White-Tailed Prairie Dog Occupancy in the Pinedale Anticline Project Area

2020 Annual Report

Prepared for:

Pinedale Anticline Project Office,

Wyoming Game and Fish Department, and U.S. Bureau of Land Management

Pinedale, Wyoming

Prepared by:

Jason D. Carlisle, Will B. McDonald, Terri Harvey, Victoria H. Zero,

Kristen Klaphake, Thomas J. Prebyl, and Chad W. LeBeau

Western EcoSystems Technology, Inc.
1610 East Reynolds Street
Laramie, Wyoming 82072

February 3, 2021

WEST

REPORT REFERENCE

Carlisle, J. D., W. B. McDonald, T. Harvey, V. H. Zero, K. Klaphake, T. J. Prebyl, and C. W. LeBeau. 2021. White-Tailed Prairie Dog Occupancy in the Pinedale Anticline Project Area: 2020 Annual Report. Prepared for Pinedale Anticline Project Office, Wyoming Game and Fish Department, and U.S. Bureau of Land Management, Pinedale, Wyoming. Prepared by Western EcoSystems Technology, Inc. (WEST), Laramie, Wyoming. February 3, 2021.

Cover photo by Terri Harvey.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 SUMMARY OF FINDINGS RELATIVE TO THE WILDLIFE MONITORING AND MITIGATION MATRIX

The Wildlife Monitoring and Mitigation Matrix of the Record of Decision (ROD) issued by the U.S. Bureau of Land Management (BLM) pertaining to oil and gas development in the Pinedale Anticline Project Area (PAPA; Appendix B of BLM 2008) near Pinedale, Wyoming, specified a requirement to monitor white-tailed prairie dog (*Cynomys leucurus;* WTPD) populations. Specifically, the ROD (BLM 2008) specified that trends in WTPD occurrence and abundance within the PAPA be monitored for evidence of decline relative to an adjacent Reference Area (see the *Introduction* section for a discussion of how the WTPD monitoring methods have changed over time and how the 2020 survey methods relate to the ROD). We estimated the occurrence of WTPD in 2020 using field surveys of 156 survey plots, and an occupancy-based survey protocol and analytical method capable of estimating the proportion of each study region occupied by WTPD while accounting for imperfect detection (MacKenzie et al. 2018). WTPD were estimated to occupy between 11–24% (95% confidence interval) of the PAPA and 12–48% of the Reference Area in the summer of 2020, with no evidence of a difference in occupancy rates based on a null-hypothesis test using $\alpha = 0.05$. The Wildlife Monitoring and Mitigation Matrix suggests trends during a 3-year period be assessed; however, a comparable occupancy survey has not been conducted since 2010. Relative to 2010, WTPD were estimated to occupy between 14% less to 2% more of the PAPA in 2020, and 1–32% more of the Reference Area in 2020. The difference in these 10-year trends between the two regions provides some evidence that WTPD occupancy may have decreased in the PAPA from 2010 – 2020 relative to WTPD occupancy in the Reference Area; however, the difference in trends was not large enough to conclude (based on a null-hypothesis test using $\alpha = 0.05$) that the 10-year trends in WTPD occupancy differed between the PAPA and Reference Area from 2010 – 2020.

2.0 INTRODUCTION

The WTPD is a Species of Greatest Conservation Need in the state of Wyoming (Wyoming Game and Fish Department 2017), and the occurrence and/or abundance of WTPD has been monitored in some manner since 2009 at the PAPA near Pinedale, Wyoming, as part of broader efforts to determine whether oil and gas development activities have affected wildlife species of concern. The ROD issued by the BLM pertaining to oil and gas development in the PAPA (BLM 2008) specified requirements for monitoring of wildlife populations that could be impacted by the development, including the WTPD. Specifically, the ROD (BLM 2008) specified that trends in WTPD occurrence and abundance within the PAPA be monitored for evidence of decline relative to an adjacent Reference Area (see Appendix B – Wildlife Monitoring and Mitigation Matrix in BLM 2008).

WTPD colonies were identified in 2009 by flying regularly spaced transects across the PAPA and Reference Area, marking the location of areas that appeared to have WTPD colonies, visiting each potential colony on foot to confirm WTPD presence, and delineating the boundary of each colony by walking the perimeter with a handheld Global Positioning System (GPS) unit (Hayden-Wing Associates 2009). In 2010, a random selection of plots throughout the study area were

surveyed for WTPD occupancy (Thompson et al. 2010); however, a power analysis raised concerns that a prohibitively large number of plots would need to be sampled to achieve the desired statistical power to detect trends (Thompson et al. 2010). Therefore, from 2011 – 2018, the known colonies identified during the 2009 aerial survey were re-delineated by walking the colony perimeter and a sample of strip transects were surveyed to count WTPD burrows and assess burrow activity (see LeBeau et al. 2019 for the latest annual report of these surveys). Based on identified shortcomings in re-delineating known colonies in a small portion of the study area, and an expressed interest by the Pinedale Area Project Office (PAPO) to increase the cost-efficiency of monitoring, a novel method was piloted in 2019 to use artificial intelligence and remote sensing methods applied to high-resolution aerial imagery to identify WTPD colonies in the entire study area (Carlisle et al. 2020).

After discussions with PAPO and project partners with the Wyoming Game and Fish Department and BLM, it was decided that an occupancy survey again be adopted for WTPD in 2020. Returning to an occupancy-based approach was intended to further improve cost-efficiency while working toward the potential to achieve the monitoring objectives outlined in the ROD (BLM 2008) for multiple species of concern (WTPD and pygmy rabbit [*Brachylagus idahoensis*]) in one unified effort. Changing the monitoring method in 2020 limited the ability to compare the status of WTPD populations in 2020 to the status in the previous three years, as specified in the ROD. Moreover, the occupancy-based approach adopted in 2020 does provide estimates of WTPD occurrence (or occupancy) but not estimates of WTPD abundance, and both population measures are specified in the ROD. However, given that the WTPD mitigation triggers specified in the ROD had never been met during the WTPD monitoring before 2020, and given that WTPD population trends appeared to be stable or increasing during that time (Carlisle et al. 2020), project partners felt that 2020 would be a reasonable time to discontinue the previous methods of monitoring (outlined above) and again adopt a flexible and cost-effective occupancy-based approach (K. Gold, personal communication). In this report, we summarize the findings of the 2020 WTPD monitoring efforts. Our objectives were to 1) compare WTPD occupancy estimates in the PAPA and adjacent Reference Area, and 2) compare 2020 occupancy estimates to previous estimates in 2010 to examine whether the trend in WTPD occupancy has differed between the PAPA and adjacent Reference Area.

3.0 STUDY AREA

The study area (979.05 square kilometers [km^2; 378.01 square miles {mi^2}]; Figure 1) near Pinedale, Wyoming, included two study regions: the PAPA (801.08 km^2 [309.30 mi^2], 81.82% of the study area) as defined in the ROD (BLM 2008), and an adjacent Reference Area (177.97 km^2 [68.71 mi^2], 18.18% of the study area) consistent with previous WTPD monitoring efforts (Hayden-Wing Associates 2009, Thompson et al. 2010, LeBeau et al. 2019). The study area is part of the Wyoming Basin ecoregion, typified by a cold-desert climate and vegetation communities dominated by arid grasslands and shrublands (Wiken et al. 2011).

4.0 METHODS

We conducted ground-based surveys at a random sample of plots to estimate the proportion of each study region (PAPA and Reference Area) occupied by WTPD based on presence-absence surveys. Our study design and methods incorporated aspects of several previous studies of prairie dogs in Wyoming and Colorado (Andelt et al. 2009, Thompson et al. 2010, Ceradini et al. 2021), and we accounted for imperfect detection of WTPD through the use of an occupancy-based survey protocol and analytical method (MacKenzie et al. 2018).

4.1 Study Design and Field Methods

4.1.1 Sampling Design

We created a sample frame consisting of 4,863 grid cells (potential survey plots), each 400 × 400 meters (m; 1,312 × 1,312 feet [ft]; 16 hectares [ha]; 39.5 acres [ac]). Although other regional studies of WTPD (Andelt et al. 2009, Thompson et al. 2010, Ceradini et al. 2021) used plots 500 × 500 m (1,640 × 1,640 ft; 25 ha; 61.8 ac), a smaller plot size was used here to allow for more plots to be visited given a fixed amount of survey time, and to be consistent with recent pygmy rabbit surveys in the area (HWA Wildlife Consulting 2018), opening the possibility to survey both species in a unified effort in the future. Only plots that had their centroid in the study area and contained no private land were included. We selected a random and spatially balanced sample of 160 plots within the study area using the Balanced Acceptance Sampling method (Robertson et al. 2013, 2017) implemented in the SDraw package (McDonald and McDonald 2020) in Program R (R Core Team 2020). Four plots were removed from the sample due to inaccessibility caused by standing water, topography, or no method to access via public land, resulting in a final sample of 156 plots. Given that the spatially balanced sample was drawn without regional stratification, the number of plots in each region was roughly proportional to region size: 133 in the PAPA (85% of the sample), and 23 in the Reference Area (15% of the sample). We further divided each plot into four search quadrants (each 200 × 200 m [656 × 656 ft]; 4 ha [9.9 ac]) to help observers focus equal amount of search effort on all portions of the survey plots.

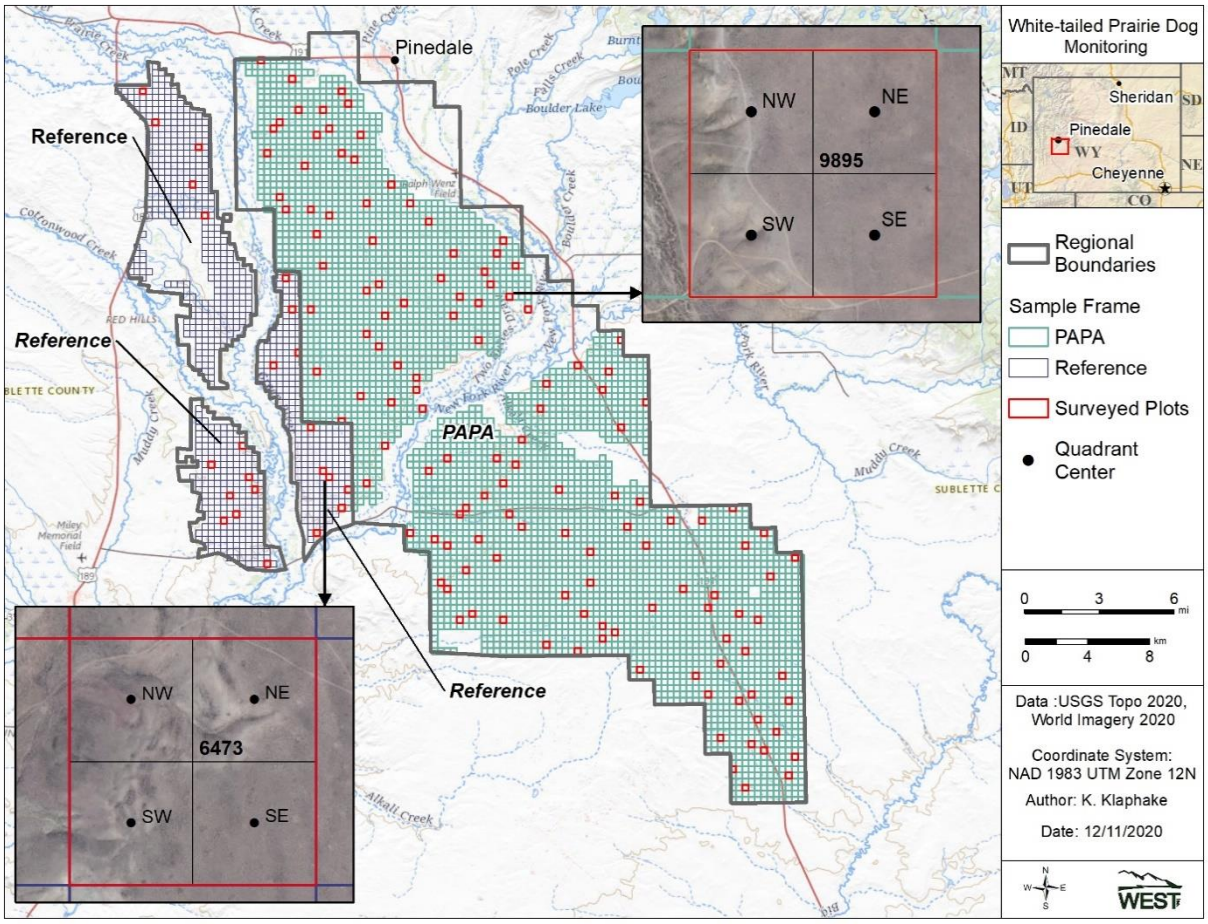

Figure 1. Study area map including the two study area regions: the Pinedale Anticline Project Area (PAPA) and the adjacent Reference Area.

4.1.2 Field Surveys

Consistent with other studies of prairie dog occupancy in Wyoming and Colorado (Andelt et al. 2009, Thompson et al. 2010, Ceradini et al. 2021), WTPD were considered present only if at least one WTPD individual was visually observed. Ground-based visual surveys for WTPD were conducted over a 3-week period from June 27 – July 14, 2020. Two independent observers conducted 4-minute visual surveys at the center of each plot quadrant using the naked eye and binoculars to search for WTPD. WTPD were considered present at the plot if seen within the plot during the 4-minute surveys in each quadrant or while commuting between the quadrants within a plot. Observers collected data electronically on GPS-enabled tablets and used laser rangefinders and the mapping capabilities of the tablets to determine if WTPDs near plot boundaries were within the survey plot. To maintain observer independence (an assumption of the occupancy model), the two observers began surveys in adjacent quadrants and rotated around the plot in opposite directions such that quadrants were never surveyed simultaneously. Moreover, when observers crossed paths as they walked between quadrants, no information was shared about survey findings. Surveys were only conducted between sunrise and sunset, and were discontinued with any precipitation more than a drizzle at the site. Although presence was

determined by visual observations of at least one WTPD individual, observers did record whether other WTPD sign was encountered (i.e., visual observation of WTPD burrows, visual observation of WTPD scat, or aural observation of WTPD vocalizations), and the raw data delivered with this report indicate all types of WTPD sign encountered during each survey.

4.2 Statistical Analysis

4.2.1 Proportion of Area Occupied by White-tailed Prairie Dogs in 2020

We estimated occupancy for each region, while accounting for probability of detection less than 100% using the single species, single season occupancy-modeling framework outlined in MacKenzie et al. (2018). Occupancy (Ψ) is defined as the probability that a 400 × 400 m plot is occupied by WTPD, or equivalently the proportion of each region occupied by WTPD (MacKenzie et al. 2018). Detection probability (*p*) is defined as the probability that WTPD are detected during sampling of an occupied plot. Occupancy models offer great flexibility in how study objectives are framed and how model components (e.g., "site" or "visit") are defined (Bailey et al. 2014); instead of basing an encounter history on multiple temporally distinct visits to plots, we utilized a double-observer method similar to Ceradini et al. (2021) to collect independent assessments of detection versus non-detection of WTPD during a single simultaneous visit by two observers.

We considered five candidate occupancy models. To meet the study objective of comparing occupancy rates between study regions, all models in the candidate set included region as covariate in the occupancy portion of the model. The five candidate models came from five definitions of the detection probability portion of the model. We included a model that assumed detection probability was the same across sites and surveys (the so-called null model or intercept-only model), then four models with a single covariate each. The four covariates were time, temperature, date, and observer. Time was the start time of the survey at a plot, temperature was the daily maximum temperature recorded at the nearby Boulder Rearing Station (National Oceanic and Atmospheric Administration 2020) on the day of survey, date was the ordinal date of the year of survey, and observer indicated which of the seven observers conducted the search. The three continuous covariates (time, temperature, and date) all had pairwise Pearson's correlation coefficients of less than 0.5.

We fit the occupancy models using the unmarked package (Fiske and Chandler 2011) in Program R (R Core Team 2020). We used an information-theoretic approach to rank models based on Akaike's Information Criterion adjusted for small samples (AICc; Burnham and Anderson 2002), and we calculated AICc-related statistics using the AICcmodavg package (Mazerolle 2020) in Program R. We assessed the model fit of the top-ranked model using a goodness-of-fit test, which compared observed counts of unique encounter histories to 1,000 bootstrap simulations of expected counts generated from the top-ranked model (MacKenzie and Bailey 2004, MacKenzie et al. 2018). To supplement the standard estimates of occupancy and detection probability, we used formulas specified in MacKenzie et al. (2018) to derive estimates of the cumulative detection probability across multiple surveys and the probability of occupancy given no WTPD were detected.

4.2.2 Trends in White-tailed Prairie Dog Occupancy

The ROD (BLM 2008) specified trends in the occurrence of WTPD be monitored over a 3-year time period. However, an estimate of WTPD occupancy based on a random sample of the study area has not been made since 2010. Therefore, we compared the occupancy rates estimated for 2020 to the only historic occupancy rates available, those estimated in 2010 (as reported in Thompson et al. 2010). We calculated the difference in occupancy from 2010 to 2020 separately for the PAPA and Reference Area regions, and we used a parametric bootstrap routine to test whether WTPD occupancy in the PAPA region had declined relative to WTPD occupancy in the Reference Area (Manly 2006). We calculated the difference in 10-year trends by subtracting the Reference Area trend from the PAPA trend, meaning that positive differences suggest that WTPD occupancy trended higher in the PAPA relative to the Reference Area, and negative differences suggest that WTPD occupancy trended lower in the PAPA relative to the Reference Area.

5.0 RESULTS

5.1 Proportion of Area Occupied by White-tailed Prairie Dogs in 2020

We surveyed 156 plots; 23 in the Reference Area and 133 in the PAPA. Six plots were only surveyed by one observer due to logistical constraints, two plots in the Reference Area region and four in the PAPA region. WTPD were visually observed at 27 plots (Figure 2).

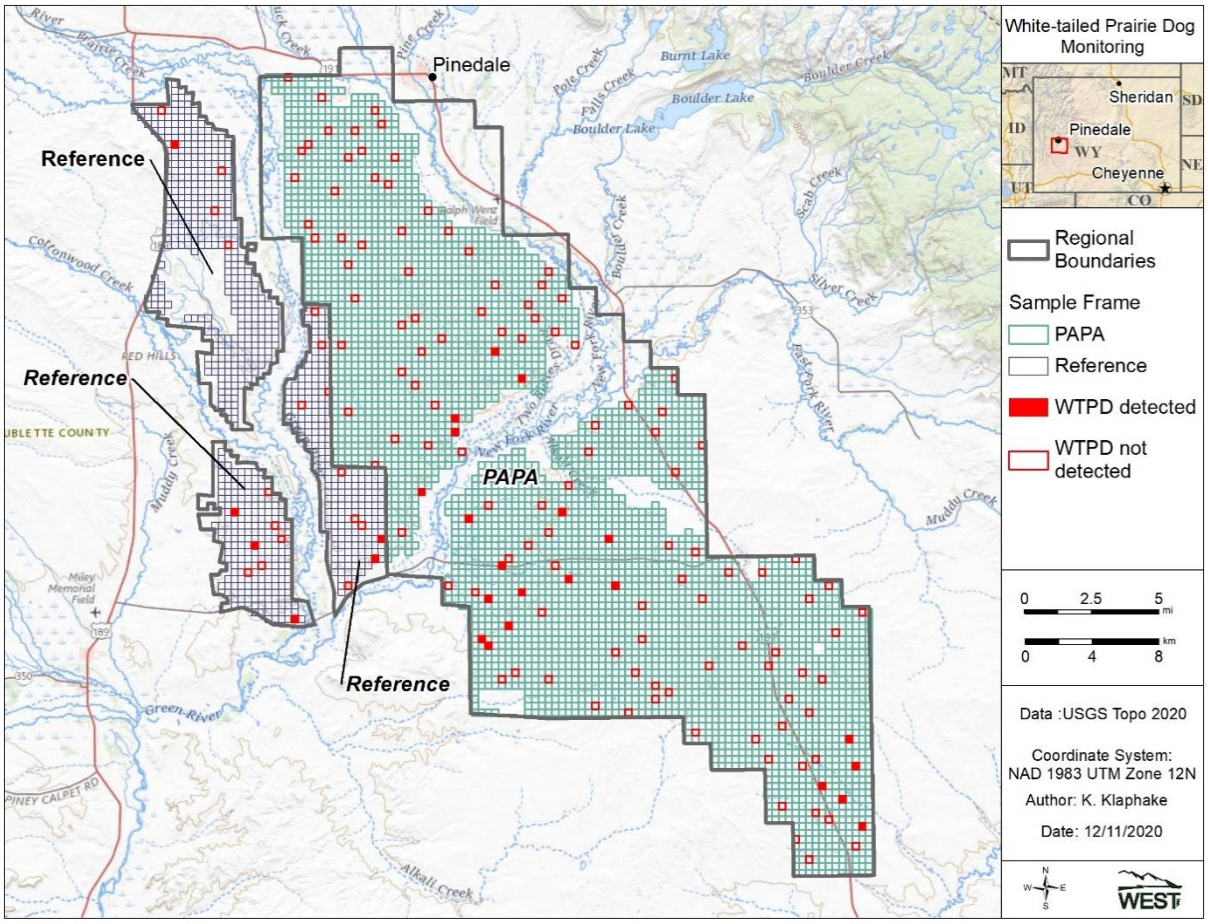

Figure 2. Map of the 156 plots (400 × 400 meters) surveyed for white-tailed prairie dogs (WTPD), including the 27 survey plots where WTPD were detected.

The top-ranked model, Ψ(region) *p*(.), was the simplest model considered, suggesting the detectability of WTPD was similar among observers and sites surveyed (Table 1). The model-selection results suggested that models that included a single continuous covariate in the detection portion of the model (i.e., date, time, and temperature) had similar support to the top-ranked model (ΔAICc values of approximately two or less; Burnham and Anderson 2002); however, given the top-ranked model was the most parsimonious model in the candidate set, we proceeded to base our inference on only the results of the top-ranked model (Table 1). The goodness-of-fit test identified a lack of model fit for the top-ranked model (P less than 0.01); however, the lack of fit was driven by differences in observed and expected counts of encounter histories with only one observer (n = 6 surveys; Table 2). Model fit was sufficiently good when only considering the encounter histories from 2-observer surveys (P = 1.0).

Table 1. Candidate models* and model-selection results describing occupancy of white-tailed prairie dogs near Pinedale, Wyoming, in summer 2020.

Model	*K*	AICc	ΔAICc	*w*
Ψ(Region) *p*(.)	3	184.25	0.00	0.40
Ψ(Region) *p*(Date)	4	184.91	0.66	0.29
Ψ(Region) *p*(Time)	4	186.24	1.99	0.15
Ψ(Region) *p*(Temperature)	4	186.26	2.01	0.15
Ψ(Region) *p*(Observer)	9	190.91	6.66	0.01

* Models are ranked by AICc (Akaike's Information Criterion adjusted for small samples; Burnham and Anderson 2002).

Table 2. Results of the goodness-of-fit test applied to the top-ranked model of white-tailed prairie dog occupancy* near Pinedale, Wyoming, in summer 2020.

Encounter History	# Observed	# Expected	Chi-square
00	127	124.09	0.07
01	2	3.17	0.43
10	4	3.17	0.22
11	17	19.57	0.34
0-	2	4.98	1.79
1-	4	1.02	8.76

* Dashes (-) in encounter histories indicate missing surveys.

Estimates of WTPD occupancy were 0.16 (95% Confidence Interval [CI] = 0.11–0.24) for the PAPA region and 0.27 (95% CI: 0.12–0.48) for the Reference Area region (Table 3, Figure 3). Based on a null-hypothesis test using α = 0.05, there was no evidence that WTPD occupancy differed between the PAPA and Reference Area regions in 2020 (P = 0.23). The estimated WTPD detection probability was 0.86 (95% CI: 0.71–0.94) for both the PAPA and Reference Area regions (Table 3), meaning the cumulative probability of detecting WTPD at least once on an occupied site when surveyed with two observers was 0.98. Additionally, the probability that WTPD were present at a plot, but were not detected was approximately 0.03–0.05 if the plot was surveyed by one observer and less than 0.01 if the plot was surveyed by two observers.

Table 3. Estimates* of white-tailed prairie dog occupancy (Ψ) and probability of detection (*p*) near Pinedale, Wyoming, in summer 2020.

	Ψ			*p*		
Region	Mean	95% CI	SE	Mean	95% CI	SE
PAPA	0.16	0.11–0.24	0.03	0.86	0.71–0.94	0.06
Reference	0.27	0.12–0.48	0.09	0.86	0.71–0.94	0.06

* Estimates are provided on the probability scale based on the top-ranked model, Ψ(Region) *p*(.). Associated 95% confidence intervals (CI) and standard errors (SE) are provided.

5.2 Trends in White-tailed Prairie Dog Occupancy

Estimated WTPD occupancy decreased by an incremental 0.10 (95% CI = -0.14–0.02; Figure 3) for the PAPA region from 2010 to 2020, and increased by an incremental 0.09 (95% CI = 0.01–0.32; Figure 3) for the Reference Area region. The difference in the 10-year trends was negative, with 95% CI that was predominantly negative, but overlapped zero (difference = -0.19; 95% CI = -0.45–0.06; Figure 4), providing some evidence that WTPD occupancy may have decreased in the PAPA from 2010 – 2020 relative to WTPD occupancy in the Reference Area. However, based on a null-hypothesis test using α = 0.05, the difference was not large enough to conclude that the 10-year trends in WTPD occupancy differed between the PAPA and Reference Area regions from 2010 – 2020 (P = 0.07).

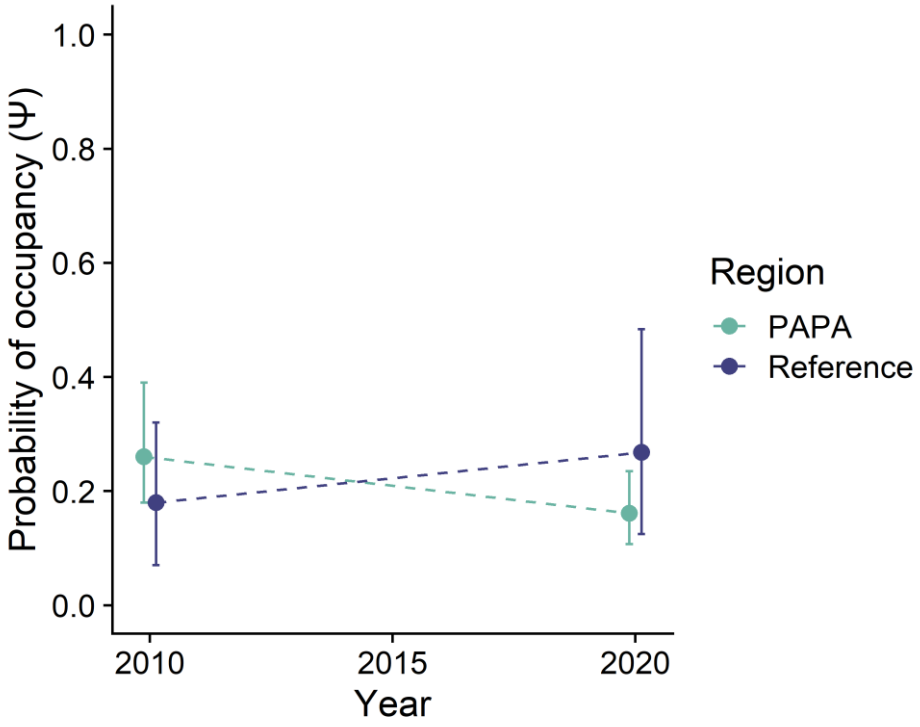

Figure 3. The probability of white-tailed prairie dog occupancy (Ψ, equivalent to proportion of area occupied) at the Pinedale Anticline Project Area (PAPA) and adjacent Reference Area. Estimates for 2010 come from Thompson et al. (2010), and estimates for 2020 come from this report. Error bars represent 95% confidence intervals.

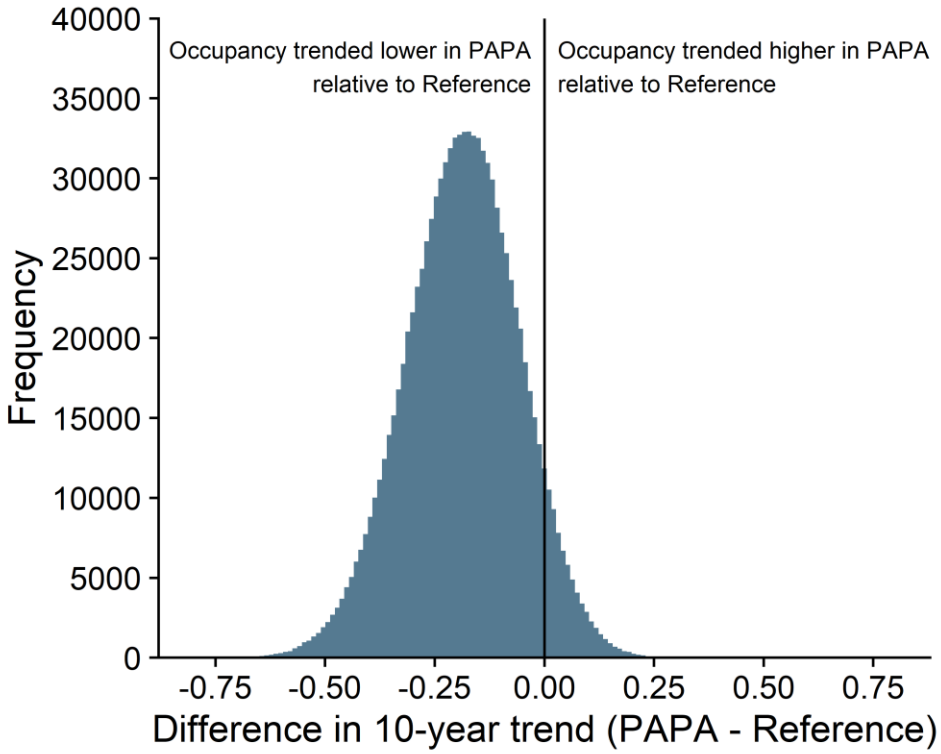

Figure 4. The distribution of the difference in 10-year trends in the probability of white-tailed prairie dog occupancy (Ψ, equivalent to proportion of area occupied) at the Pinedale Anticline Project Area (PAPA) and adjacent Reference Area. Estimates for 2010 come from Thompson et al. (2010), and estimates for 2020 come from this report.

Note: Values >0 indicate occupancy trended higher in the PAPA relative to the Reference Area, and values <0 indicate occupancy trended lower in the PAPA relative to the Reference Area.

6.0 DISCUSSION

The Wildlife Monitoring and Mitigation Matrix of the ROD (BLM 2008) specified that trends in WTPD occurrence and abundance within the project area be monitored for evidence of decline relative to an adjacent reference area. We estimated the occurrence (or occupancy) of WTPD in 2020 using field surveys at a random sample of plots in the PAPA and adjacent Reference Area. Based on null-hypothesis tests using $\alpha = 0.05$, we concluded the proportion of area occupied by WTPD in 2020 did not differ between the PAPA and Reference Area, and the 10-year trend in occupancy from 2010 – 2020 did not differ between the PAPA and Reference Area. Notwithstanding, our results provide some evidence that WTPD occupancy may have decreased in the PAPA from 2010 – 2020 relative to WTPD occupancy in the Reference Area. Prairie dog population sizes can vary dramatically by year or even season (Buskirk 2016), so inferring a trend based solely on two years of monitoring spaced 10 years apart is tenuous. Given the Wildlife Monitoring and Mitigation Matrix specified that trends should be evaluated on a 3-year timescale, these 2020 estimates can be used as the baseline data against which to assess future trends in the coming years, provided

a similarly designed occupancy study is conducted each year. Monitoring methods implemented previously were used to track changes in estimated WTPD abundance at known colonies (LeBeau et al. 2019, Carlisle et al. 2020). Because the occupancy-based methods used this year do not provide a reliable way to estimate abundance, we did not estimate WTPD abundance for 2020, nor did we conduct any trend analysis related to abundance.

7.0 ACKNOWLEDGMENTS

We thank L. Dempsey, S. Opitz, and C. Stumpner for assistance with field surveys. T. McDonald provided advice on study design, and A. Tredennick assisted with analytical methods. This study and report were improved by discussions of WTPD ecology and monitoring methods with K. Gold, M. Thonhoff, B. Scurlock, and K. Roadifer.

8.0 LITERATURE CITED

Andelt, W. F., G. C. White, P. M. Schnurr, and K. W. Navo. 2009. Occupancy of Random Plots by White-Tailed and Gunnison's Prairie Dogs. Journal of Wildlife Management 73(1): 35-44. doi: 10.2193/2007-312.

Bailey, L. L., D. I. Mackenzie, and J. D. Nichols. 2014. Advances and applications of occupancy models. Methods in Ecology and Evolution 5:1269–1279.

Bureau of Land Management (BLM). 2008. Record of Decision, Final Supplemental Environmental Impact Statement for the Pinedale Anticline Oil and Gas Exploration and Development Project, Sublette County, Wyoming. US Department of the Interior, BLM, Cheyenne, Wyoming.

Burnham, K. P., and D. R. Anderson. 2002. Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach. Second edition. Springer, New York, New York.

Buskirk, S. W. 2016. Wild Mammals of Wyoming and Yellowstone National Park. University of California Press, Oakland, California.

Carlisle, J. D., J. Thompson, T. Harvey, K. Klaphake, R. Anderson, C. W. LeBeau, and T. L. McDonald. 2020. Remote Sensing of White-Tailed Prairie Dogs in the Pinedale Anticline Project Area Using Aerial Imagery and Artificial Intelligence: 2019 Annual Report. Prepared for Pinedale Anticline Project Office (PAPO), Pinedale, Wyoming. Prepared by Western EcoSystems Technology, Inc. (WEST), Cheyenne, Wyoming. April 17, 2020.

Ceradini, J., D. Keinath, I. Abernethy, M. Andersen, and Z. Wallace. 2021. Crossing Boundaries in Conservation: Land Ownership and Habitat Influence the Occupancy of an At-Risk Small Mammal. Ecosphere 12(1):e03324.

Esri. 2020. World Imagery and Aerial Photos. (World Topo). ArcGIS Resource Center. Environmental Systems Research Institute (Esri), producers of ArcGIS software, Redlands, California. Last updated October 14, 2020. Information online: https://www.arcgis.com/home/webmap/viewer.html?useExisting=1&layers=10df2279f9684e4a9f6a7f08febac2a9

Fiske, I. J. and R. B. Chandler. 2011. Unmarked: An R Package for Fitting Hierarchical Models of Wildlife Occurrence and Abundance. Journal of Statistical Software 43(10):1-23. doi: 10.18637/jss.v043.i10.

Hayden-Wing Associates, LLC (HWA). 2009. 2009 Annual Report: White-tailed Prairie Dog (*Cynomys leucurus*) Colony Mapping in the Pinedale Anticline Project Area. Report prepared for US Department of the Interior, Bureau of Land Management, Pinedale Anticline Project Office, Pinedale, Wyoming. Prepared by Hayden-Wing Associates, LLC, Laramie, Wyoming.

HWA Wildlife Consulting, LLC. 2018. Pygmy Rabbit Monitoring in the Pinedale Anticline Project Area, Sublette County, Wyoming 2018. Report prepared for Wyoming Game and Fish Department, Pinedale Anticline Project Office, and Bureau of Land Management, Pinedale, Wyoming. Prepared by HWA Wildlife Consulting, LLC, Laramie, Wyoming.

LeBeau, C., T. Harvey, A. Telander, and C. Fritchman. 2019. White-Tailed Prairie Dog Monitoring for the Pinedale Anticline Project Area. 2018 Annual Report. Prepared for Pinedale Anticline Project Office (PAPO), Pinedale, Wyoming. Prepared by Western EcoSystems Technology, Inc. (WEST), Cheyenne, Wyoming.

Mackenzie, D. I. and L. L. Bailey. 2004. Assessing the Fit of Site-Occupancy Models. Journal of Agricultural, Biological, and Environmental Statistics 9(3):300–318. doi: 10.1198/108571104x3361.

MacKenzie, D. I., and J. A. Royle. 2005. Designing occupancy studies: general advice and allocating survey effort. Journal of Applied Ecology 42(6):1105–1114.

MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H Pollock, L. L. Bailey, and J. E. Hines. 2018. Occupancy estimation and modeling: Inferring patterns and dynamics of species occupancy. Second edition. Academic Press, London, United Kingdom.

Manly, B. F. J. 2006. Randomization, Bootstrap and Monte Carlo Methods in Biology. Third Edition. Chapman and Hall/CRC, Boca Raton, Florida.

Mazerolle, M. J. 2020. AICcmodavg: model selection and multimodel inference based on (Q)AIC(c). R package version 2.3-1. Information online: https://cran.r-project.org/web/packages/AICcmodavg/

McDonald, T., and A. McDonald. 2020. SDraw: Spatially Balanced Samples of Spatial Objects. R package version 2.1.13. Available online: https://CRAN.R-project.org/package=SDraw

National Oceanic and Atmospheric Administration (NOAA). 2020. Climate data online. Boulder Rearing Station, Wyoming. Accessed August 25, 2020. Information online: https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USC00480951/detail

North American Datum (NAD). 1983. NAD83 Geodetic Datum.

R Core Team. 2020. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. Available online: https://www.R-project.org/

Robertson, B. L., J. A. Brown, T. McDonald, and P. Jaksons. 2013. BAS: Balanced Acceptance Sampling of Natural Resources. Biometrics 69: 776–784. doi: 10.1111/biom.12059.

Robertson, B. L., T. L. McDonald, C. J. Price, and J. A. Brown. 2017. A modification of balanced acceptance sampling. Statistics and Probability Letters 129:107–112.

Thompson, J., S. Howlin, and T. Rintz. 2010. White-tailed Prairie Dog Monitoring for the Pinedale Anticline Project Area: 2010 Pilot Year, Final Report. Prepared by Western EcoSystems Technology, Inc. (WEST), Cheyenne, Wyoming.

U.S. Geological Survey (USGS). 2020. USGS Topographic Maps. Accessed November 2020. Information online: https://nationalmap.gov/ustopo/index.html

Wiken, E., F. Jimenez Nava, and G. Griffith. 2011. North American Terrestrial Ecoregions - Level III. Commission for Environmental Cooperation. Montreal, Canada. 149 pp. Available online: ftp://newftp.epa.gov/EPADataCommons/ORD/Ecoregions/pubs/NA_TerrestrialEcoregionsLevel3_Final-2june11_CEC.pdf

Wyoming Game and Fish Department (WGFD). 2017. State Wildlife Action Plan. WGFD, Cheyenne, Wyoming. Available online: https://wgfd.wyo.gov/Habitat/Habitat-Plans/Wyoming-State-Wildlife-Action-Plan