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Potential Landscapes for Conservation of the Black-Tailed Prairie Dog Ecosystem

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ABSTRACT

Aim: To identify potential landscapes for the conservation of the black-tailed prairie dog (*Cynomys ludovicianus*; BTPD) ecosystem, across their historical geographical range within the United States.

Location: Central Grasslands of the United States.

Methods: We used a structured decision analysis approach to identify landscapes with high conservation potential (HCP) for the BTPD ecosystem. Our analysis incorporated ecological, political and social factors, along with changing climate and land use to maximise long-term conservation potential.

Results: The landscapes we identified with HCP (top 30% rangewide) represented 22% of the historical distribution of BTPDs and remained strongholds under projected climate change. We provide a suite of HCP area scenarios to help inform different conservation and management interests, including those that consider projected climate change and jurisdictional (state-level) boundaries.

Main Conclusions: Our findings highlight the large conservation potential for BTPDs and associated species, and the maps we generated can be incorporated into other large-scale, multispecies conservation planning efforts being developed for the Central Grasslands of North America.

1 | Introduction

Conservation planning involves identifying where, when and how to allocate limited conservation resources to maximise the preservation of biodiversity (Pressey et al. 2007). Of central importance to determining areas with high conservation potential (hereafter, HCP) is identifying the most ecologically suitable habitat for the species or communities of interest—the biophysical landscape. However, for conservation goals to be effectively implemented on the ground, understanding the human landscape is also critical (Knight et al. 2008). Systematic conservation planning (Margules and Pressey 2000) has evolved over the last several decades, going beyond the biophysical landscape, to holistically incorporate biodiversity processes, habitat connectivity, ecosystem services, climate change, dynamic threats, economics and political and social landscapes (Pressey et al. 2007). Yet, incorporating human dimensions into a spatial landscape to inform conservation planning remains a challenge and has been limited in its application (Knight and Cowling 2007; Knight et al. 2008; Whitehead et al. 2014; Williamson et al. 2018). Insights into the human dimensions are especially needed for species that have large, transformative effects on ecosystems and are consequently often in conflict with human activities, such as prairie dogs (*Cynomys* spp.), beavers, wolves (*Canis lupis*), and bison (*Bison bison*) (Miller et al. 2007; Pilliod et al. 2018; Niemiec et al. 2021; Pejchar et al. 2021; Livieri et al. 2022). Even if the biophysical landscape is highly suitable for conservation or recovery of these high-conflict species, the human sociocultural landscape might prohibit on-the-ground success (Knight et al. 2008; Niemiec et al. 2021).

North America's Central Grasslands are among the most endangered ecosystems in the world and face a suite of conservation challenges associated with habitat loss, transformation and fragmentation (Samson, Knopf, and Ostlie 2004; Olimb and Robinson 2019; Lark et al. 2020; Augustine et al. 2021). Millions of bison, pronghorn and elk historically inhabited the Central Grasslands, along with wolves and grizzly bears, once rivalling the wildlife abundance of Africa's Serengeti (Samson, Knopf, and Ostlie 2004; Dan Flores 2017). The region since has been converted to a highly domesticated landscape, with fences, livestock, crops and complex jurisdictional boundaries making large-scale conservation efforts and planning challenging (Augustine et al. 2021). The impact of human activities on the Central Grasslands has resulted in widespread declines in native wildlife, including >95% declines in bison and prairie dogs, >50% decline in grassland birds, and near extirpation of wolves and grizzly bears (Hoogland 2006; Sanderson et al. 2008; Rosenberg et al. 2019). Recent awareness of the plight of the Central Grasslands and associated species has inspired new conservation initiatives like the *Central Grasslands Roadmap*, *Great Plains Summit*, WAFWA's *Western Grasslands Initiative* and *The North American Grasslands Conservation Act of 2024* recently introduced in the U.S. Congress (Western Association of Fish and Wildlife Agencies 2011; Finch 2018; Heady and Child 2019; Lark 2020; Haaland et al. 2021; Central Grasslands Roadmap 2022; Mace 2024). One of the conservation strategies taken by these and other initiatives is to focus prioritisation efforts on umbrella species, whose conservation results in protecting suites of associated species or entire ecosystems (Carroll, Dunk, and Moilanen 2010; Gary et al. 2022).

Black-tailed prairie dogs are often at the centre of many conservation efforts throughout the Central Grasslands because of the disproportionate ecological role they play (Davidson, Detling, and Brown 2012; Hoogland 2006). Prairie dogs transform the grassland landscape through their burrowing and herbivory, creating islands of open grassland habitat dotted with numerous mounds that are linked to extensive burrow systems tunnelling deep underground (Davidson, Detling, and Brown 2012; Hoogland 2006). Their colonies attract grassland animals that prefer open habitats and utilise their burrows for homes and shelter, including mountain plovers and burrowing owls, lizards, snakes, numerous arthropods, rabbits and other rodents (Augustine and Baker 2013; Augustine and Derner 2012; Davidson, Detling, and Brown 2012; Duchardt, Augustine, and Beck 2019). Pollinators are also attracted to their colonies because of the greater floral abundance and open bare soil for oviposition sites (Hardwicke 2006), and large herbivores like bison and cattle are attracted to the more nutritious forage that can be found in their colonies (Kotliar et al. 2006; Bayless and Beier 2011; Connell, Porensky, and Scasta 2019). Prairie dogs also provide an important source of prey for numerous predators, including coyotes (*Canis latrans*), American badgers (*Taxidea taxus*), raptors [e.g. golden eagles (*Aquila chrysaetos*), ferruginous hawks (*Buteo regalis*)] and the highly endangered black-footed ferret (*Mustela nigripes*) (Davidson, Detling, and Brown 2012; Eads and Biggins 2015; Eads, Biggins, Grassel, et al. 2016; Goodrich and Buskirk 1998; Grassel, Rachlow, and Williams 2015; Kotliar et al. 2006).

Yet, prairie dog populations have declined dramatically since the early 1900s due to widespread extermination efforts, introduced plague, shooting and habitat loss. The declines of prairie dogs rangewide, and locally following cyclic plague events, has resulted in cascading declines in associated species (Cully et al. 2010; Eads and Biggins 2015; Davidson et al. 2022; Duchardt et al. 2023). The black-footed ferret, for example, is considered North America's most endangered mammal largely as a result of the dramatic decline in prairie dogs, their primary prey (U.S. Fish and Wildlife Service 2013; Livieri et al. 2022). These declines in prairie dogs and associated species underscore the need for conserving the prairie dog ecosystem by identifying potential landscapes for conservation both now and into the future. And—critically—such areas need to be considered within the context of the social, environmental and economic factors that influence where prairie dog complexes can be conserved and expanded across large blocks of continuous habitat so that they can support numerous grassland species (Davidson, Detling, and Brown 2012; Duchardt, Augustine, and Beck 2019; Livieri et al. 2022).

Here, we use a systematic spatial conservation prioritisation approach (Moilanen, Kujala, and Leathwick 2009) to determine HCP areas for the conservation of the prairie dog ecosystem. Our approach provides a structured decision analysis (*sensu* Gregory et al. 2012) that disentangles the complex biophysical and sociopolitical landscapes of North America's Central Grasslands and illuminates areas with the greatest potential for conservation successes. We provide a suite of HCP area scenarios to help inform different conservation and management interests, including those that consider projected climate change and jurisdictional (state-level) boundaries.

2 | Methods

2.1 | Spatial Data Layers Used in Conservation Prioritisation Analysis

We used the spatial conservation prioritisation method and Zonation software (Moilanen et al. 2005) to evaluate how landscapes varied in their potential for prairie dog ecosystem conservation and restoration across the full range of species in the United States. Our analysis included a total of 23 environmental input datasets for the full study area, based on the data sources described in Table 1. The most important layer we used to inform our analysis was the BTPD habitat suitability model, as it provided the basis for where, ecologically, the best places are to conserve and restore the BTPD ecosystem (Davidson et al. 2023). This habitat suitability model (HSM) was based on presence and absence data for BTPD occurrences across their geographical range within the United States (McDonald et al. 2015), and quantified how prairie dog occurrences related to climate, soils, topography and land cover (see Davidson et al. 2023 for details). We also utilised HSMs for BTPDs under two future climate scenarios: (1) warm and wet and (2) hot and dry, to inform where the most ecologically suitable habitat will likely be located under a warming climate (Davidson et al. 2023).

However, the goal of our analysis was to not only determine potential landscapes for conservation based on local habitat suitability but also to examine how the distribution and connectivity of native grassland habitat at broad spatial scales, the distribution of threats to prairie dog habitat (such as development and conversion to cropland) and the political and social landscape collectively influence opportunities to conserve and restore the BTPD ecosystem (Table 1; Figure S1). We used the 2016 National Land Cover Database (NLCD) to inform on the location, extent and connectivity of favourable habitats (grassland/shrubland), versus unfavourable habitats (forest/woodland and emergent wetland) for prairie dogs (USGS 2019a). We also created a landscape fragmentation layer by mapping the degree of rangeland fragmentation across the historical BTPD range. To do this, we followed the methods of Augustine et al. (2021), except that we used the 2016 NLCD as the source data layer rather than a combination of the 2011 NLCD and USDA Cropland Data Layers. Briefly, every pixel was classified as either (1) rangeland, which we defined as grassland, shrubland and improved pasture/hay cover types, (2) a fragmenting land cover type, which we defined as forest, cropland or developed lands or (3) neutral land cover types which were not rangeland, but also did not fragment adjacent rangelands. In the final fragmentation map, we set all pixels mapped as either a fragmenting or a neutral land cover type to a value of zero and then calculated the distance to the nearest fragmenting land cover type for each rangeland pixel (e.g. Figure 3 of Augustine et al. 2021). Additionally, we incorporated spatial data on land use: oil and gas well locations, distance to transmission lines, wind turbine count, and road density (Homeland Security Infrastructure Program (HSIP) 2020; United States Census Bureau 2020; Federal Aviation Administration 2021; Welldatabase 2021). These land use data layers provide information on anthropogenic activity that reflects the presence of humans and habitat quality. Areas that have higher levels of human activity may be less favourable for the BTPD ecosystem because of the increased potential for shooting of prairie dogs, impacts on associated species through behavioural modification, and habitat degradation. We also included spatial layers on projected habitat loss. The tillage risk layer (Olimb and Robinson 2019) informs where habitat is most likely to be lost to cropland. Further, we included scenarios of overall landcover change projected into the future (Sohl et al. 2018), with a focus on areas that would retain the greatest amount of favourable grassland habitat. We then obtained PAD-US (USGS 2019b), National Conservation Easement Database (NCED; Ducks Unlimited and The Trust for Public Land 2021) and other private conservation land data to determine the landownership of identified HCP areas (Table 1). We also obtained data from Carlson, Bevins, and Schmid (2022; Wildlife model presented in Figure 1) to relate HCP areas to plague risk.

We also included social and political spatial data in our analysis. We collated percent of Conservation Reserve Program (CRP) grasslands per county and the League of Conservation Voters Conservation Score Card (LCVCSC) to reflect political and social support for the environment (on a per county basis) (USDA Farm Service Agency 2020; League of Conservation Voters 2022). We also included data from a novel survey of wildlife governance preferences delivered to Canadian, Mexican and American residents (Williamson et al. 2023a, 2023b) to determine the probability that a region would support increases in prairie dog populations or support federal or private incentives for prairie dog conservation. Census tract level estimates were generated using a Bayesian multilevel regression with poststratification wherein the demographics of survey respondents were used to map the probability to census geographies based on the demographic composition of the Census tracts (Williamson et al. 2023b; Gelman 2007; Hanretty 2020). Finally, we created a spatial layer of the count of Land and Water Conservation Fund (LWCF) projects (The Wilderness Society 2015) to reflect a regions' institutional capacity to actualise conservation.

2.2 | Data Preparation

To prepare the underlying data for Zonation, the data layers were integrated into a nested hexagon framework (NHF). A NHF grid is based around a 1 km^2 hexagon unit that is aggregated up by units of 7 to generate coarser scale cells of 7 km^2 (cogs), 49 km^2 (wheels) and 343 km^2 (rings), allowing for cross-scale multidisciplinary analysis while obscuring precise sensitive location data.

A total of 31 data layers representing point, polygon and raster formats were processed and summarised into the NHF for consideration in the Zonation analysis (Table S1). While the exact process used to integrate the data layers into the NHF and subsequently into raster files for the Zonation analysis was slightly different for each data layer, the general process was the same. All GIS data processing was done using ESRI ArcMap 10.7 software. Input data layers were intersected with the NHF and the data layers were summarised per NHF hexagon cell using Zonal Statistics, Tabulate Area or other similar geoprocessing tools to generate a summary of the source layer data per hexagon. Examples of the resulting tabular summaries conveyed the area of each landcover class per hexagon cell (later converted to a percent), the mean tillage risk, majority landscape condition, the sum of the metres of road or number of wells within a cell, or the presence of wind turbines within each 1 km^2 hexagon cell.

TABLE 1 | Data layers used in the Zonation analysis and in post hoc analyses, and the original data sources.

Data layer	Source dataset	In final Zonation analysis
Fine-scale habitat suitability		
BTPD habitat suitability model (HSM)	Ensemble model of BTPD habitat potential, under current climate (Davidson et al. 2023)	Yes
BTPD non-habitat mask[a]	Mask layers of unsuitable habitat, based on the BTPD HSMs (Davidson et al. 2023)[a]	Yes
Habitat suitability under climate change	BTPD HSM under future climate (2100), warm and wet scenario (Davidson et al. 2023)	Yes
Habitat suitability under climate change	BTPD HSM under future climate (2100), hot and dry scenario (Davidson et al. 2023)	Yes
Landscape scale land use/land cover		
Percent cover grassland/shrubland	2016 NLCD (land cover class: 52, 71, 81; USGS 2019a)	Yes
Percent cover emergent wetland	2016 NLCD (land cover class: 95; USGS 2019a)	Yes
Percent cover of forests/woodlands	NLCD trees (USGS 2019a) + USFS % tree cover (United States Forest Service 2019) + PLJV cedar and mesquite (Playa Lakes Joint Venture)	Yes
Percent cover of grassland/shrubland in the 6 adjacent hexagons	Raster surface of % grass/shrub from NLCD (land cover class: 52, 71, 81; USGS 2019a) within 1 mile	Yes
Landscape fragmentation	Modified from Augustine et al. (2021)[b]	Yes
Oil/gas wells (well count)	Welldatabase (Welldatabase 2021)	Yes
Distance to transmission lines	(Homeland Security Infrastructure Program 2020)	Yes
Wind turbine count	FAA obstruction database (Federal Aviation Administration 2021)	Yes
Road density (primary and secondary)	US Census Tiger Roads (United States Census Bureau 2020)	Yes
Risk of future habitat loss		
Tillage risk	Olimb tillage risk (Olimb and Robinson 2019)	Yes
Land cover change	Scenario A2, projected 2050; Sohl et al. (2018)	Yes
Land cover change	Scenario A2, projected 2100; Sohl et al. (2018)	Yes
Land cover change	Scenario B2, projected 2050; Sohl et al. (2018)	Yes
Land cover change	Scenario B2, projected 2100; Sohl et al. (2018)	Yes
Land ownership		
Protected area	PAD-US (USGS 2019a)	No, Posthoc
Private lands conservation	NCED (Ducks Unlimited and The Trust for Public Land 2021) + Turner[c] + SPLT[d] + APR[e] properties	No, Posthoc
Social environment		
Political support for the environment	League of Conservation Voters Conservation Scorecard (League of Conservation Voters 2022)	Yes
Preference for prairie dog population increases	Prairie dog survey[f] (Williamson et al. 2023a, 2023b)	Yes

(Continues)

TABLE 1 | (Continued)

Data layer	Source dataset	In final Zonation analysis
Preference for federal economic incentives for prairie dog conservation	Prairie dog survey[f] (Williamson et al. 2023a, 2023b)	No, Posthoc
Preference for private economic incentives for prairie dog conservation	Prairie dog survey[f] (Williamson et al. 2023a, 2023b)	No, Posthoc
% (Conservation Reserve Program) CRP	County level CRP (USDA Farm Service Agency 2020)	Yes
Institutional capacity to actualise conservation	Count of Land and Water Conservation Fund projects (The Wilderness Society 2015)	Yes

[a]BTPD non-habitat mask: We created a layer to mask out highly unsuitable habitats. We classified highly unsuitable habitats as those areas where suitability was in the 10th (lowest) percentile for each of the BTPD HSMs generated under the current and future climate scenarios, and where soils were comprised of 90% or greater of sand.
[b]Landscape fragmentation layer: We mapped the degree of rangeland fragmentation across the historic BTPD range following the methods of Augustine et al. (2021), except that we used the 2016 NLCD as the source data layer, rather than a combination of the 2011 NLCD and USDA Cropland Data Layers. Briefly, every pixel was classified as (1) rangeland, which we defined as grassland, shrubland and improved pasture/hay cover types, (2) a fragmenting land cover type, which we defined as forest, cropland or developed lands or (3) neutral land cover types which were not rangeland, but also did not fragment adjacent rangelands. In the final fragmentation map, we set all pixels mapped as either a fragmenting or a neutral land cover type to a value of zero and then calculated the distance to the nearest fragmenting land cover type for each rangeland pixel (e.g. Figure 3 of Augustine et al. 2021).
[c]Turner Ranches. https://www.tedturner.com/turner-ranches/.
[d]Southern plains land trust properties. https://southernplains.org/en/.
[e]American Prairie (AP)" properties. https://americanprairie.org/.
[f]Prairie dog survey (Williamson et al. 2023a, 2023b): The probability that a region would support increases in prairie dog populations or support federal incentives for prairie dog conservation was based on survey responses from over 29,000 North American residents. Census tract level estimates were generated using a Bayesian multilevel regression with poststratification wherein the demographics of survey respondents were used to map the probability to Census geographies based on the demographic composition of the Census tracts.

Within the attribute table of the hexagon feature class, a series of new attribute fields were created to convey the newly summarised data (e.g. % grassland, number of wells). Using the unique hexagon IDs, the data tables of the summarised information were joined with the feature class attribute table, and the summarised data were copied into the newly created hexagon attribute fields using the 'calculate field' process. Due to the number of hexagons (over 2 million record rows) being calculated, this process often took several days so researchers later began using a python script to 'update cursor' that proved much faster than join/calculate field process. The resulting attribute table of the NHF 1-km cells provided a summary of the datasets integrated, all presummarised to the same framework for compatibility and easy use (Table S1). *S*ome source data layers like percent of CRP and the political voting data were originally in coarse (county/voting district) spatial resolutions. As a result of summarising these datasets to hexagons, the results displayed a false level of spatial precision regarding the data values conveyed. In cases where coarse data were summarised and displayed at a higher spatial resolution, many individual hexagons share the same value that originally represented the district/county as a whole, not a specific hexagon.

The hexagon feature class data were exported to a series of raster layers using the ArcMap Feature to Raster function to accommodate the conservation prioritisation software requirements that all input data be in a raster format. Output raster layers were specified to have a 90-m resolution, were snapped to the same 90-m pixels as the ensemble habitat suitability models, and the raster values were derived from the values in each of the feature class attribute fields representing the 1-km^2 hexagon summarised data. The intersect, calculate field and convert to raster processes were done in batches using the 5 × 5 degree NHF tile or by regional groupings of seven tiles for the northern half of the range and nine tiles for the southern half of the range for efficient processing. After each tile was converted to a raster layer, they were mosaiced together to create a series of rangewide raster layers and then clipped to the BTPD range boundary (Figure S2).

2.3 | Prioritisation Analysis

We used Zonation, an approach and software for spatial conservation prioritisation, to select HCP areas for the conservation of the prairie dog ecosystem. Zonation produces a hierarchical spatial priority ranking of the study region, accounting for complementarity by considering the local representation of the biodiversity features (species, ecosystem types, etc.; Moilanen et al. 2005). Zonation iteratively removes cells whose removal causes the smallest loss in feature representation across the overall remaining region until no cells are left in the region. The hierarchical conservation rank of the region is based on the order of cell removal, which is recorded and can be used later to select any given top fraction (e.g. best 25%) of the region. We used the additive benefit function (ABF) removal rule, which is based on the sum of the features represented in each cell, favouring places containing high habitat quality for a large number of biodiversity features.

The relative weighting of data layers is an important component of the Zonation algorithm and impacts the order in which cells are removed from the prioritisation landscape. Cells that contain a high-weight feature are kept longer in the analysis than cells with only low-weight features. Features with a negative weight are considered undesirable. Consequently, they

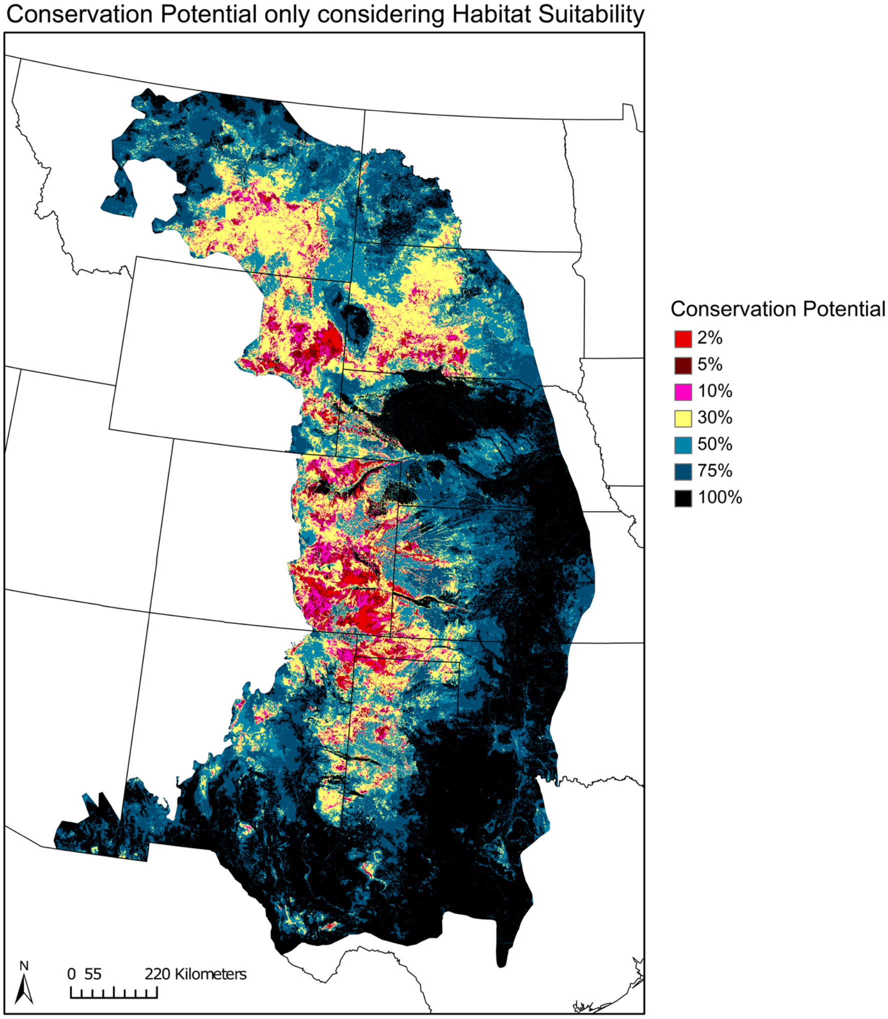

FIGURE 1 | Map of conservation potential across the black-tailed prairie dog (BTPD) geographical range within the United States, considering only habitat suitability and current climate. The priority rankings are as follows: 2% (from 0.98 to 1 of priority rank) Light red; 5% (from 0.95 to 0.979 of priority rank) Dark red; 10% (from 0.90 to 0.949 of priority rank) Pink; 30% (from 0.70 to 0.89 of priority rank) Yellow; 50% (from 0.50 to 0.79 of priority rank) Light blue; 75% (from 0.25 to 0.499 of priority rank) Dark blue; 100% (from 0.00 to 0.249 of priority rank) Black.

are found among the cells with low conservation priority and removed from the landscape early in the analysis. To identify those areas with the highest potential for prairie dog ecosystem conservation, we used a weight of 10 for spatial layers describing habitat suitability for BTPDs, a weight of 1 for landscape-scale land use/land cover features that have a positive influence on conservation potential and a weight of 1 for social environment layers with a positive influence on conservation potential. The spatial layers were considered as features in the analysis with positive values (i.e. higher values indicated favourable places for BTPD conservation). Because suitable habitat is ultimately the most important variable for conservation, we assigned habitat suitability features with the highest weighting among all positive features. We also considered land use in the selection of priorities, aiming to avoid places with high intensity of anthropogenic activities and potential conservation conflicts. Those layers within the landscape-scale land use/land cover and risk of habitat loss categories that negatively affect conservation potential were given negative weights (−4). These areas consequently had low values of conservation priority and were removed from the study region early in the analysis. Details on each feature used can be found in Table 1. Areas with low habitat suitability or high sandy soil (> 90%) were masked out of the analysis using an area mask file, where cells with value '1' were included in the analysis, while cells with value '0' were excluded (Table 1).

We used Zonation to evaluate conservation potential under various scenarios. First, we evaluated HCP areas across the geographical range of BTPDs using suitable habitats under the current climate. Next, we created scenarios that involved current and future projected suitable BTPD habitat, across the BTPD range within the United States. To do this, we used the interaction function that induces connectivity of suitable sites for the interacting features to account for distribution shifts due to climate change. Additionally, because conservation policies and funding decisions are often made by political entities, we also identified conservation priorities within each state, under both present and projected future climate. For this, we used the administrative units (ADMU) function in Zonation to also select state-level priorities in the final conservation ranking (Moilanen and Arponen 2011).

Finally, we conducted several post hoc analyses to help illuminate: (1) those areas where habitat, anthropogenic threats and the social landscape changed the priority ranking and (2) where conservation incentives may help facilitate prairie dog ecosystem conservation. We evaluated changes in priority ranking by calculating the priority value per cell when habitat, threats or social layers were included in the Zonation analysis minus the priority value of each cell when habitat, threats or social layers were excluded, respectively (see Table 1). The habitat layer was based on the percent of grass (in the NLCD and in the future projections by Sohl et al. 2018), tree and wetland cover and landscape fragmentation (i.e. mean distance to fragmenting feature). The threats layer was based on mean tillage risk, number of active wells, wind turbine count, distance to transmission lines and the density of primary and secondary roads. The social layer was based on the LCV Conservation Scorecard, percent of county-level CRP land, count of LWCF projects and the social survey by Williamson et al. (2023a, 2023b). Lastly, we evaluated the overlap of conservation priority rankings with responses from survey participants' willingness to support federal or private conservation incentives for prairie dog conservation.

3 | Results

We show extensive regions with HCP for the BTPD ecosystem when considering only habitat suitability under the current climate (Figure 1). When we considered all spatial variables (Table 1), in addition to habitat suitability, we found 96,944 km^2 (top 10%) and 359,425 km^2 (top 30%) of lands that have high conservation potential for the BTPD ecosystem across all climate scenarios (Figure 2d,e); these areas have high-quality habitat for BTPDs, intact grassland, high habitat connectivity and low threats. This represents 6% (top 10%) and 22% (top 30%), respectively, of the historical BTPD range; the entire prairie dog geographical range boundary within the United States, encompasses 1,645,749 km^2, not all of which is suitable habitat (Davidson et al. 2023). Land with the lowest conservation potential includes high elevation and urban landscapes, the Nebraska sandhills (high-quality grassland habitat, but unsuitable sandy soils) and grassland that has been converted to or is severely fragmented by cropland (much of the eastern portion of the BTPD range).

We found that landscapes with the highest conservation potential for the BTPD ecosystem were largely distributed across the western portion of the current/historical BTPD range (Figures 1, 2 and 4a). Northeastern New Mexico, eastern Colorado, eastern Wyoming, eastern Montana, far western Nebraska and western South Dakota harboured the greatest amount of HCP habitat now and into the future. Much of (but not all) of the high HCP habitat in Arizona, southern New Mexico and Texas under today's climate does not maintain such status under future climate scenarios (Figure 2d). From a rangewide perspective, the states with the largest amount of HCP habitat (top 10%) were as follows: Colorado, Montana, South Dakota, and Wyoming respectively (Table 2). These four states harbour 87% of the lands with the highest conservation potential for the BTPD ecosystem, both now and into the future.

The priorities changed dramatically when we looked by state, instead of across the entire BTPD range (Figure 3). This is to be expected because we were specifically selecting for HCP habitat *within* each state, whereby each state had its own suite of lands with high, medium and low conservation potential. In these state-based scenarios, much of the high HCP habitats in Arizona, New Mexico and Texas remained HCP under the future climate scenarios.

Rangewide, there were large differences in the amount of HCP lands across different landownership types. Most of the areas with HCP into the future (top 10%) were located on private land (65%; 63,447 km^2) (Table 3, Figure 4b). Whereas 24% (23,467 km^2) of lands with HCP were public, with 14.5% on Federal and 9.6% on State lands. Some of the strongholds (top 10%) on public land included State Trust Lands, lands managed by Bureau of Land Management (BLM) and National Grasslands (NGs) managed by the US Forest Service: Thunder Basin NG in Wyoming; Comanche NG in Colorado; Pawnee NG in Colorado; Oglala NG in Nebraska; Kiowa and Rita Blanca NGs in New Mexico, Texas and Oklahoma. Indigenous lands also supported considerable HCP area habitat (8%; 7,779 km^2). Other long-term hotspots included those on Private Conservation Lands (2%; 2,250 km^2), such as ranches managed by: American Prairie in Montana; Southern Plains Land Trust in southeastern Colorado; Turner Enterprises Inc. (multistate); The Nature Conservancy (multistate) and Malpai Border Lands Group in Arizona. Less than 4% of the top 30% of land with HCP (shown in Figures 2e and 4a) is currently protected (4,643 km^2; 1.29% of lands with PAD-US Gap 1 and Gap 2 status and 8,818.24 km^2; 2.45% of Private Conservation Lands).

Plague risk (Carlson, Bevins, and Schmid 2022) was high across most landscapes identified as having HCP (Figure 5). Indeed, 87% of the top 30% of landscapes with HCP occurred where plague risk was medium to high (Figure 5b). Few areas with HCP in the top 10% overlapped with low plague risk, these included the eastern portion of Standing Rock and Cheyenne River Reservations in South Dakota, northeastern Colorado and Arizona. Overall, the most suitable, intact habitat for the prairie dog ecosystem overlapped with medium to high plague risk (Figures 1 and 5; see also Davidson et al. 2023).

Figure 6 illuminates how priority rankings changed due to the inclusion versus exclusion of habitat, threat and social layers in the conservation prioritisation analysis. For the habitat layer (Figure 6a), intact grassland (current and future) had a strong, positive influence on conservation potential, especially throughout New Mexico, southeast Colorado, Montana, the Conata Basin region of South Dakota and the desert grasslands of southwest Arizona. Indeed, the western distribution of the BTPD range had the most extensive grassland both now and projected into the future and the least fragmented habitat overall, except for northeastern Colorado and northern Montana (Figure S1). The areas that lost priority rankings due to habitat were largely because of mountainous terrain and/or tree cover (Figure 6a). For the threats layer (Figure 6b), we found cropland development and consequent loss of intact grassland to be the most extensive habitat threat across the BTPD range both today and under projected land use change (Figure S1). The eastern portion of their range was the most impacted by cropland development, especially across the Central and Southern Plains in Texas, Oklahoma and Kansas, and across parts of the Northern Plains in Montana and North Dakota. Oil and gas development was extensive across southeast New Mexico, Texas, Oklahoma, Kansas, northeast Colorado, northwest Wyoming and some parts

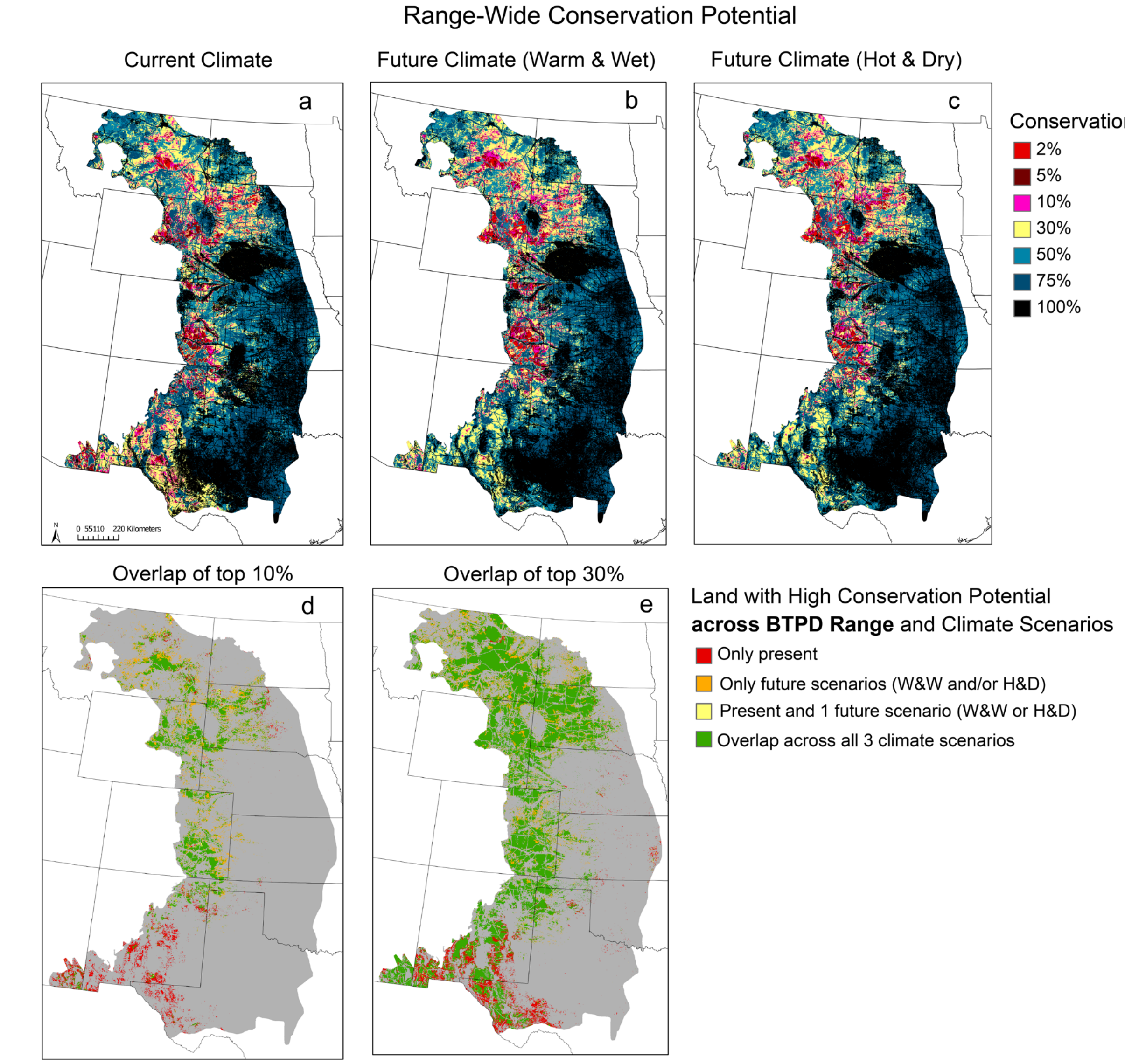

FIGURE 2 | Maps showing conservation potential across the black-tailed prairie dog geographical range under current and future climate scenarios, considering all spatial variables (see Table 1). (a) Conservation potential under the current climate; (b) conservation potential under the warm and wet (W&W) future climate scenario; (c) conservation potential under the hot and dry (H&D) future climate scenario; (d) overlap of the top 10% of lands with high conservation potential across the present and future climate scenarios; (e) overlap of the top 30% of lands with high conservation potential across the present and future climate scenarios. The priority rankings in panels a, b and c are as follows: 2% (from 0.98 to 1 of priority rank) Light red; 5% (from 0.95 to 0.979 of priority rank) Dark red; 10% (from 0.90 to 0.949 of priority rank) Pink; 30% (from 0.70 to 0.89 of priority rank) Yellow; 50% (from 0.50 to 0.79 of priority rank) Light blue; 75% (from 0.25 to 0.499 of priority rank) Dark blue; 100% (from 0.00 to 0.249 of priority rank) Black.

of Montana and North Dakota. Road densities, wind farm development and transmission lines were especially high across Texas, Oklahoma and Kansas, and across the eastern distribution of the BTPD range in general. Areas that lost priority rankings due to threats included the Texas-Oklahoma panhandle region, southwest Kansas, much of eastern Colorado and Wyoming. For the social layer (Figure 6c), a few areas exhibited positive social support for prairie dog conservation, such as in northeast New Mexico and southeast Arizona, and increased in priority rank. Unsurprisingly, there was low social support for BTPD conservation across most of the BTPD range.

Lastly, Figure S3 shows places where conservation incentives may be helpful for securing HCP habitat. These areas (in maroon) included the Thunder Basin ecoregion of northwestern Wyoming, southeast Arizona, New Mexico, southwest Texas and the panhandle, eastern Colorado, parts of Montana and South Dakota. The places in blue indicate where incentives are likely to be adopted but may fail to secure meaningful conservation, and yellow represents HCP areas that are not likely to be successfully secured with incentives. Overall, we found generally greater support for private than federal conservation incentives throughout much of the lands with HCP.

4 | Discussion

We identify extensive areas of high conservation potential habitat for BTPD ecosystem conservation, especially across the western portion of the BTPD geographical range. These HCP areas

TABLE 2 | Shows how much of the top 10% of lands with high conservation potential (identified in Figures 2d and 4a) occurs within each state.

State	Area (km^2)	%
Total	96,944	100
Colorado	24,084	24.8
Montana	19,401	20.0
South Dakota	19,331	19.9
Wyoming	18,947	19.5
New Mexico	7,082	7.3
Nebraska	2,525	2.6
Arizona	1,845	1.9
Texas	1,552	1.6
Oklahoma	1,059	1.1
North Dakota	699	0.7
Kansas	420	0.4

represent 6% (top 10%) and 22% (top 30%) of their historical distribution within the United States and remain strongholds under projected climate change. Davidson et al. (2023) identified 20.8 million hectares of suitable grassland habitat for the BTPD ecosystem, of which only 9% is currently occupied by prairie dogs (see also BTPD population estimates; McDonald et al. 2015). Here, we build on this work, showing that of the suitable habitat, 96,944 km^2 have the greatest conservation potential (the top 10%; Figures 2d and 4a) when also considering the threat, social and political landscapes, future climate and habitat connectivity. Our findings highlight the large conservation potential for BTPDs and associated species, especially those that depend on extensive prairie dog colony complexes and intact habitat to support their populations.

Much of the HCP habitat is located across regions where extensive, intact grassland habitat remains. These areas were also located where climate, soils and topography were most suitable for BTPDs. The suitable soils had medium to high clay content, organic matter, pH and low sand content (Davidson et al. 2023), which reflects their preference for clayey-loam soils when burrowing and mound building (Augustine et al. 2012). Regions like the Nebraska Sandhills have extensive, intact grasslands, but have unsuitable soils for prairie dogs (Davidson et al. 2023). The HCP habitats we found were located in areas that also had low topographical ruggedness (Davidson et al. 2023), as BTPDs do not associate with montane habitats and are often found around 700–1700 m elevation (Hoogland 1995). HCP areas were located where a suitable climate exists for the BTPD ecosystem, which is characterised by intermediate levels of net primary productivity, with relatively high winter–spring precipitation, and moderate summer–fall precipitation (Davidson et al. 2023). These climate variables reflect the importance of forage resources during offspring production in the spring (Zaks et al. 2007; Davidson et al. 2014; Hayes, Talbot, and Wolf 2016) and the need for sufficient forage resources for overwinter survival, while too much summer–fall precipitation can result in tall vegetation that can hamper colony growth (Grassel, Rachlow, and Williams 2016; Bruggeman and Licht 2020).

The HCP areas we identified expanded significantly across the northern distribution of their range under the future climate projections (Davidson et al. 2023). In contrast, the southern distribution of their range became less optimal habitat in the future (Davidson et al. 2023), which is the underlying driver for the HCP area shifts under a changing climate in our analysis (Figure 2). Indeed, prairie dog colonies in the southern distribution of the BTPD range are already in decline in part due to increasing intensity and frequency of drought under climate change (Ceballos et al. 2010; Facka et al. 2010; Hale, Koprowski, and Hicks 2013; Davidson et al. 2014, 2018; Hayes, Talbot, and Wolf 2016). We suggest BTPD conservation might be best maximised by focusing on those areas we highlight in Figure 4a that have HCP under both current and projected future climate. Our analysis also highlights HCP areas in the southern part of the range, such as northeastern New Mexico, that may remain priorities well into the future and be worthy of conservation investment from a rangewide perspective.

Plague risk was relatively high across much of the land we identified as having HCP, as well as where grassland habitat for the prairie dog ecosystem was most suitable and intact (Carlson, Bevins, and Schmid 2022; Figure 5). We evaluated plague risk post hoc, instead of as a variable in our conservation planning analysis, because plague is now endemic across much of the remaining habitat for the prairie dog ecosystem (Davidson et al. 2023; Carlson, Bevins, and Schmid 2022). Additionally, the plague-prairie dog system is complex and poorly understood, creating too much uncertainty when identifying lands with HCP now and into the future. Epizootics are a result of a suite of interactions among climate, landscape connectivity, colony sizes, metapopulation dynamics and host and vector population densities (Collinge et al. 2005; Snäll et al. 2008; Johnson et al. 2011; George et al. 2013; Eads, Biggins, Long et al. 2016; Eads and Hoogland 2017; Biggins and Eads 2019; Barrile et al. 2023), and there remains different hypotheses about how future climate change might alter plague dynamics across the BTPD range (Snäll, Benestad, and Stenseth 2009; Eads and Biggins 2017; Eads and Hoogland 2017; Carlson, Bevins, and Schmid 2022). But, it appears climate change is increasing plague risk across the BTPD range (Carlson, Bevins, and Schmid 2022). Conservation planning for the BTPD system would benefit from a better understanding of plague dynamics in general and from a rangewide perspective of where plague vulnerability is greatest today and where it may increase or decrease under a changing climate. There is a suite of tools currently available to mitigate the impact of plague, often administered in areas considered high priority for BTPD ecosystem conservation and black-footed ferret recovery. These include administering deltamethrin dust to BTPD burrows and/or fipronil grain bait to reduce flea abundance, and/or the oral sylvatic plague vaccine for prairie dogs (Rocke et al. 2017; Biggins, Godbey, and Eads 2021; Eads et al. 2022). Our work, here, highlights that such plague mitigation efforts will be important for colonies selected for conservation prioritisation across most of the habitat that has been identified as having HCP, with a few potential exceptions (Figure 5). Future research might explore how the HCP areas and the spatial

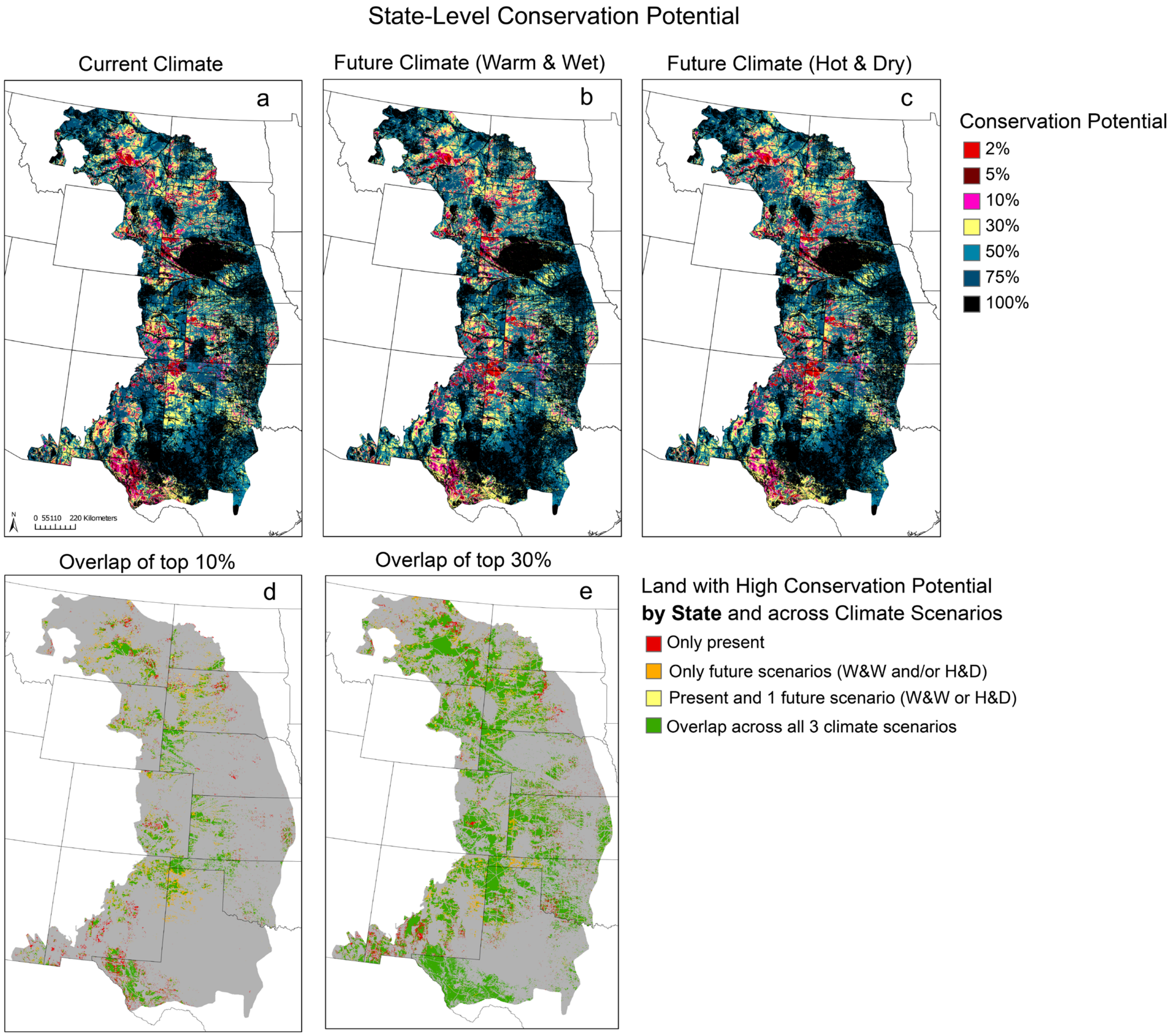

FIGURE 3 | Maps showing state-level conservation potential across the black-tailed prairie dog geographical range under current and future climate scenarios, considering all spatial variables (see Table 1). (a) Conservation potential under the current climate; (b) conservation priorities under the warm and wet (W&W) future climate scenario; (c) conservation potential under the hot and dry (H&D) future climate scenario; (d) overlap of the top 10% of lands with high conservation potential across the present and future climate scenarios; (e) overlap of the top 30% of lands with high conservation potential across the present and future climate scenarios. The priority rankings in panels a, b and c are as follows: 2% (from 0.98 to 1 of priority rank) Light red; 5% (from 0.95 to 0.979 of priority rank) Dark red; 10% (from 0.90 to 0.949 of priority rank) Pink; 30% (from 0.70 to 0.89 of priority rank) Yellow; 50% (from 0.50 to 0.79 of priority rank) Light blue; 75% (from 0.25 to 0.499 of priority rank) Dark blue; 100% (from 0.00 to 0.249 of priority rank) Black.

plague model (Carlson, Bevins, and Schmid 2022) could be used to help inform which areas have the greatest need for plague mitigation and how to best focus such efforts.

State-based conservation priorities differed considerably from rangewide priorities, under both current and future climate scenarios. The largest difference was among the southern states (Arizona, New Mexico and Texas), where climate change reduces the conservation priorities across this region more when viewed from a rangewide perspective than when viewed from a state-level perspective. Additionally, from a rangewide perspective, the eastern states have fewer areas with HCP compared to the western states within the BTPD range, but when viewed from a state-level perspective there are considerably more areas with HCP. We expected such differences because our question was aimed at understanding the HCP areas within each state, so the analysis sought conservation solutions within each of the states' boundaries. Identifying state-based conservation priorities is important because funding sources and management priorities are often focused at the state level, and not rangewide (Meretsky et al. 2012; Lacher and Wilkerson 2013; Riley et al. 2020). This way, each state has information on conservation priorities within its own jurisdictional boundaries. We suggest each state focus conservation efforts for the BTPD ecosystem, especially in those areas highlighted in green in Figure 3d,e that remain priorities into the future at the state level, while also considering those priorities identified within their state under the rangewide perspective (Figure 2d,e).

The BTPD ecosystem faces a suite of extrinsic threats. Plague is perhaps the greatest threat facing their populations and that of associated species, followed by lethal control, shooting and habitat loss (Hoogland 2006). We found that the conversion of grasslands to croplands and consequent fragmentation was the overwhelming threat causing habitat loss across the BTPD range (Figure S1). Indeed, the loss of native prairie to agriculture has been and is predicted to be greatest across the eastern part of the BTPD range (Davidson et al. 2023; Sohl et al. 2012; Lark et al. 2020; Augustine et al. 2021; Olimb et al. 2022). Our analysis does not explicitly evaluate the loss of grassland habitat through desertification, as conversion of grasslands to shrublands across the southern distribution of their range has occurred prior to the spatial data on landcover that we used (from 2016; USGS 2019a). But, we know that extensive regions where prairie dogs formerly were abundant across the southwest and northern Mexico are no longer occupied by the BTPD ecosystem (Weltzin, Archer, and Heitschmidt 1997; Ceballos et al. 2010; Hale, Koprowski, and Hicks 2013; Davidson et al. 2014). These desert grasslands continue to be vulnerable to desertification with the ongoing combination of overgrazing by livestock and warming climate, reducing their long-term potential as HCP habitat (Ceballos et al. 2010; Gutzler and Robbins 2010; Hale, Koprowski, and Hicks 2013; Davidson et al. 2014). Although prairie dogs themselves probably are not that impacted by oil and gas development, wind farms, roads and transmission lines (especially common across the eastern distribution of their range), they all increase grassland fragmentation and the presence of humans (Augustine et al. 2021). Smaller, fragmented colonies are less able to support the populations of species that

TABLE 3 | Shows how much high potential conservation habitat (top 10%, identified in Figures 2d and 4a) overlaps with different landownership categories, across the black-tailed prairie dog geographical range (based on PADUS, NCED and our private conservation lands layer; see Table 1).

Landownership	Area (km^2)	%
Total	96,944	100.0
Private	63,447	65.4
Federal	14,021	14.5
State	9,347	9.6
Indigenous lands	7,779	8.0
NGO/private conservation	2,250	2.3
Local/regional	100	0.1

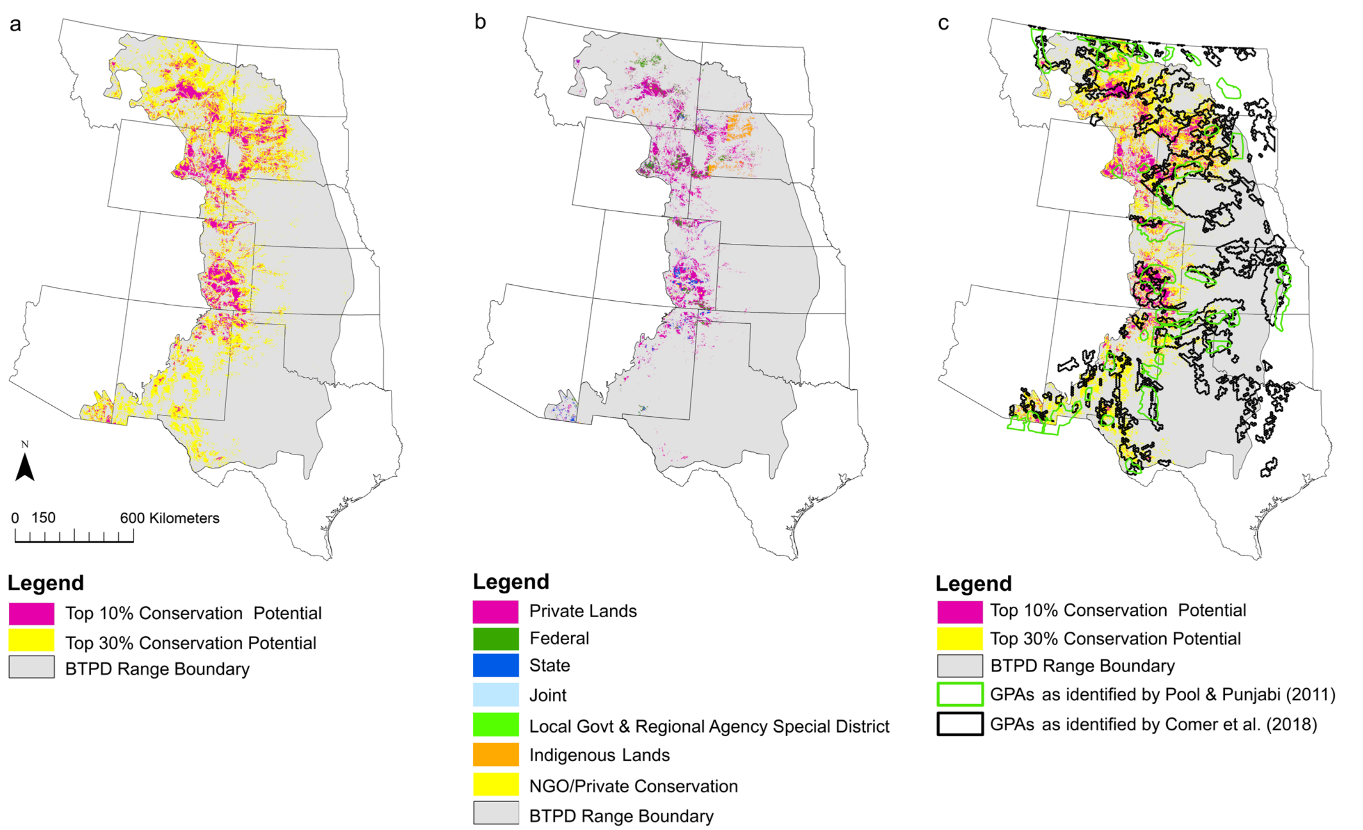

FIGURE 4 | Maps of (a) the intersection of the top 10% and 30% of areas with high conservation potential for the black-tailed prairie dog ecosystem (across the three climate scenarios (Figure 2 respectively)), (b) those same top 10% of areas with high conservation potential intersected with different landownership types (data are from PAD-US (USGS 2019b) and NCED and other Private Land Conservation areas, Table 1; see also Table 3) and (c) the top 10% and 30% of areas with high conservation potential (as in panel a) overlapped with grassland priority areas (GPAs) for the Central Grasslands identified by Pool and Panjabi (2011) and by Comer et al. (2018).

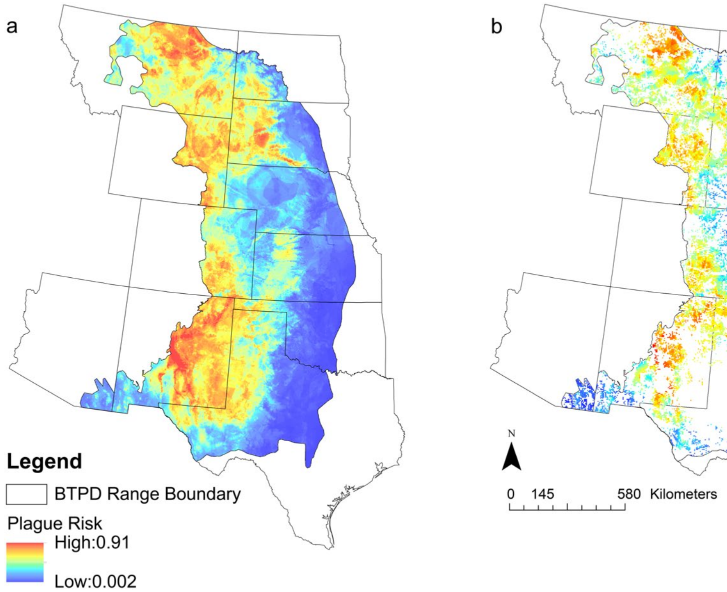

FIGURE 5 | Maps of plague risk (a) across the black-tailed prairie dog geographical range within the United States (data from wildlife model presented in Figure 1 of Carlson, Bevins, and Schmid 2022) and (b) within the top 30% of areas with high conservation potential.

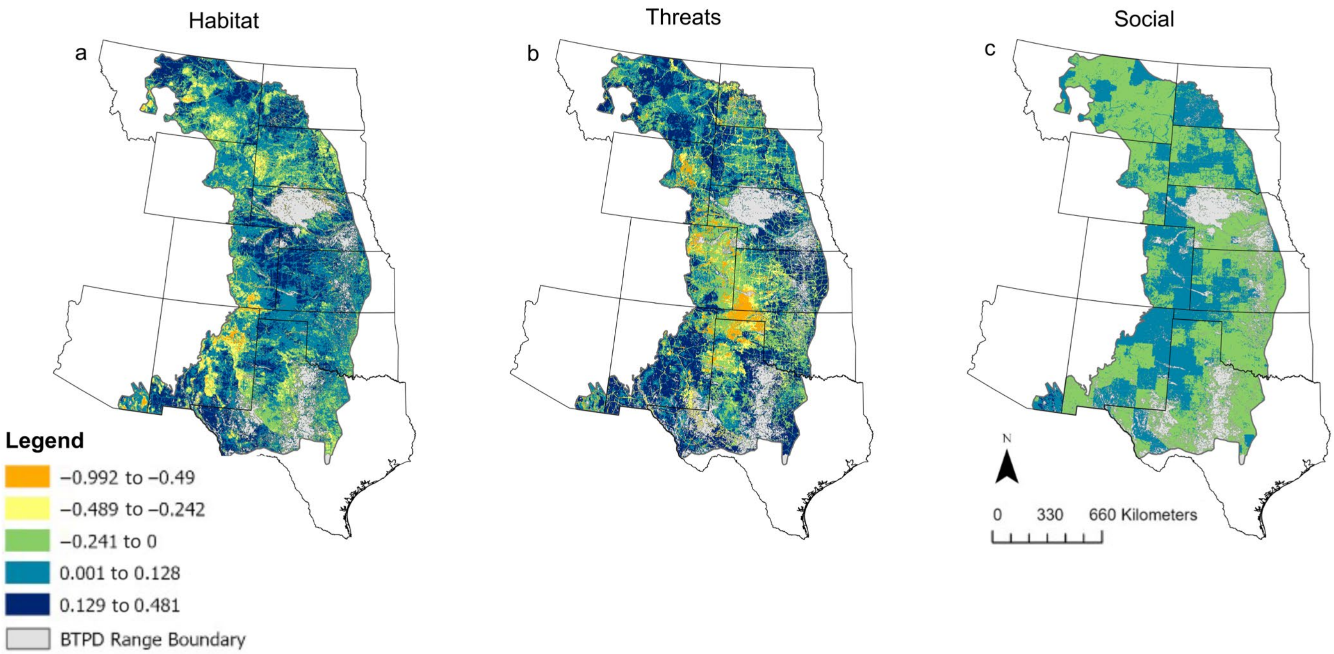

FIGURE 6 | Maps show the change in the conservation potential when (a) habitat (b) anthropogenic threats and (c) social layers were included versus excluded from the analysis shown in Figure 2a. Change in conservation potential was calculated by obtaining priority value per cell when (a) habitat (b) threats and (c) social layers were included in the model minus the priority values when (a) habitat (b) threats and (c) social layers were excluded respectively. The positive values show places where conservation potential (represented in Figure 2a) was increased by the presence of (a) quality habitat (b) low threats and (c) social support for prairie dog conservation, whereas negative values show areas that lost conservation potential due to (a) poor habitat quality (b) high threats and (c) low social support for prairie dog conservation. The original social data are from Williamson et al. (2023a, 2023b). Grey areas represent masked-out regions of unsuitable habitat (see Table S1).

depend on large, connected prairie dog colony complexes, such as mountain plovers, black-footed ferrets and other mesocarnivores and raptors (Duchardt et al. 2023; Augustine and Baker 2013; Augustine and Skagen 2014; Davidson, Detling, and Brown 2012; Duchardt, Beck, and Augustine 2020; Livieri et al. 2022; U.S. Fish and Wildlife Service 2013). Additionally, the greater presence of humans increases the likelihood of prairie dogs being shot and occurrence of plague epizootics, and high levels of development and anthropogenic activity may negatively impact the behaviour and populations of associated species (Pauli and Buskirk 2007;

Lendrum, Crooks, and Wittemyer 2017; Biggins and Eads 2019; Chalfoun 2021).

Somewhat surprisingly, we found that general spatial patterns of HCP areas, across present and future climate scenarios, were not strongly impacted by the social and political data layers used in our analysis. Indeed, most of the HCP areas we identified remained priorities when we removed the social layers in our analysis, even when we increased the weightings of the social data in our analysis. Habitat suitability, habitat connectivity and threats played a larger role in determining the potential landscapes for conservation priority in our analysis. This makes good sense, as the primary goal when identifying conservation priorities for on-the-ground implementation should be to protect and restore habitat that is most suitable, followed by the surrounding landscape potential and threat presence (Margules and Pressey 2000; Watson et al. 2011). Secondary to this should be the relative ease or difficulty in securing those HCP habitats (Watson et al. 2011). For example, when evaluating two high-quality patches of habitat, managers might choose to focus their efforts in areas with greater social support and institutional capacity for actualising conservation action (Figure 5c and Figure S3; Watson et al. 2011).

The social landscape was relatively similar across the BTPD range, with regard to social support for their conservation (Figure S1). This lack of large variability in social support likely explains why the social data in our analysis did not have a larger influence on the HCP area locations. Additionally, the social data we used may not have captured the full depth of the social and political landscapes well enough; indeed, reflecting human attitudes and perspectives in a spatial framework is complex and challenging (Ban et al. 2013). Nevertheless, our conservation planning analysis provides a novel assessment of priorities by including social and political spatial data, and spatial social data specific to BTPDs (Williamson et al. 2023a, 2023b). Inclusion of such data layers is lacking in most spatial conservation planning efforts, largely because of the paucity of available data and difficulty of obtaining it in a meaningful way (Knight and Cowling 2007; Knight et al. 2008; Ban et al. 2013; Whitehead et al. 2014). We strongly encourage more research in this area to gain much needed insights into the social and political landscapes for future spatial conservation planning, as it has the potential to provide much needed insights for on-the-ground conservation implementation.

Landownership also plays an important role in on-the-ground conservation potential (Table 3, Figure 4b; Burger et al. 2019; Dawson et al. 2019; Maxwell et al. 2020; Augustine et al. 2021). Most (65%) of the top 10% of land with HCP, across all three climate scenarios, were located on private land, compared to public land (24%). However, across the western distribution of the BTPD range, there remains considerable public land, especially federal and state land, and indigenous land (8%) that may provide valuable opportunities for conservation of the BTPD ecosystem. Yet, the extent to which private, public and indigenous lands will support BTPD ecosystem conservation, is strongly influenced by the social and political landscapes within which they are embedded. While the prairie dog ecosystem faces numerous threats from plague and habitat loss, the social landscape is often considered the greatest and most challenging barrier to successful conservation of the BTPD ecosystem (Miller et al. 2007; Augustine et al. 2021). To facilitate co-existence between BTPDs and humans, incentive programmes, grass banks to mitigate economic losses from ranching during droughts and other local community-based conservation solutions are needed (Augustine and Derner 2021; Crow et al. 2022). Our maps can be used to guide where might be best to focus conservation incentive programmes with private landowners, for example, such as the NRCS incentive programme that pays private landowners for maintaining BTPD colonies to support black-footed ferret recovery (NRCS 2023). Managers can identify which landowners to include in the incentive programme, based on where they occur within the HCP landscapes. Likewise, funds and efforts to create grassbanks can be focused on those lands that are in HCP hotspots. The landownership maps and their relationship to the HCP landscapes we identify underscore the importance of working with private landowners and local communities when implementing conservation measures to support BTPD ecosystem conservation.

Most (> 96%) of the HCP habitat we identify is not located within already protected areas. This assessment is based on those areas that have been identified as Gap 1 or Gap 2 status within the Protected Areas Database (USGS 2019b). Examples of Gap 1 protected areas include National Parks and Wilderness Areas, and of Gap 2 include National Wildlife Refuges, State Parks and The Nature Conservancy Preserves. Our assessment also includes those lands we identify as 'Private Conservation Lands', which included properties owned by the American Prairie, Turner Enterprises Inc. and Southern Plains Land Trust because they are private lands properties with a focus on BTPD ecosystem conservation. National Forests, BLM Lands, State Forests and some State Parks, are under Gap Status 3, and while some of these lands, as well as Tribal lands, may be partially managed for conservation, we did not include them in our assessment of how Protected Areas overlap with the HCP areas we identify. There are numerous conservation easements on private lands throughout our study region that also are not included in our assessment, because we found the data to be inconsistent and unreliable (see also Ducks Unlimited and Trust for Public Land 2023). Yet, even if a private lands property has a conservation easement, this does not necessarily translate into BTPD ecosystem protection. Despite the limitations of our protected areas assessment, our analysis shows that most grasslands throughout the BTPD currently lack an explicit mandate to promote the conservation of the BTPD ecosystem.

The HCP areas we identify encompassed or overlapped with many of the regions also identified in other landscape-level conservation priority analysis for the Central Grasslands (Comer et al. 2018; Pool and Panjabi 2011), but we also illuminate extensive, additional regions of grassland priority. NatureServe identified potential conservation areas (PCAs) based on long-term trends, species of concern, current level of protection and landscape intactness and connectivity, across the Central Grasslands (Comer et al. 2018). Our HPC areas overlapped with these PCAs across much of the intact western grasslands within the BTPD range (Figure 4c). They also overlapped with many of the grassland priority conservation areas (GPCAs) identified by the Commission for Environmental Cooperation and The Nature Conservancy, based on ecoregion representation, condition of native grassland and 20 focal grassland-dependent species (BTPDs and 18 species of grassland birds) (Pool and Panjabi 2011). Again, most of the areas of overlap were across the western distribution of the BTPD range (see Pool and Panjabi 2011). Differences among these more generalised grassland conservation priorities with those of the BTPD ecosystem were mostly in the eastern portion of the historic BTPD range where their suitable habitat declines under today's existing grassland landscape (Augustine et al. 2021; Davidson et al. 2023).

5 | Conservation Implications and Conclusions

Prairie dogs are a keystone species of the central grasslands of North America, and consequently, they are often at the centre of grassland conservation efforts. Yet, conservation of the BTPD ecosystem is fraught with complex challenges that include: (1) the non-native disease, plague, that devastates BTPD populations and that of some associated species (Cully et al. 2010; USFWS 2013; Eads and Biggins 2015); (2) widespread habitat loss (Davidson et al. 2023; Augustine et al. 2021) and (3) high conflict with human activities, especially ranching (Detling 2006; Miller et al. 2007; Augustine and Derner 2021; Crow et al. 2022). The duality of being ecologically important while also being in high conflict with humans creates one of the greatest conservation challenges facing North America's Central Grasslands. Finding solutions to facilitate the co-existence of BTPDs and humans is central to the conservation of the BTPD ecosystem, but to date remains largely lacking and remarkably inadequate.

Here, we provide maps that identify the best locations to focus limited conservation resources for the BTPD ecosystem, both now and into the future. These maps can be explored down to 90 m resolution. The algorithm we used in our conservation planning analysis created a conservation value for each cell across the gridded geographical landscape of the BTPD range, based on climate, land use, habitat suitability and social and institutional support for conservation. Through this insight, our maps provide decision support for where limited conservation resources might best be invested and where conservation goals have the best chance of being actualised. Furthermore, the maps can inform efforts like the Central Grasslands Roadmap, and be overlaid with priority landscapes identified for other umbrella species or functional groups, such as the lesser prairie-chicken (*Tympanuchus pallidicinctus*), greater sage-grouse (*Centrocercus urophasianus*), grassland birds, bison and biodiversity conservation in general (Sanderson et al. 2008; Van Pelt et al. 2013; Reeves et al. 2014; Jenkins et al. 2015; Gary et al. 2019; Central Grasslands Roadmap 2022; Dreiss et al. 2024), in addition to those identified by (Pool and Panjabi 2011 and Comer et al. 2018). Doing so, can provide a more complete picture of where to focus conservation resources across the Central Grasslands and inform efforts aimed at conserving 30% of United States lands and waters by the year 2030 (EOP 2021).

Author Contributions

Ana D. Davidson: conceptualization, data curation, methodology, formal analysis, writing – original draft, editing and review, visualization, supervision, project administration. **Fernanda Thiesen Brum:** methodology, formal analysis, writing – editing and review. **Michael Houts:** data curation, methodology, formal analysis, writing – review. **Michael Menefee:** conceptualization, visualization, writing – review. **Matt Williamson:** methodology, visualization, writing – review. **Lindsey Sterling Krank:** conceptualization, visualization, project administration, funding acquisition, writing – review. **Bill Van Pelt:** funding acquisition, visualization, writing –review. **David J. Augustine:** conceptualization, visualization, methodology, writing – editing and review.

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Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability Statement

The data that support the findings of this study are openly available through Data Dryad: https://doi.org/10.5061/dryad.wpzgmsbr5.

The Homes on the Range project web page can be found here, where the data also is publically available for download: https://cnhp.colostate.edu/projects/hotr/.

Additionally, an interactive web page is available for users to explore the maps without having to download the data: https://kars.geoplatform.ku.edu/maps/KU::black-tailed-prairie-dog-conservation-priority-areas-1/about.

Peer Review

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1111/ddi.13945.

References

Augustine, D. J., W. E. Armstrong, J. F. Cully, and M. F. Antolin. 2012. "*Black-Tailed Prairie Dog Habitat Suitability Modeling for the Southern Great Plains: Cross-Scale Analysis of Soils, Topography and Climate. Final GLCC Report With 28 Map Products and 73 County-Level Geodatabases*."

Augustine, D. J., and B. W. Baker. 2013. "Associations of Grassland Bird Communities with Black-Tailed Prairie Dogs in the North American Great Plains." *Conservation Biology* 27: 324–334.

Augustine, D. J., A. D. Davidson, K. Dickinson, and B. Van Pelt. 2021. "Thinking Like a Grassland: Challenges and Opportunities for Biodiversity Conservation in the Great Plains of North America." *Rangeland Ecology & Management* 78: 281–295.

Augustine, D. J., and J. D. Derner. 2012. "Disturbance Regimes and Mountain Plover Habitat in Shortgrass Steppe: Large Herbivore Grazing Does Not Substitute for Prairie Dog Grazing or Fire." *Journal of Wildlife Management* 76: 721–728.

Augustine, D. J., and J. D. Derner. 2021. "Long-Term Effects of Black-Tailed Prairie Dogs on Livestock Grazing Distribution and Mass Gain." *Journal of Wildlife Management* 85: 1332–1343.

Augustine, D. J., and S. K. Skagen. 2014. "Mountain Plover Nest Survival in Relation to Prairie Dog and Fire Dynamics in Shortgrass Steppe." *Journal of Wildlife Management* 78: 595–602.

Ban, N. C., M. Mills, J. Tam, et al. 2013. "A Social-Ecological Approach to Conservation Planning: Embedding Social Considerations." *Frontiers in Ecology and the Environment* 11: 194–202.

Barrile, G. M., D. J. Augustine, L. M. Porensky, et al. 2023. "A Big Data–Model Integration Approach for Predicting Epizootics and Population Recovery in a Keystone Species." *Ecological Applications* 33: 1–23.

Bayless, T. A., and P. Beier. 2011. "Occurrence and Habitat Characteristics of Burrowing Owl Nests in Gunnison's Prairie Dog Colonies of Northeastern Arizona." *Journal of the Arizona-Nevada Academy of Science* 42: 65–74.

Biggins, D. E., and D. A. Eads. 2019. "Prairie Dogs, Persistent Plague, Flocking Fleas, and Pernicious Positive Feedback." *Frontiers in Veterinary Science* 6: 1–12.

Biggins, D. E., J. L. Godbey, and D. A. Eads. 2021. "Epizootic Plague in Prairie Dogs: Correlates and Control With Deltamethrin." *Vector-Borne and Zoonotic Diseases* 21: 172–178.

Bruggeman, J. E., and D. S. Licht. 2020. "Drought-Mediated Changes in Black-Tailed Prairie Dog Colonies in the Northern Great Plains." *Journal of Mammalogy* 101: 1–16.

Burger, L. W., K. O. Evans, M. D. Mcconnell, and L. M. Burger. 2019. "Private Lands Conservation: A Vision for the Future." *Wildlife Society Bulletin* 43: 398–407.

Carlson, C. J., S. N. Bevins, and B. V. Schmid. 2022. "Plague Risk in the Western United States Over Seven Decades of Environmental Change." *Global Change Biology* 28: 753–769.

Carroll, C., J. R. Dunk, and A. Moilanen. 2010. "Optimizing Resiliency of Reserve Networks to Climate Change: Multispecies Conservation Planning in the Pacific Northwest, USA." *Global Change Biology* 16: 891–904.

Ceballos, G., A. Davidson, R. List, et al. 2010. "Rapid Decline of a Grassland System and Its Ecological and Conservation Implications." *PLoS One* 5: e8562.

Central Grasslands Roadmap. 2022. "*The Central Grasslands Roadmap Appendices*." https://www.tedturner.com/turner-ranches/.

Chalfoun, A. D. 2021. "Responses of Vertebrate Wildlife to Oil and Natural Gas Development: Patterns and Frontiers." *Current Landscape Ecology Reports* 6: 71–84.

Collinge, S. K., W. C. Johnson, C. Ray, et al. 2005. "Landscape Structure and Plague Occurrence in Black-Tailed Prairie Dogs on Grasslands of the Western USA." *Landscape Ecology* 20: 941–955.

Comer, P. J., J. C. Hak, K. Kindscher, E. Muldavin, and J. Singhurst. 2018. "Continent-Scale Landscape Conservation Design for Temperate Grasslands of the Great Plains and Chihuahuan Desert." *Natural Areas Journal* 38: 196–211.

Connell, L. C., L. M. Porensky, and J. D. Scasta. 2019. "Prairie Dog (*Cynomys ludovicianus*) Influence on Forage Quantity and Quality in a Grazed Grassland-Shrubland Ecotone." *Rangeland Ecology & Management* 72: 360–372.

Crow, L., L. Porensky, D. Augustine, J. Ritten, C. Bastian, and S. Paisley. 2022. "Evaluating Economic Impacts of Prairie Dog–Cattle Competition on Ranching Enterprises in the Western Great Plains." *Rangeland Ecology & Management* 85: 56–65.

Cully, J. F., T. L. Johnson, S. K. Collinge, and C. Ray. 2010. "Disease Limits Populations: Black-Tailed Prairie Dogs." *Vector Borne and Zoonotic Diseases* 10: 7–15.

Dan Flores. 2017. *American Serengeti: The Last Big Animals of the Great Plains*. Lawrence: University Press of Kansas.

Davidson, A. D., D. J. Augustine, H. Jacobsen, et al. 2022. "Boom and Bust Cycles of Black-Tailed Prairie Dog Populations in the Thunder Basin Grassland Ecosystem." *Journal of Mammalogy* 103: 1112–1126.

Davidson, A. D., J. K. Detling, and J. H. Brown. 2012. "Ecological Roles and Conservation Challenges of Social, Burrowing, Herbivorous Mammals in the world's Grasslands." *Frontiers in Ecology and the Environment* 10: 477–486.

Davidson, A. D., M. Fink, M. Menefee, L. Sterling-krank, W. E. Van Pelt, and D. J. Augustine. 2023. "Present and Future Suitable Habitat for the Black-Tailed Prairie Dog Ecosystem." *Biological Conservation* 286: 110241.

Davidson, A. D., M. T. Friggens, K. T. Shoemaker, C. L. Hayes, J. Erz, and R. Duran. 2014. "Population Dynamics of Reintroduced Gunnison's Prairie Dogs in the Southern Portion of Their Range." *Journal of Wildlife Management* 78: 429–439.

Davidson, A. D., E. A. Hunter, J. Erz, et al. 2018. "Reintroducing a Keystone Burrowing Rodent to Restore an Arid North American Grassland: Challenges and Successes." *Restoration Ecology* 26: 909–920.

Dawson, S. J., L. Broussard, P. J. Adams, et al. 2019. "An Outback Oasis: The Ecological Importance of Bilby Burrows." *Journal of Zoology* 308: 149–163.

Detling, J. K. 2006. "Do Prairie Dogs Compete With Livestock?" In *Conservation of the Black-Tailed Prairie Dog: Saving North America's Western Grasslands*, edited by J. L. Hoogland, 65–88. Washington, DC: Island Press.

Dreiss, L. M., M. G. Anderson, B. L. Bateman, R. T. Belote, J. L. Michalak, and M. B. Rice. 2024. "Agreeing That Maps Can Disagree: Moving Away From Map Confusion in Conservation." *Bioscience* 74: 281–289.

Duchardt, C. J., D. J. Augustine, and J. L. Beck. 2019. "Threshold Responses of Grassland and Sagebrush Birds to Patterns of Disturbance Created by an Ecosystem Engineer." *Landscape Ecology* 34: 895–909.

Duchardt, C. J., D. J. Augustine, L. M. Porensky, et al. 2023. "Disease and Weather Induce Rapid Shifts in a Rangeland Ecosystem Mediated by a Keystone Species (*Cynomys ludovicianus*)." *Ecological Applications* 33: 1–19.

Duchardt, C. J., J. L. Beck, and D. J. Augustine. 2020. "Mountain Plover Habitat Selection and Nest Survival in Relation to Weather Variability and Spatial Attributes of Black-Tailed Prairie Dog Disturbance." *Condor* 122: 1–15.

Ducks Unlimited & The Trust for Public Land. 2021. "National Conservation Easment Database (NCED)." https://www.conservationeasement.us/.

Ducks Unlimited & Trust for Public Land. 2023. "National Conservation Easment Database (NCED): Completness." https://www.conservationeasement.us/completeness/.

Eads, D., T. Livieri, T. Tretten, et al. 2022. "Assembling a Safe and Effective Toolbox for Integrated Flea Control and Plague Mitigation: Fipronil Experiments With Prairie Dogs." *PLoS One* 17: 1–19.

Eads, D. A., and D. E. Biggins. 2015. "Plague Bacterium as a Transformer Species in Prairie Dogs and the Grasslands of Western North America." *Conservation Biology* 29: 1086–1093.

Eads, D. A., and D. E. Biggins. 2017. "Paltry Past-Precipitation: Predisposing Prairie Dogs to Plague?" *Journal of Wildlife Management* 81: 990–998.

Eads, D. A., D. E. Biggins, S. M. Grassel, T. M. Livieri, and D. S. Licht. 2016. "Interactions Among American Badgers, Black-Footed Ferrets, and Prairie Dogs in the Grasslands of Western North America." In *Badgers: Systematics, Biology, Conservation and Research Techniques*, edited by G. Proulx and E. Do Linh San, 193–218. Sherwood Park: Alpha Wildlife Publications.

Eads, D. A., D. E. Biggins, D. H. Long, K. L. Gage, and M. F. Antolin. 2016. "Droughts May Increase Susceptibility of Prairie Dogs to Fleas: Incongruity With Hypothesized Mechanisms of Plague Cycles in Rodents." *Journal of Mammalogy* 97: 1044–1053.

Eads, D. A., and J. L. Hoogland. 2017. "Precipitation, Climate Change, and Parasitism of Prairie Dogs by Fleas That Transmit Plague." *Journal of Parasitology* 103: 309–319.

EOP (Executive Office of the President). 2021. "Executive Order 14008–Tackling the Climate 491 Crisis at Home and Abroad. 86 FR 7619."

Facka, A. N., G. W. Roemer, V. L. Mathis, M. Kam, and E. Geffen. 2010. "Drought Leads to Collapse of Black-Tailed Prairie Dog Populations Reintroduced to the Chihuahuan Desert." *Journal of Wildlife Management* 74: 1752–1762.

Federal Aviation Administration. 2021. "Digital Obstruction File." https://www.faa.gov/air_traffic/flight_info/aeronav/digital_products/dof/.

Finch, D. 2018. "Great Plains Grassland Summit: Challenges and Opportunities From North To South." https://westernforestry.org/upcoming-conference-2nd-page/great-plains-grassland-summit-agenda.

Gary, D., K. Mougey, N. E. McIntyre, and K. L. Griffis-Kyle. 2019. "Identification of Hotspots of At-Risk Terrestrial Vertebrate Species in the South-Central Great Plains of North America: A Tool to Inform and Address Regional-Scale Conservation." *Journal for Nature Conservation* 50: 125684.

Gary, D. M., K. Mougey, N. E. McIntyre, and K. L. Griffis-Kyle. 2022. "Species as Conservation Umbrellas: A Case Study With Lesser Prairie-Chicken (*Tympanuchus pallidicinctus*) in the Southern Great Plains of North America." *Global Ecology and Conservation* 38: e02256.

Gelman, A. 2007. "Struggles With Survey Weighting and Regression Modeling." *Statistical Science* 22: 153–164.

George, D. B., C. T. Webb, K. M. Pepin, L. T. Savage, and M. F. Antolin. 2013. "Persistence of Black-Tailed Prairie-Dog Populations Affected by Plague in Northern Colorado, USA." *Ecology* 94: 1572–1583.

Goodrich, J. M., and S. W. Buskirk. 1998. "Spacing and Ecology of North American Badgers (*Taxidea taxus*) in a Prairie-Dog (*Cynomys leucurus*) Complex." *Journal of Mammalogy* 79: 171–179.

Grassel, S. M., J. L. Rachlow, and C. J. Williams. 2015. "Spatial Interactions Between Sympatric Carnivores: Asymmetric Avoidance of an Intraguild Predator." *Ecology and Evolution* 5: 2762–2773.

Grassel, S. M., J. L. Rachlow, and C. J. Williams. 2016. "Reproduction by Black-Tailed Prairie Dogs and Black-Footed Ferrets: Effects of Weather and Food Availability." *Western North American Naturalist* 76: 405–416.

Gregory, R., L. Failing, M. Harstone, G. Long, T. McDaniels, and D. Ohlson. 2012. *Structured Decision Making: A Practical Guide to Environmental Management Choices*. Chichester: John Wiley & Sons.

Gutzler, D. S., and T. O. Robbins. 2010. "Climate Variability and Projected Change in the Western United States: Regional Downscaling and Drought Statistics." *Climate Dynamics* 37: 835–849.

Haaland, D., T. J. Vilsack, G. M. Raimondo, and B. Mallory. 2021. "*Conserving and Restoring America the Beautiful*."

Hale, S. L., J. L. Koprowski, and H. Hicks. 2013. "Review of Black-Tailed Prairie Dog Reintroduction Strategies and Site Selection: Arizona Reintroduction." In *USDA For. Serv. Proc*., RMRS-P-67, 310–315.

Hanretty, C. 2020. "An Introduction to Multilevel Regression and Post-Stratification for Estimating Constituency Opinion." *Political Studies Review* 18: 630–645.

Hardwicke, K. 2006. "*Prairie Dogs, Plants, and Pollinators: Tri-Trophic Interactions Affect Plant-Insect Floral Visitor Webs in Shortgrass Steppe*." Doctoral diss., Colorado State University.

Hayes, C. L., W. A. Talbot, and B. O. Wolf. 2016. "Abiotic Limitation and the C3 Hypothesis: Isotopic Evidence From Gunnison's Prairie Dog During Persistent Drought." *Ecosphere* 7: e01626.

Heady, H. F., and R. D. Child. 2019. *Rangeland Ecology and Management*. New York, NY: Routledge.

Homeland Security Infrastructure Program (HSIP). 2020. "Transmission Lines." https://hifld-geoplatform.opendata.arcgis.com/datasets/electric-power-transmission-lines/explore?location=6.862172%2C-7.477918%2C2.00.

Hoogland, J. L. 1995. *The Black-Tailed Prairie Dog: Social Life of a Burrowing Mammal*. Chicago, IL: University of Chicago Press.

Hoogland, J. L. 2006. *Conservation of the Black-Tailed Prairie Dog: Saving North America's Western Grasslands*. Washington, DC: Island Press.

Jenkins, C. N., K. S. Van Houtan, S. L. Pimm, and J. O. Sexton. 2015. "US Protected Lands Mismatch Biodiversity Priorities." *Proceedings of the National Academy of Sciences of the United States of America* 112: 5081–5086.

Johnson, T. L., J. F. Cully, S. K. Collinge, C. Ray, C. M. Frey, and B. K. Sandercock. 2011. "Spread of Plague Among Black-Tailed Prairie Dogs is Associated With Colony Spatial Characteristics." *Journal of Wildlife Management* 75: 357–368.

Knight, A. T., and R. M. Cowling. 2007. "Embracing Opportunism in the Selection of Priority Conservation Areas." *Conservation Biology* 21: 1124–1126.

Knight, A. T., R. M. Cowling, M. Rouget, A. Balmford, A. T. Lombard, and B. M. Campbell. 2008. "Knowing But Not Doing: Selecting Priority Conservation Areas and the Research-Implementation Gap." *Conservation Biology* 22: 610–617.

Kotliar, N. B., B. J. Miller, R. P. Reading, and T. W. Clark. 2006. "The Prairie Dog as a Keystone Species." In *Conservation of the Black-Tailed Prairie Dog: Saving North America's Western Grasslands*, edited by J. L. Hoogland. Washington, DC: Island Press.

Lacher, I., and M. L. Wilkerson. 2013. "Wildlife Connectivity Approaches and Best Practices in U.S. State Wildlife Action Plans." *Conservation Biology* 28: 13–21.

Lark, T. J. 2020. "Protecting Our Prairies: Research and Policy Actions for Conserving America's Grasslands." *Land Use Policy* 97: 104727.

Lark, T. J., S. A. Spawn, M. Bougie, and H. K. Gibbs. 2020. "Cropland Expansion in the United States Produces Marginal Yields at High Costs to Wildlife." *Nature Communications* 11: 1–11.

League of Conservation Voters. 2022. "National Environmental Scorecard." https://scorecard.lcv.org/.

Lendrum, P. E., K. R. Crooks, and G. Wittemyer. 2017. "Changes in Circadian Activity Patterns of a Wildlife Community Post High-Intensity Energy Development." *Journal of Mammalogy* 98: 1265–1271.

Livieri, T. M., S. C. Forrest, M. R. Matchett, and S. W. Breck. 2022. "Conserving Endangered Black-Footed Ferrets: Biological Threats, Political Challenges, and Lessons Learned." In *Imperiled: The Encyclopedia of Conservation*, 458–470. Elsevier Inc.

Mace, N. 2024. "H.R.9945 – North American Grasslands Conservation Act of 2024." https://www.congress.gov/bill/118th-congress/house-bill/9945.

Margules, C. R., and R. L. Pressey. 2000. "A Framework for Systematic Conservation Planning." *Nature* 405: 243–253.

Maxwell, S. L., V. Cazalis, N. Dudley, et al. 2020. "Area-Based Conservation in the Twenty-First Century." *Nature* 586: 217–227.

McDonald, L., J. Mitchell, S. Howlin, and C. Goodman. 2015. *Range-Wide Monitoring of Black-Tailed Prairie Dogs in the United States: Pilot Study. Tech. Rep.* Laramie, WY: Western Ecosystems Technology.

Meretsky, V. J., L. A. Maguire, F. W. Davis, et al. 2012. "A State-Based National Network for Effective Wildlife Conservation." *Bioscience* 62: 970–976.

Miller, B. J., R. P. Reading, D. E. Biggins, et al. 2007. "Prairie Dogs: An Ecological Review and Current Biopolitics." *Journal of Wildlife Management* 71: 2801–2810.

Moilanen, A., and A. Arponen. 2011. "Administrative Regions in Conservation: Balancing Local Priorities With Regional to Global Preferences in Spatial Planning." *Biological Conservation* 144: 1719–1725.

Moilanen, A., A. M. A. Franco, R. I. Early, R. Fox, B. Wintle, and C. D. Thomas. 2005. "Prioritizing Multiple-Use Landscapes for Conservation:

Methods for Large Multi-Species Planning Problems." *Proceedings of the Royal Society B: Biological Sciences* 272: 1885–1891.

Moilanen, A., H. Kujala, and J. R. Leathwick. 2009. "The Zonation Framework and Software for Conservation Prioritization." In *Spatial Conservation Prioritization: Quantitative Methods and Computational Tools*, 196–210. Oxford: Oxford University Press.

Natural Resources Conservation Service. 2023. "Black-Footed Ferret (BFF) Initiative – Colorado." https://www.nrcs.usda.gov/programs-initiatives/eqip-environmental-quality-incentives/colorado/black-footed-ferret-bff.

Niemiec, R. M., R. Gruby, M. Quartuch, et al. 2021. "Integrating Social Science Into Conservation Planning." *Biological Conservation* 262: 109298.

Olimb, S. K., C. A. Olimb, K. Bly, N. C. Guernsey, and D. Li. 2022. "Resource Selection Functions of Black-Tailed Prairie Dogs in Native Nations of Montana." *Wildlife Society Bulletin* 46: 1–16.

Olimb, S. K., and B. Robinson. 2019. "Grass to Grain: Probabilistic Modeling of Agricultural Conversion in the North American Great Plains." *Ecological Indicators* 102: 237–245.

Pauli, J. N., and S. W. Buskirk. 2007. "Risk-Disturbance Overrides Density Dependence in a Hunted Colonial Rodent, the Black-Tailed Prairie Dog *Cynomys ludovicianus*." *Journal of Applied Ecology* 44: 1219–1230.

Pejchar, L., L. Medrano, R. M. Niemiec, J. P. Barfield, A. Davidson, and C. Hartway. 2021. "Challenges and Opportunities for Cross-Jurisdictional Bison Conservation in North America." *Biological Conservation* 256: 109029.

Pilliod, D. S., A. T. Rohde, S. Charnley, et al. 2018. "Survey of Beaver-Related Restoration Practices in Rangeland Streams of the Western USA." *Environmental Management* 61: 58–68.

Pool, D., and A. Panjabi. 2011. "*Assessment and Revisions of North American Grassland Priority Conservation Areas*." Montreal.

Pressey, R. L., M. Cabeza, M. E. Watts, R. M. Cowling, and K. A. Wilson. 2007. "Conservation Planning in a Changing World." *Trends in Ecology & Evolution* 22: 583–592.

Reeves, J. L., J. D. Derner, M. A. Sanderson, et al. 2014. "Seasonal Weather Influences on Yearling Beef Steer Production in C3-Dominated Northern Great Plains Rangeland." *Agriculture, Ecosystems and Environment* 183: 110–117.

Riley, B., P. Van Ryzin, M. Fuller, and R. Strozier. 2020. "The State Wildlife Grant Program: Measuring the Public Value of a Proactive Conservation Program." *Journal of Fish and Wildlife Management* 11: 353–368.

Rocke, T. E., D. W. Tripp, R. E. Russell, et al. 2017. "Sylvatic Plague Vaccine Partially Protects Prairie Dogs (*Cynomys* spp.) in Field Trials." *EcoHealth* 14: 438–450.

Rosenberg, K. V., K. V. Rosenberg, A. M. Dokter, et al. 2019. "Decline of the North American Avifauna." *Science* 366: 120–124.

Samson, F. B., F. L. Knopf, and W. R. Ostlie. 2004. "Great Plains Ecosystems: Past, Present, and Future." *Wildlife Society Bulletin* 32: 6–15.

Sanderson, E. W., K. H. Redford, B. Weber, et al. 2008. "The Ecological Future of the North American Bison: Conceiving Long-Term, Large-Scale Conservation of Wildlife." *Conservation Biology* 22: 252–266.

Snäll, T., R. E. Benestad, and N. C. Stenseth. 2009. "Expected Future Plague Levels in a Wildlife Host Under Different Scenarios of Climate Change." *Global Change Biology* 15: 500–507.

Snäll, T., R. B. O'Hara, C. Ray, and S. K. Collinge. 2008. "Climate-Driven Spatial Dynamics of Plague Among Prairie Dog Colonies." *American Naturalist* 171: 238–248.

Sohl, T. L., K. L. Sayler, M. A. Bouchard, et al. 2018. "Conterminous United States Land Cover Projections – 1992 to 2100." *U.S. Geol. Surv. Data Release*. https//doi.org/10.5066/P95AK9HP. https://www.sciencebase.gov/catalog/item/5b96c2f9e4b0702d0e826f6d.

Sohl, T. L., B. M. Sleeter, K. L. Sayler, et al. 2012. "Spatially Explicit Land-Use and Land-Cover Scenarios for the Great Plains of the United States." *Agriculture, Ecosystems and Environment* 153: 1–15.

The Wilderness Society. 2015. "Land and Water Conservation Fund database." https://www.wilderness.org/articles/article/mapping-land-and-water-conservation-fund-lwcf.

USDA Forest Service. 2019. "NLCD 2016 Tree Canopy Cover." https://apps.fs.usda.gov/fsgisx01/rest/services/RDW_LandscapeAndWildlife/NLCD_2016_TreeCanopyCover_CONUS/ImageServer.

U.S. Fish and Wildlife Service. 2013. "*Recovery Plan for the Black-Footed Ferret* (*Mustela nigripes*)." Denver.

United States Census Bureau. 2020. "TIGER/Line Shapefiles." https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html.

USDA Farm Service Agency. 2020. "Conservation Reserve Program Enrollment by County."

USGS. 2019a. "NLCD 2016: Land Cover Conterminous United States, 2016 Edition. Remote-Sensing Image." *U.S. Geol. Surv*. https://www.mrlc.gov/data.

USGS. 2019b. "Protected Areas Database (PAD-US)." *Gap Anal. Proj.* https://www.usgs.gov/core-science-systems/science-analytics-and-synthesis/gap/science/protected-areas.

Van Pelt, W. E., S. Kyle, J. Pitman, et al. 2013. *The Lesser Prairie-Chicken Range-wide Conservation Plan*, 302. Cheyenne, Wyoming: Western Association of Fish and Wildlife Agencies.

Watson, J. E. M., H. S. Grantham, K. A. Wilson, and H. P. Possingham. 2011. "Systematic Conservation Planning: Past, Present and Future." In *Conservation Biogeography*, edited by R. J. Ladle and R. J. Whittaker, 136–160. Oxford: Blackwell Publishing Ltd.

Welldatabase. 2021. "Welldatabase." Welldatabase.com.

Weltzin, J. F., S. Archer, and R. K. Heitschmidt. 1997. "Small-Mammal Regulation of Vegetation Structure in a Temperate Savanna." *Ecology* 78: 751–763.

Western Association of Fish & Wildlife Agencies. 2011. "*Western Grasslands Initiative: A Plan for Conserving Grassland Habitat and Wildlife*."

Whitehead, A. L., H. Kujala, C. D. Ives, et al. 2014. "Integrating Biological and Social Values When Prioritizing Places for Biodiversity Conservation." *Conservation Biology* 28: 992–1003.

Williamson, M. A., S. A. Lischka, A. Olive, J. Pittman, and A. T. Ford. 2023a. "Who Should Govern Wildlife? Examining Attitudes Across the Country." In *Transform. Polit. Wild Underst. Overcoming Barriers to Conservation in Canada*, edited by A. Olive, C. Finnegan, and K. F. Beazley. Toronto, ON: University of Toronto Press.

Williamson, M. A., L. Parrott, N. H. Carter, and A. T. Ford. 2023b. "Implementation Resistance and the Human Dimensions of Connectivity Planning." *People and Nature* 5: 1922–1936.

Williamson, M. A., M. W. Schwartz, and M. N. Lubell. 2018. "Spatially Explicit Analytical Models for Social–Ecological Systems." *Bioscience* 68: 885–895.

Zaks, D. P. M., N. Ramankutty, C. C. Barford, and J. A. Foley. 2007. "From Miami to Madison: Investigating the Relationship Between Climate and Terrestrial Net Primary Production." *Global Biogeochemical Cycles* 21: GB3004.

Supporting Information

Additional supporting information can be found online in the Supporting Information section.