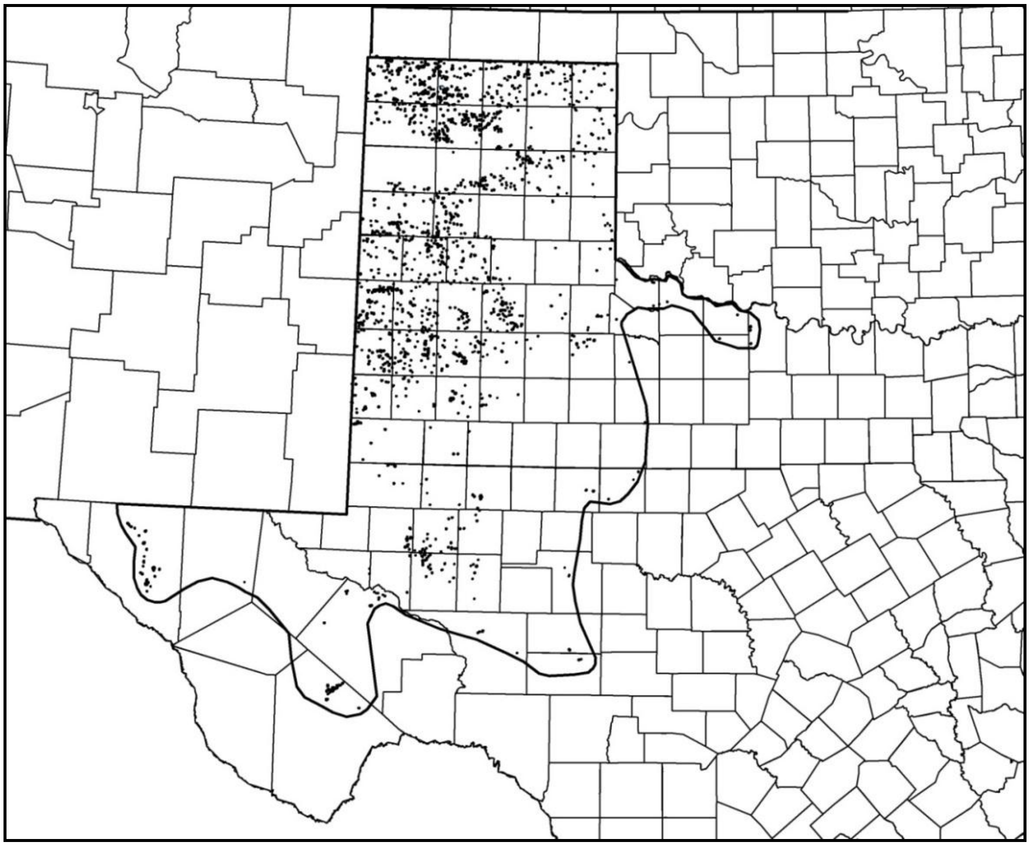

Fig. 4. Estimated current (2002-04) distribution of the black-tailed prairie dog in Texas.

The mean rate of occupancy of ground-truthed colonies was 77.8%, so the maximum and best aerial estimates were adjusted to assume 22.2% of NA layer colonies were unoccupied. With the adjustment, the maximum aerial estimate became 59,700 ha and the best aerial estimate became 53,300 ha (Table 1, Adjusted for Occupancy).

Comparing historical and current distributions.–Of the historical records in the High Plains Ecoregion, 59.7% were found, whereas 84.4% of the current colonies were in the High Plains. For both historical and current distributions, colonies were found to be more densely distributed in the northern and central High Plains than in the southern High Plains (Fig. 3 and Fig. 4).

Throughout the Rolling Plains Ecoregion, 18.3% of the historical records were found, whereas 7.66% of current colonies

Table 1. Summary of black-tailed prairie dog population estimates. Data adjusted for occupancy assume inaccessible colonies were 77.8% occupied. Data adjusted for imagery assume 10.8% more colonies and 11.3% more area.

Prairie dog population estimates		
	Colonies	Area (ha)
Raw data		
min.	1676	36,400
best	2870	58,100
max.	3590	66,300
Adjusted for occupancy		
min.	1676	36,400
best	2870	53,300
max.	3590	59,700
Adjusted for imagery		
min.	1860	40,500
best	3180	59,300
max.	3980	66,400

were found scattered throughout the Rolling Plains. Most current colonies were found in the northern quarter of the ecoregion. Both historical records and current colonies were virtually absent from the Canadian Breaks (Fig. 3 and Fig. 4). Within the perimeter of the historical Rolling Plains megatown between Clarendon and San Angelo, 183 widely scattered colonies totaling 1,840 ha were located, whereas early researchers reported the megatown as covering nearly 6.5 million ha between the two Texas towns (Merriam 1902; Bailey 1905).

Throughout the northern half of the Edwards Plateau Ecoregion, 6.82% of historical records were found. Historical records were much more sparse on the eastern plateau. Scattered throughout the northwestern Edwards Plateau 3.43% of current colonies were found, but they were concentrated near where the plateau meets the High Plains. Both historical records and current colonies were absent from the Balcones Canyonlands (Fig. 3 and Fig. 4).

Throughout the Trans-Pecos Ecoregion, 13.5% of historical records were found and were sparse in the eastern Trans-Pecos. Only 3.22% of current colonies were found in scattered clusters in the ecoregion (see Discussion: Estimating current distribution). Both historical records and current colonies were absent from Big Bend National Park (Fig. 3 and Fig. 4).

Scattered throughout the northwestern quarter of the Cross Timbers and Prairies Ecoregion, 1.69% of historical records were found. Historical records were most dense in the area between the Red River and the Rolling Plains. One historical outlier was found near the border of Bell and Coryell Counties (Normand 1993). In the Cross Timbers and Prairies, 1.29% of current colonies were concentrated near the northernmost border with the Rolling Plains. A current report of a colony was received in Tarrant County; the colony might be the descendant of relocation (Fig. 3 and Fig. 4).

One historical outlier in the Blackland Prairies Ecoregion (Flores 1985) was found, and no reports of current colonies were received in the ecoregion (Fig. 3 and Fig. 4). For this reason, no remote sensing work was performed in the region.

Based on these results, the range of the BTPD in Texas had receded from the southern and eastern historical boundaries and from the western historical boundary in the Trans-Pecos (Fig. 3 and Fig. 4). The distribution of the BTPD had declined more in the Rolling Plains Ecoregion than elsewhere, and the distribution was more stable in the High Plains than in other regions.

Evaluating BTPD complexes.–Depending on the data layers used, 2–6 BTPD complexes >2,023 ha in Texas were found. Buffering only the truth layer, only two complexes >2,023 ha were found, occurring in the northern High Plains. The largest of these contained >10,000 ha of occupied colonies. When the truth and NA layers were jointly buffered, six complexes >2,023 ha were found, occurring on the High Plains ($n = 4$), on the western edge of the Edwards Plateau (*n* = 1), and in the Trans-Pecos (*n* = 1). The largest complex from the jointly buffered layers contained >20,000 ha of occupied colonies. Of the BTPDs in Texas, 40-80% were living in complexes >404 ha. The 2004 NAIP imagery showed 10.8% more colony signatures and 11.3% more area of colony signatures than on the 1994-97 DOQs. Adjusting colony estimates to reflect improvement in imagery, between 1,860–3,980 colonies in Texas were found with a best estimate of 3,180 colonies. After adjustments, 40,500–66,400 ha of BTPD colonies were found with a best estimate of 59,300 ha (Table 1).

DISCUSSION

Estimating historical distribution.–BTPD advocates have used an historical baseline of 800 million animals to compare to the current population of BTPDs in Texas. Bailey (1905) calculated the number by doubling Merriam's (1902) estimation of animals in the megatown between Clarendon and San Angelo. The megatown reportedly cut a continuous, 161-km-wide swath between the two Texas towns. Merriam used a mean density of 62 BTPD/ha to estimate the number of animals in the 64,750 km^2 megatown. Merriam's mean density figure was high relative to the observations in this study of the counties encompassing the megatown. King (1955) reported mean densities >21 BTPD/ha from three years of measurements and an anecdotal density >86 BTPD/ha.

The assumption that BTPDs occupied the entire 64,750 km^2 of the megatown is probably incorrect for three reasons. First, BTPD colonies shift on the landscape when the animals exhaust food resources in an area and then move towards fresh vegetation (King 1955, Hoogland 1995). Second, though BTPDs will dig test holes in many types of soil, they normally abandon holes in rocky soils to colonize tight, clayey soils (King 1955, Buseck et al. 2005). Third, BTPDs avoid colonizing slopes >10% (Buseck et al. 2005) and prefer slopes of 2–5% with well-drained soil (Vermeire et al. 2004). Sloping drainages, rivers basins, and rocky outcrops interrupt grasslands within the perimeter of the Rolling Plains megatown, all features which are not normally suitable for BTPD colonization. Historical observers were probably not describing a continuous town but were reporting that they were rarely away from the sight and sound of BTPDs between Clarendon and San Angelo.

Even if the assumptions made to estimate an historical population of 800 million BTPDs in Texas were correct, the population might have been increasing at the time for both climatic and anthropogenic reasons. Because the assumptions and conditions integral to the historical estimate were not justifiable by the authors of this study, the historical estimate was not used as a baseline to which to compare the current Texas population.

The historical distribution in this study was conservative for three reasons. First, although the Tarrant, Smith, Fayette, and Bexar county historical records were classified as relocations, the Tarrant and Bexar county records might have been classified as natural occurrences south and east of the historical range. Second, classifying the Bell and Lamar county historical records as outliers, rather than as part of the contiguous range, confined the historical range to areas where clusters of historical records were found. The methodology in this study for accumulating BTPD records was not exhaustive, so clusters of records may exist in areas not included in the historical distribution. Third, the degree to which the BTPD occupied mixed–grass prairies remains unresolved. Mixed–grass prairies existed throughout the Cross Timbers and Prairies and Blackland Prairies ecoregions, but some researchers believe that the prairies were suitable for the BTPDs only after disturbance reduced the height of the vegetation (Vermeire et al. 2004). Droughts in the last quarter of the 19th century (Bailey 1905; Haley 1953), coupled with increased grazing pressure and predator control resulting from settlement, may have facilitated the expansion of the BTPD into formerly marginal habitats (Bailey 1905; Haley 1953; Vermeire et al.

2004). A BTPD reintroduction attempt in Callahan County may corroborate this hypothesis. Reintroduction failed twice during years of average and above average rainfall only to succeed after a drought had reduced the height of the vegetation on the site. The landowner and project manager posited reduced cover for predators as the reason for eventual success (J. Wood, U. S. Department of Agriculture, pers. comm.).

Classifying the Bell and Lamar county historical records as part of the contiguous range, classifying the Tarrant and Bexar county records as natural occurrences, and assuming that undisturbed mixed–grass prairies were more than marginal habitat for the BTPD could have placed the species in >130 Texas counties.

Estimating current distribution.–Equating colonies with polygons overstated the number of colonies, since disjunct populations of BTPDs were found separated by a road, a draw, or unoccupied mounds. An extreme example occurred where five small patches of occupied mounds were found remaining within a poisoned colony. Clearly, the five polygons did not represent five separate colonies but rather the disjunct remnants of a single colony.

In defining polygons within 200 m of one other to be part of the same colony, the average maximum distance at which we could hear a BTPD alarm call was estimated. The assumption was that disjunct populations derived colonial benefits from each other when alarm calls were audible among populations, with BTPDs hearing an alarm call at least as well as human beings. A generic 200 m buffer, however, mistakenly implied a BTPD might hear an alarm call from one mesquite opening to another as well as across open grasslands.

In the search for a definition of a BTPD colony, the historical megatown between Clarendon and San Angelo was considered. The historical perimeter of the town encompassed 183 current colonies by the definition. The colonies might be classified either as subpopulations of a fragmented historical colony or as individual current colonies. For this reason, a colony might require definition on the landscape on an individual basis. Although a mean rate of occupancy of a colony of 77.8% was found, occupancy rates >90% were observed on shortgrass prairies in the High Plains and <20% in desert habitats in the Trans-Pecos.

The current estimates in this study were conservative for two reasons. First, the entire potential historical range of the BTPD in Texas was not remotely sensed. The Trans-Pecos ecoregion contained vast tracts of land that were out of sight of roadsides, creating more uncertainty about BTPD populations there than in other ecoregions. Reported colonies and historical records were utilized more than direct remote sensing work in the Trans-Pecos more so than in other ecoregions because the arid Trans-Pecos habitat resulted in high reflectance in the DOQs. The reflectance made large areas of the Trans-Pecos look like BTPD signature variants. In this ecosystem, 60% of the historical range of the BTPD was remotely sensed, and 2,300 ha of occupied colonies were ground-truthed. The colonies might represent only a fraction of the population in the Trans-Pecos. Another area included the southernmost and easternmost portions of the historical range. Less remote sensing work was performed there because fewer recent reports of BTPDs were received in those areas. Isolated colonies not represented in the data might exist in the area and would affect the current range. The potential colonies would not significantly affect aerial and colonial estimates.

The second reason the current estimates of this study were conservative was that the methodology contained two procedures that restricted the magnitude of the estimates. The first procedure occurred before ground-truthing, when polygons from the raw layer representing the lowest probability signature variants were removed. The second procedure occurred after ground-truthing, when polygons from the edit layer representing classes of signature variants that had not yielded BTPDs were removed. The examination of the results on top of 2004 NAIP imagery confirmed that some polygons removed would have remained in the dataset had the NAIP imagery been used instead of the 1994-97 DOQs. An underlying assumption was that BTPD colonies are relatively stable over a 3-5 year period. This assumption was supported by post-inventory observations from 2005-2007.

General conclusions about trends in the Texas BTPD population were drawn, but historical data could not be precisely compared to current data for three reasons. First, no well-defined study area from a previous inventory was found to compare to this study area. Second, no well-defined historical data was found to compare to the current population data in this study. Third, no well-defined methods from previous studies were found to validate comparisons to estimates generated by methods in this study (see Bailey 1905, Cottam and Caroline 1965, U. S. Department of Agriculture Soil Conservation Service 1973, and Cheatheam 1977).

Estimating effects of imagery.–Some BTPD signatures appearing as variants on 1994-97 DOQs appeared as puck and halo signatures on 2004 NAIP imagery. Similarly, signatures not interpretable on DOQs were interpretable on NAIP imagery. This was true even though the DOQs were in *.tif* and *.img* formats and NAIP imagery was in compressed *.sid* format. Future researchers will need to be aware of the formats and technical specifications of future imagery used to generate comparisons to the population data from this study. Resolution and type of color used will be especially relevant, since NAIP imagery subsequent to 2004 has varied from 1-2 m resolution and has varied from false color with infrared to true color.

Management implications.–The diverse emotional responses triggered by the BTPD will continue to be a factor in management efforts affecting the species, but with more landowners managing lands for wildlife, a BTPD recovery program may generate more interest. The dependence of the black-footed ferret on BTPD metapopulations may increase interest in recovery programs for both species on lands located within complexes >2,023 ha.

In areas with frequent sylvatic plague outbreaks, fragmentation of BTPD complexes may benefit the BTPD, since plague is more devastating in areas with dense concentrations of BTPDs than in areas with isolated colonies (Luce 2003). Since the 2003 outbreak in the northern High Plains occurred in the largest BTPD complex in Texas, black-footed ferret recovery programs there may be affected. The threat posed by plague justifies the goal in BTPD management plans (Luce 2003, Texas BTPD Working Group 2005) to maintain colonies in 75% of the historical range of the species. Distance from an epidemic is the only defense against plague (Luce 2003), so colonies far from an epidemic represent potential recovery populations.

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JRS at: jason.singhurst@tpwd.state.tx.us