From Genes to Landscapes: Plague-Resistance Genomics, Priority Areas, and Decision Support for Prairie Dog Ecosystem Conservation

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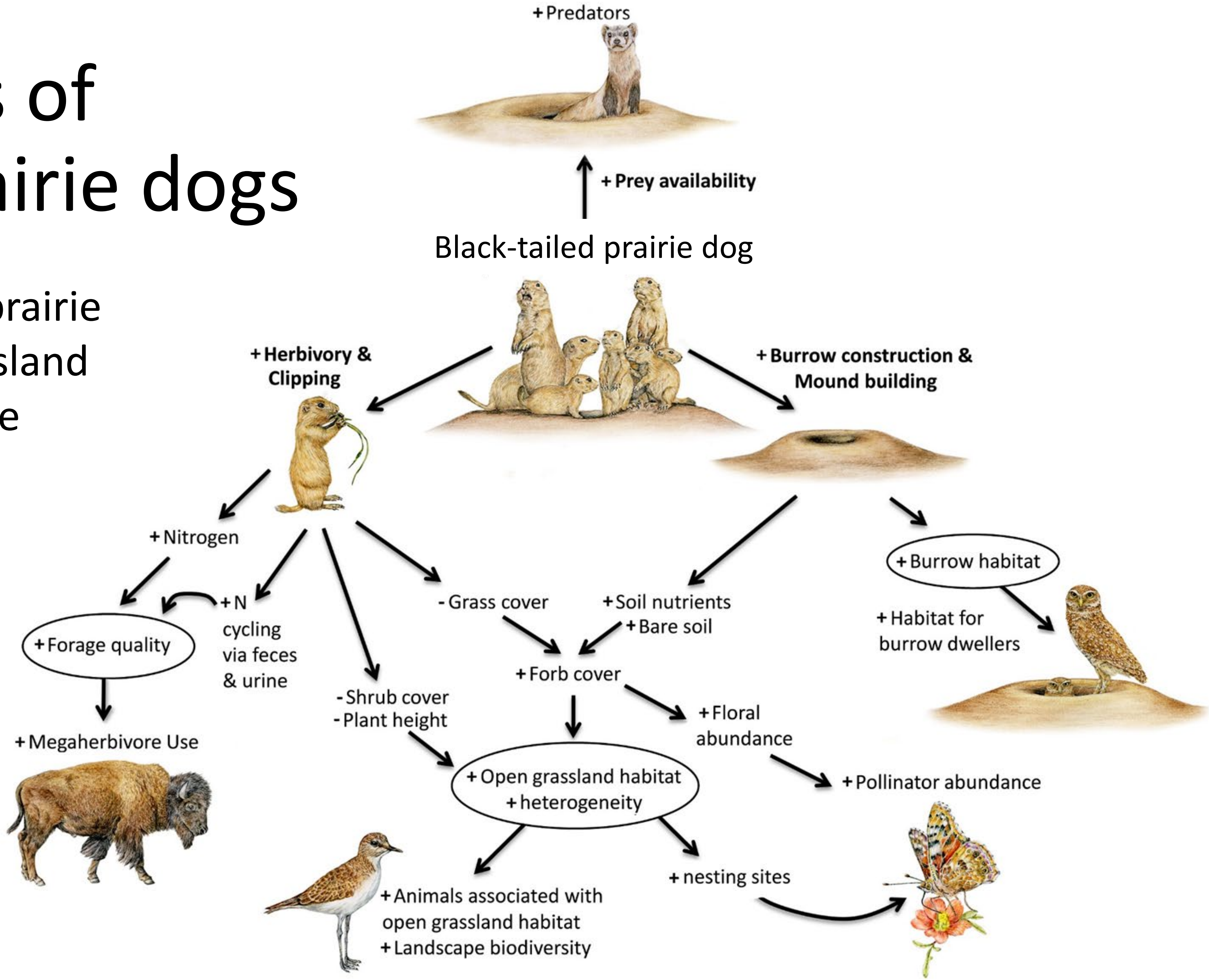
COLORADO NATURAL HERITAGE PROGRAM

FISH, WILDLIFE, AND CONSERVATION BIOLOGY
COLORADO STATE UNIVERSITY


The last
2 %
EARTH
EXPLAINED

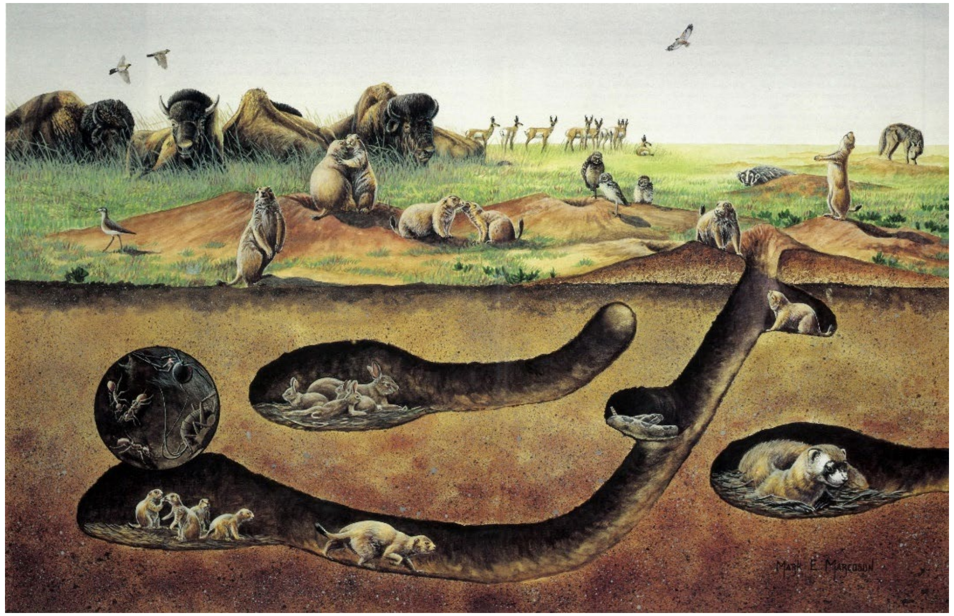
Ecological roles of black-tailed prairie dogs

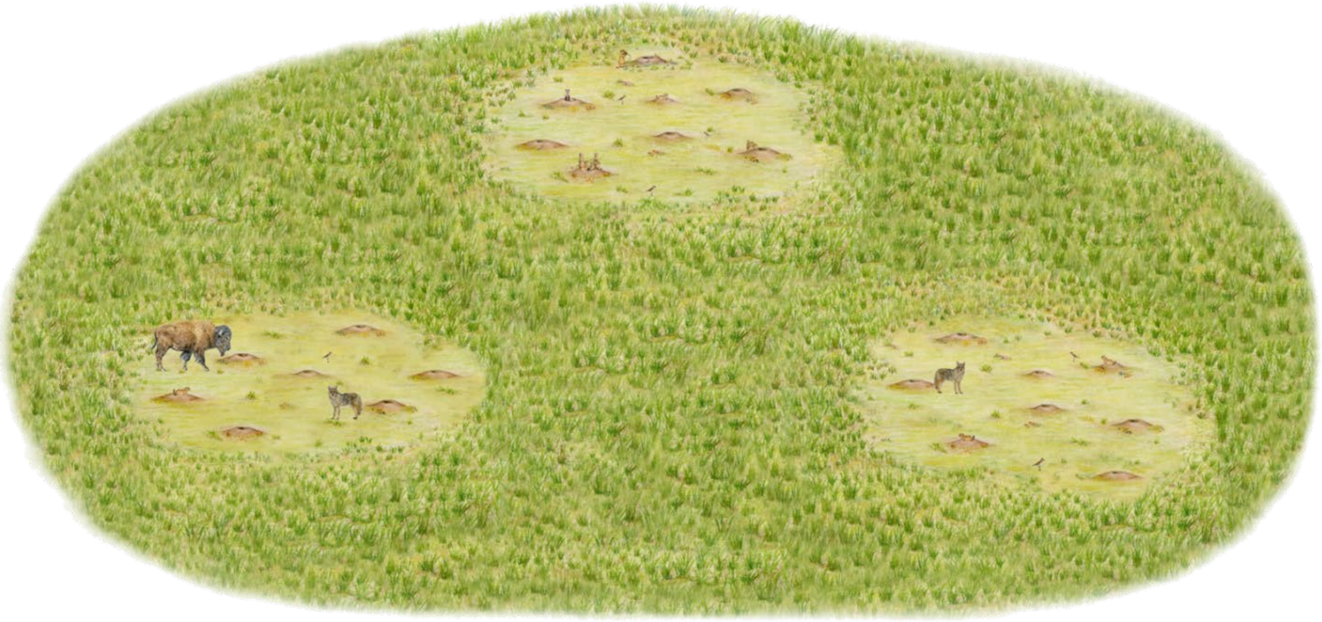
Restoring and maintaining prairie dogs lies at the core of grassland conservation, because of the fundamentally important keystone role they play



Davidson et al. 2012, *Frontiers in Ecology & Evolution*

The prairie dog ecosystem



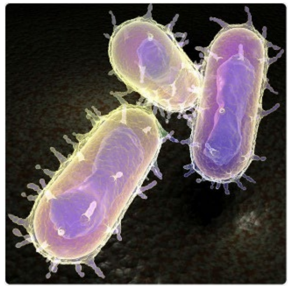


Black-tailed prairie dog colonies

Davidson et al. 2012, *Frontiers*

USFWS black-footed ferret recovery plan specifically states, "We believe the single, most feasible action that would benefit black-footed ferret recovery is to improve prairie dog conservation. If efforts were undertaken to more proactively manage existing prairie dog habitat for ferret recovery, all other threats to the species would be substantially less difficult to address."

Global distribution of plague



Plague occurs in ground-dwelling rodents on all continents, except Australia & Antarctica

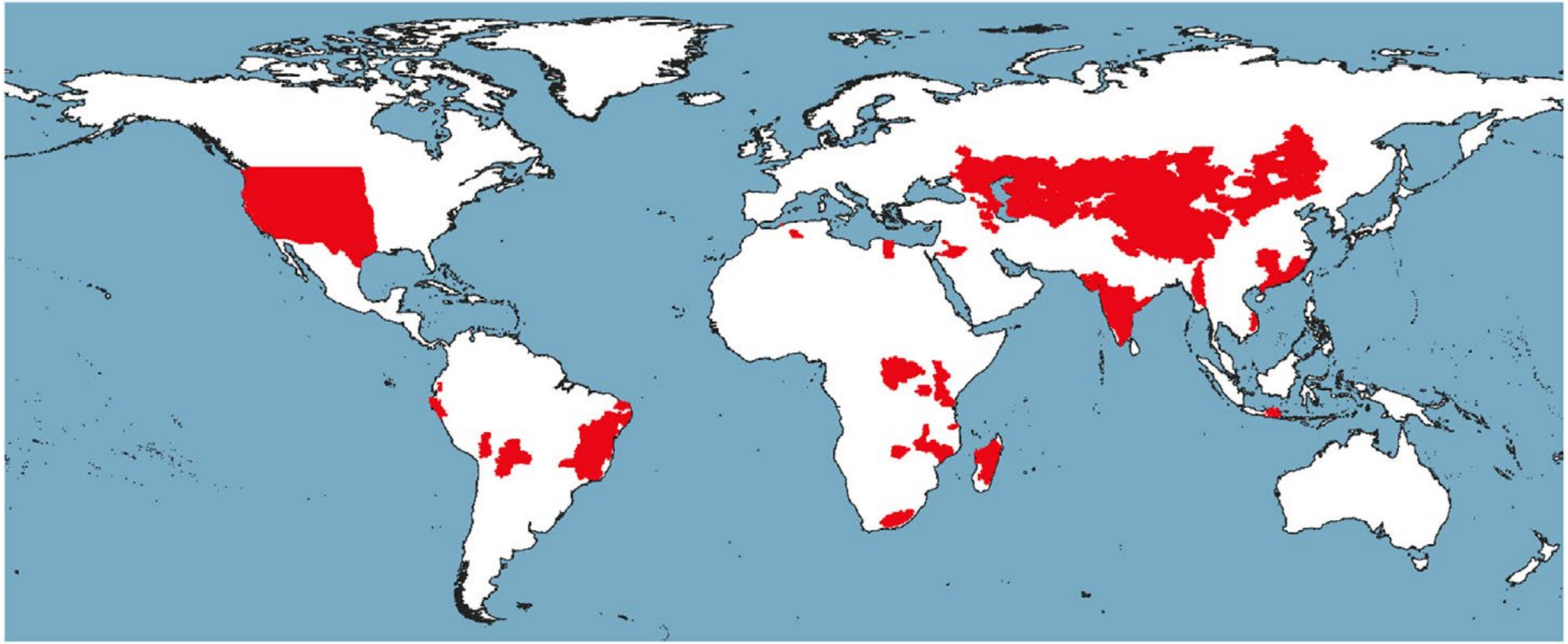
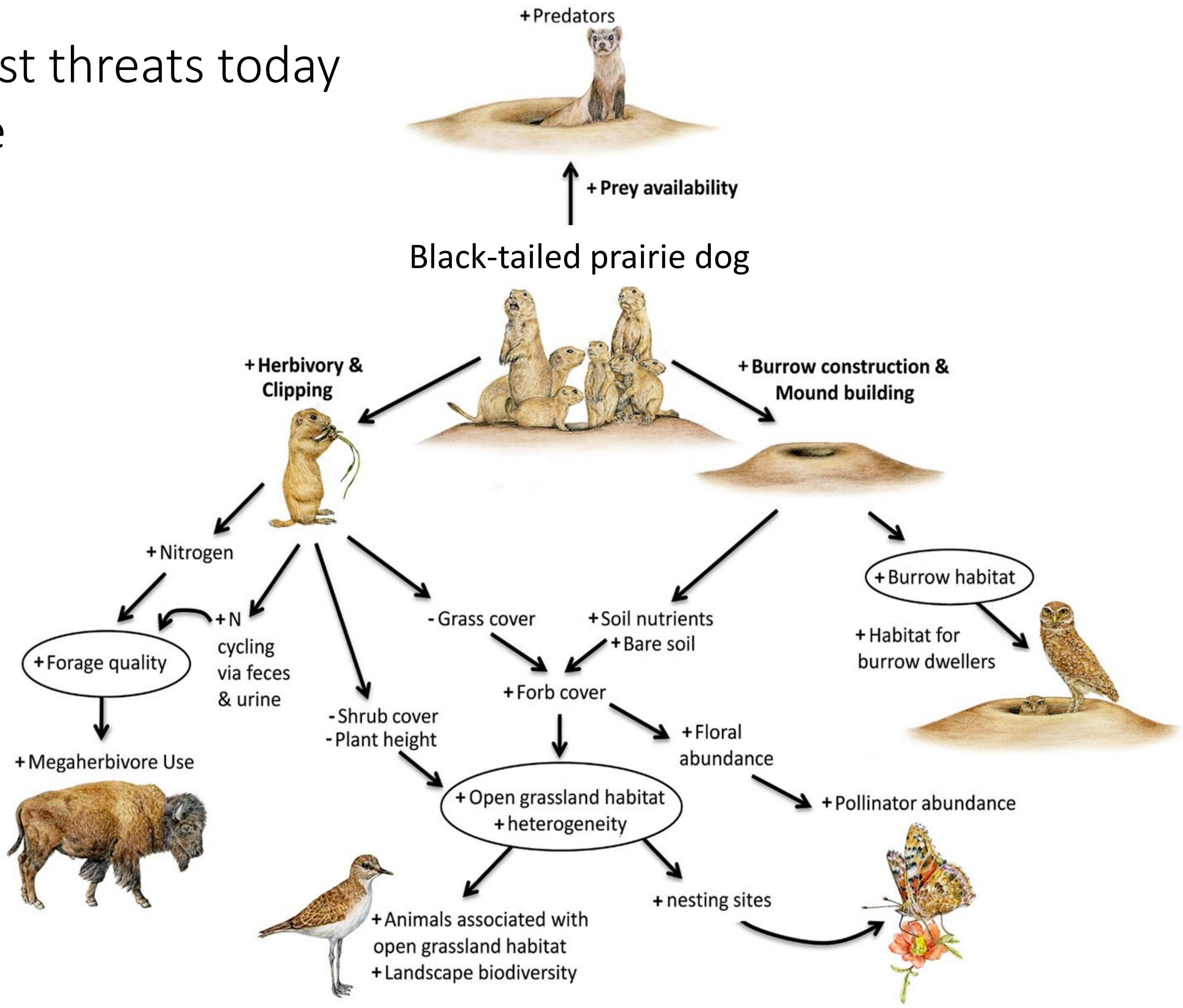


Figure 1 Global distribution of natural plague foci as of March 2016, based on the historical data and current information (modified after the WHO 2016).

Mahmoudi et al. 2020 *Int Zoo*

Plague devastates populations of prairie dogs

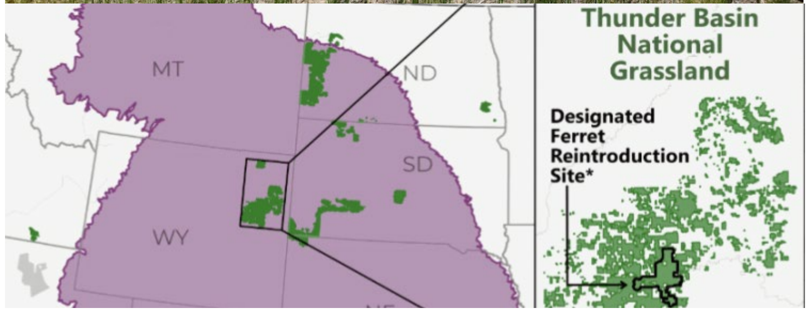
- Plague is one of the greatest threats today
- Lack of immunity to plague

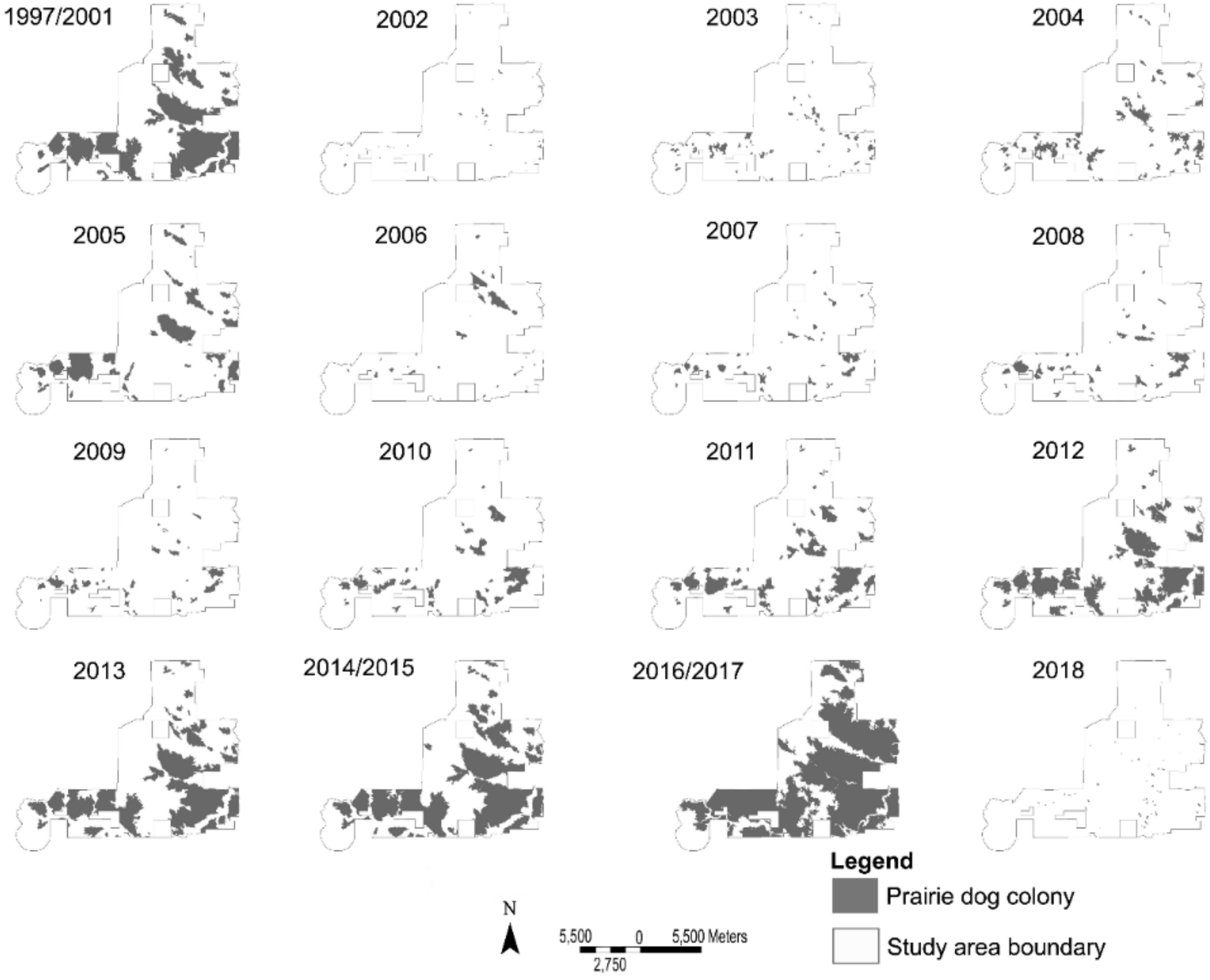


Davidson et al. 2012, *Frontiers in Ecology & Evolution*

Boom and bust cycles of black-tailed prairie dog populations in the Thunder Basin grassland ecosystem

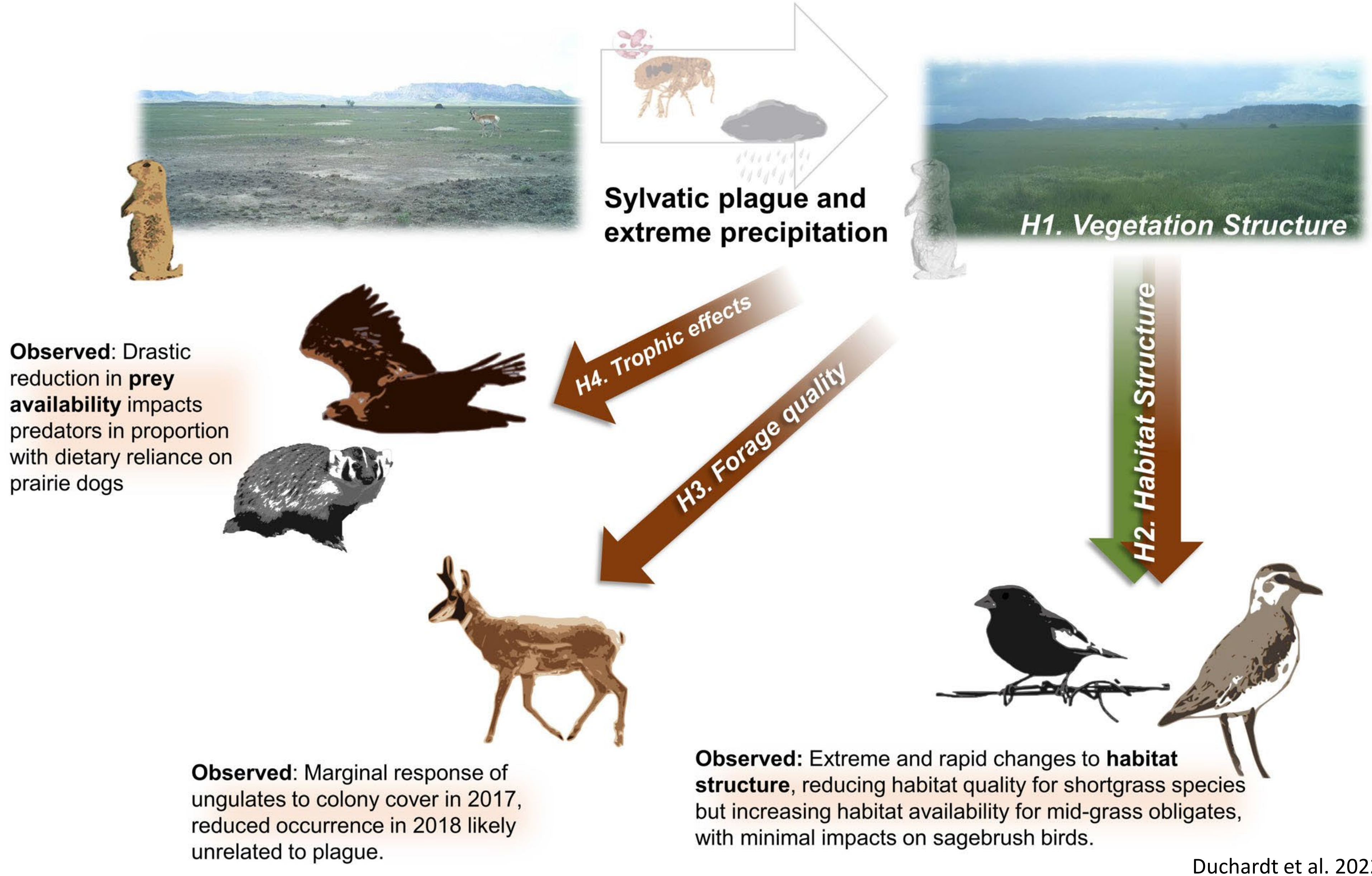
Ana D. Davidson,[1,2,*] David J. Augustine,[3] Hannah Jacobsen,[4] Dave Pellatz,[5] Lauren M. Porensky,[3]
Gwyn McKee,[6] and Courtney Duchardt[7]





Davidson et al. 2022, *Journal of Mammalogy*

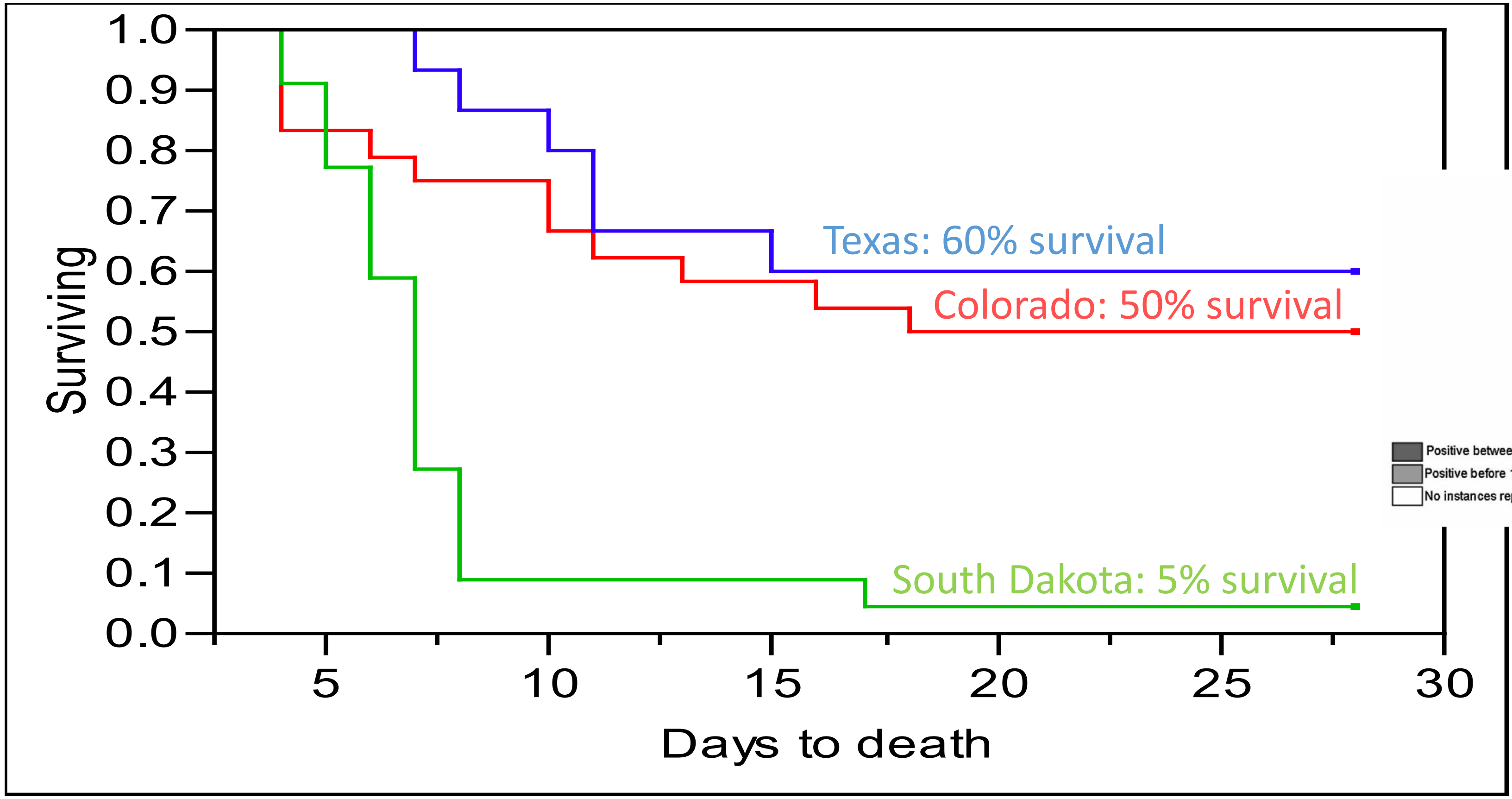
Impact of plague on prairie dog ecosystems

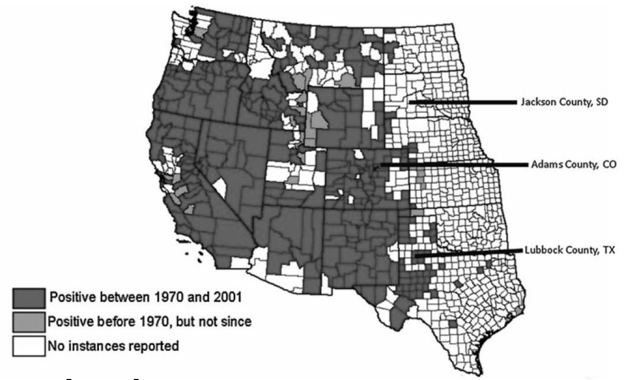


USDA NIFA
United States Department of Agriculture
National Institute of Food and Agriculture

Duchardt et al. 2022, *Ecological Applications*

Some populations are showing resistance to plague





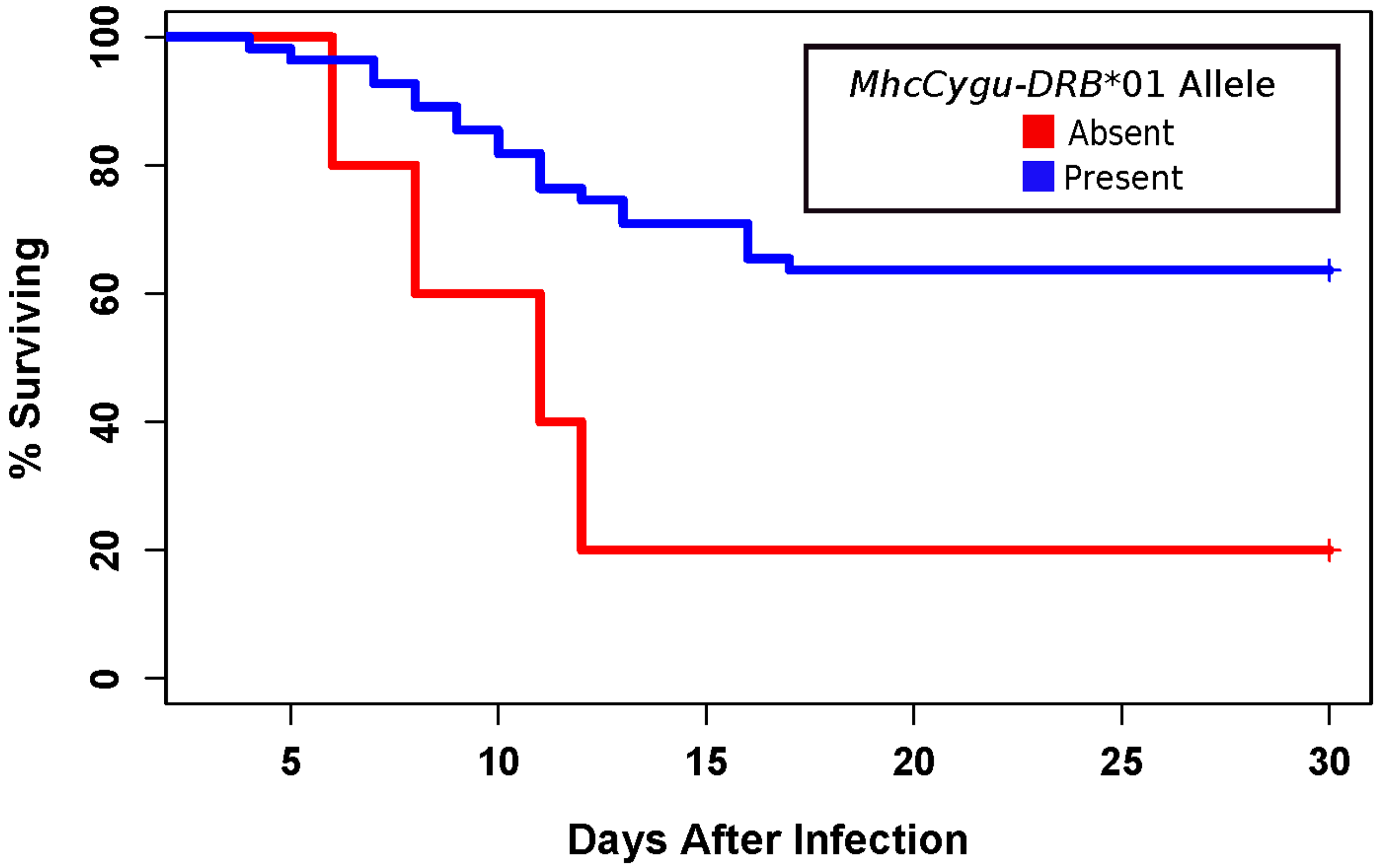
Resistance to Plague Among Black-Tailed Prairie Dog Populations

Tonie E. Rocke,[1] Judy Williamson,[1] Kacy R. Cobble,[2] Joseph D. Busch,[2] Michael F. Antolin,[3] and David M. Wagner[2]

Rocke *et al.* 2012. Vector-Borne and Zoonotic Diseases

Genetic basis of resistance

- MHC gene is an important immune system gene
- GPD individuals that had this 1 common allele had better (60%) survival in GPD compared to those lacked it (20%)



Cobble et al. 2016, *Ecol & Evo*

Genome-wide scans have identified DNA differences in GPDs that survived vs. died in plague challenge

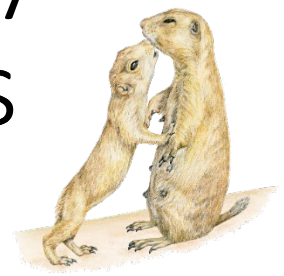
Uncovering the genetic fingerprint and evolutionary trajectory of plague resistance in prairie dogs

Ana D. Davidson[1,2], Loren Cassin-Sackett[3,4], Kevin Shoemaker[5], Joeseph Busch[6], and Tonie Rocke[6]

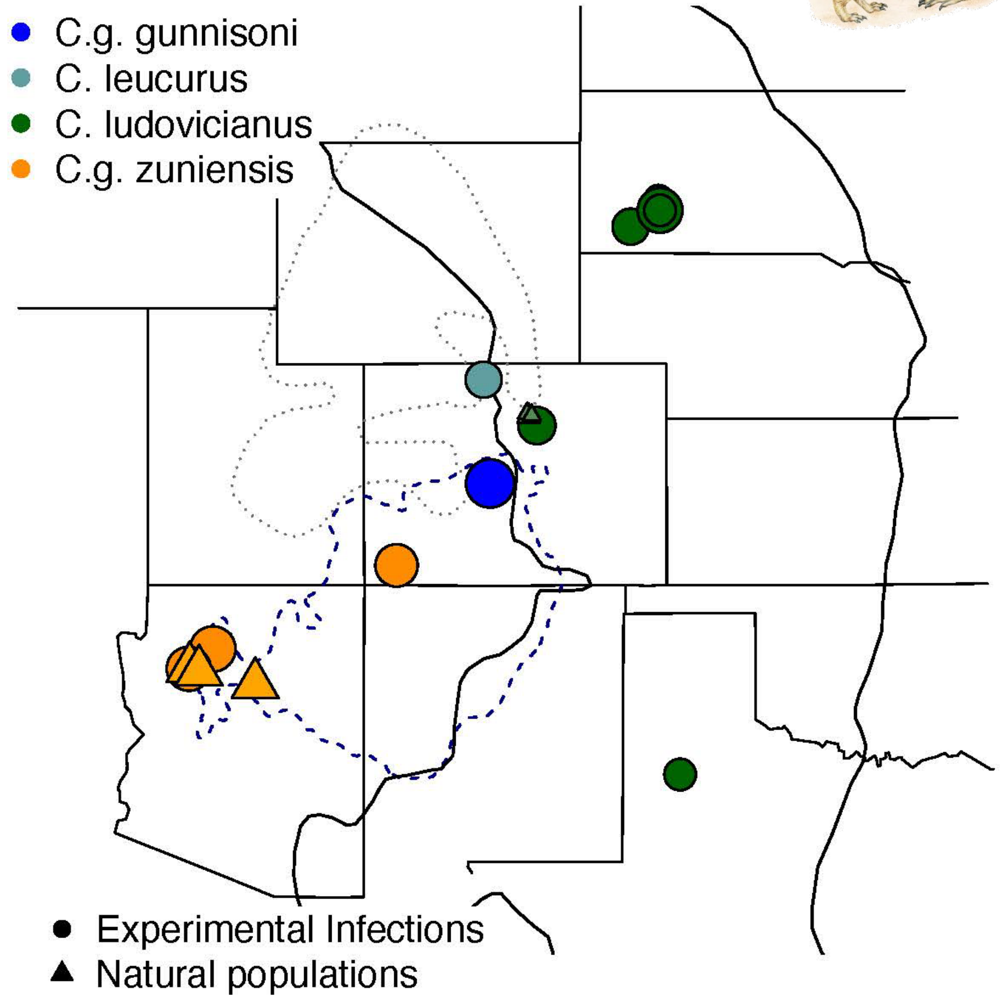
[1]Colorado Natural Heritage Program, Colorado State University
[2]Department of Fish, Wildlife, and Conservation Biology, Colorado State University
[3]Department of Biology, University of Louisiana
[4]Center for Conservation Genomics, Smithsonian Conservation Biology Institute
[5]Kevin Shoemaker, University of Nevada, Reno
[6]Pathogen & Microbiome Institute (PMI), Northern Arizona University
[7]National Wildlife Health Center, United States Geological Survey




Research Approach: Uncover the evolutionary trajectory of plague resistance in prairie dogs

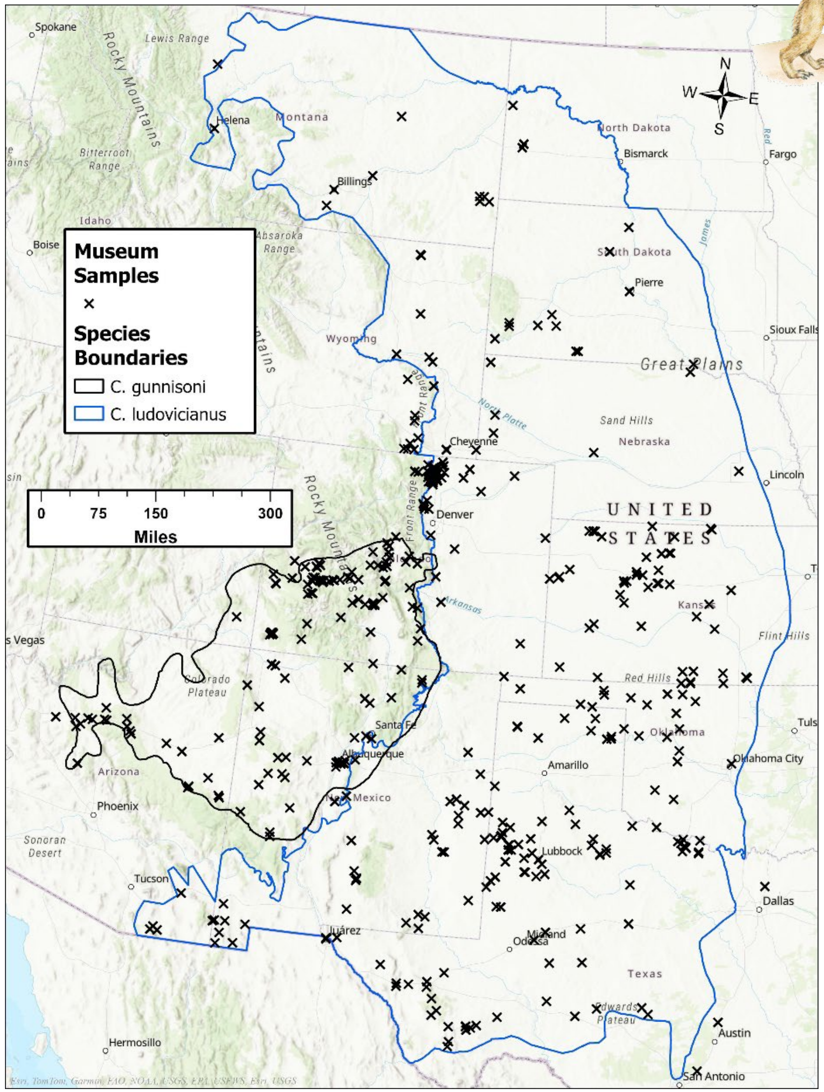


- **Identification of plague resistant alleles across space and time**
  - Genotype whole genomes
  - Neutral vs resistance allele frequencies
  - Sequenced 159/>200 genomes from plague challenge (Rocke et al.) studies
  - Will be conducting an additional plague challenge experiment this summer to allow (Rocke et al.)



Research Approach: Uncover the evolutionary trajectory of plague resistance in prairie dogs

- Identification of plague resistant alleles across space and time
  - Collect tissue samples across range of BTPDs & GPDs
  - Historical (3100) and contemporary samples (>4000)
  - Genotype whole genomes; so far sequenced 92/>4000
  - Neutral vs resistance allele frequencies



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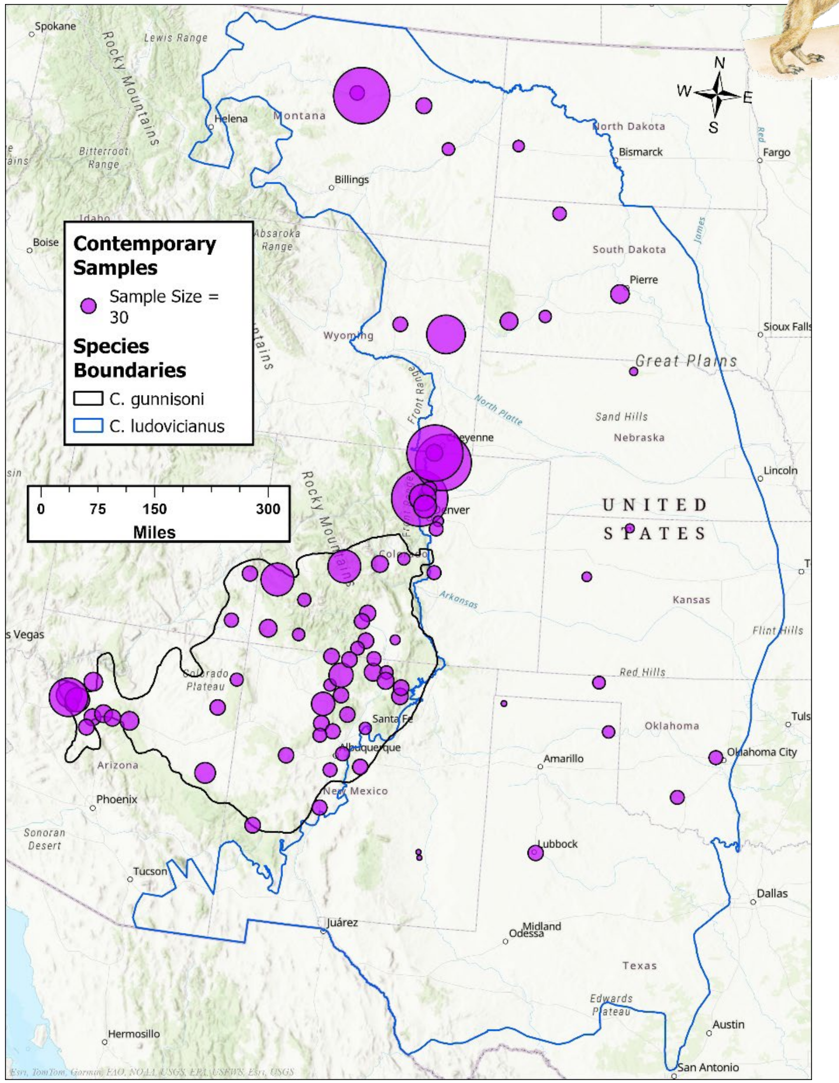

Research Approach: Uncover the evolutionary trajectory of plague resistance in prairie dogs

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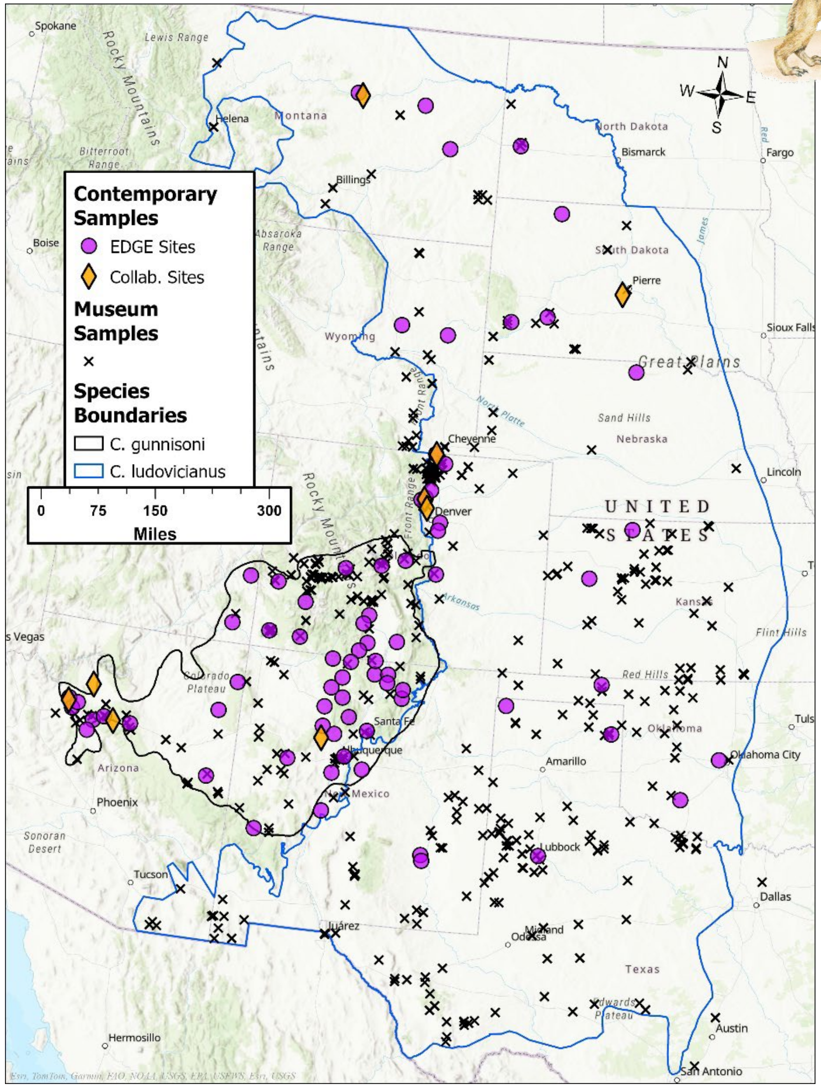
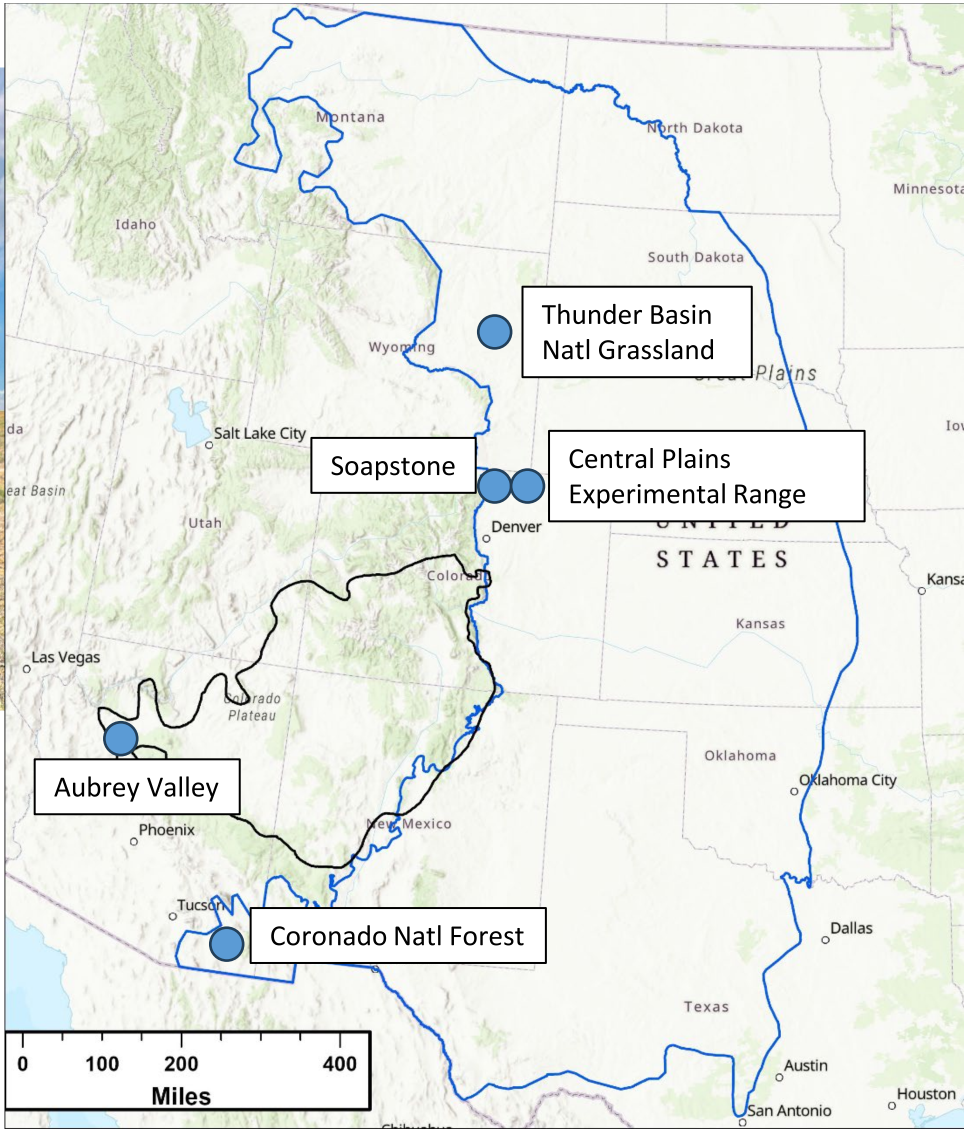


Research Approach: Ecological and Demographic Signatures of Plague Resistance

- Long-term mark-recapture study sites
  - Arizona
  - Colorado
  - Wyoming
- Collect tissue samples
- Population and demographic monitoring
- Sequence whole genomes; correlate fitness (survival and fecundity) with presence of specific candidate alleles




First field season 2024!
CSU Team (2024):
Brooke Dodge
Ethan Harrington
Caroline Silva
Galen Burrell
Loren Cassin-Sackett
Ana Davidson
Aiden Davidson-Heinold
(Team Supervisor)
Kevin Castle
Charlize Haynes &
Matthew Ewing


Second field season 2025!
CSU Team (2025):
Reese Good
Caroline Silva
Ronan Johnston
Abby Kogan
Tao Liu
Brooke Dodge
Danielle Terry
Galen Burrell
Devin-Danielle Webb
Joel Sorensen

Research Team:

PIs: Ana Davidson CSU, **Loren Cassin Sackett** UL & Smithsonian, **Tonie Rocke** USGS,
Kevin Shoemaker UNR, **Joseph Busch** NAU, **Rhiannon West** NNMC, and **Palmer Netongo** Navajo Tech

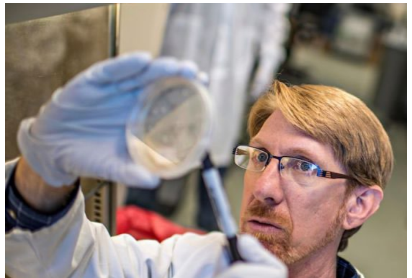
Collaborators:
Lise Aubry (CSU); Holly Hicks, Jennifer Cordova, Heather Heimann, David Drever (AZDGF);
David Augustine (USDA-ARS); Henry Pollock (SPLT); David Eads (EES); Dan Tripp (CPW);
Randy Matchett (USFWS); Levi Fettig (BRR); Gabe Barrile (UW); Tyler Tretten (BFF CC); Rickey Jones (USFWS)

Students:
- PhD student, MS student, and undergraduates at UL, with Loren Cassin-Sackett
- PhD student (Galen Burrell) and undergraduates at CSU, with Ana Davidson & Lise Aubry
- Undergraduates with Rhiannon West at NNMC and Irene Ane-Anyangwe & Palmer Netongo at Navajo Tech








Thank you!

Chamois Anderson, David Augustine, Joel Berger, Dean Biggins, Kristy Bly, Sanara Brock, Joe Busch, Kevin Castle, Eddie Childers, Jennifer Cordova, Jack Cully, Dave Eads, Christine Fallon, Levi Fettig, Steve Forrest, Brooke Fricke, Ken Gage, Mick Hanan, Holly Hicks, Chistina Hiser, Mark Howery, John Hughes, Melissa Johnston, Rickey Jones, Todd Juhasz, Rachel Keller, Michael Kosoy, Kurt Kuklinski, Brody Larkin, Travis Livieri, Julie Lyke, Randy Matchett, Dan McDonald, Peter McDonald, Gwyn McKee, Ashley Merkel, Aran Meyer, Sara Olson, Greg Paff, Scott Parry, Dave Pellatz, Fiona Petersen, Lauren Porensky, Jonathan Proctor, Katie Richgels, Kalee Robinson, Angela Rose, Hayden Savage, Matt Schuler, Lindsey Sterling-Krank, Jim Stuart, Tyler Tretten, Courtney Tomlinson, Dan Tripp, Bill Van Pelt, Dave Wagner, Kristen Warren, Bret Wolford

City of Fort Collins Natural Areas, Colorado Natural Heritage Program Siegele Conservation Science Internship, The Prairie Dog Coalition, Thunder Basin Grasslands Prairie Ecosystem Association, USDA-Agricultural Research Station, USGS North Central Climate Adaptation Science Center

NORTH CENTRAL Climate Adaptation Science Center

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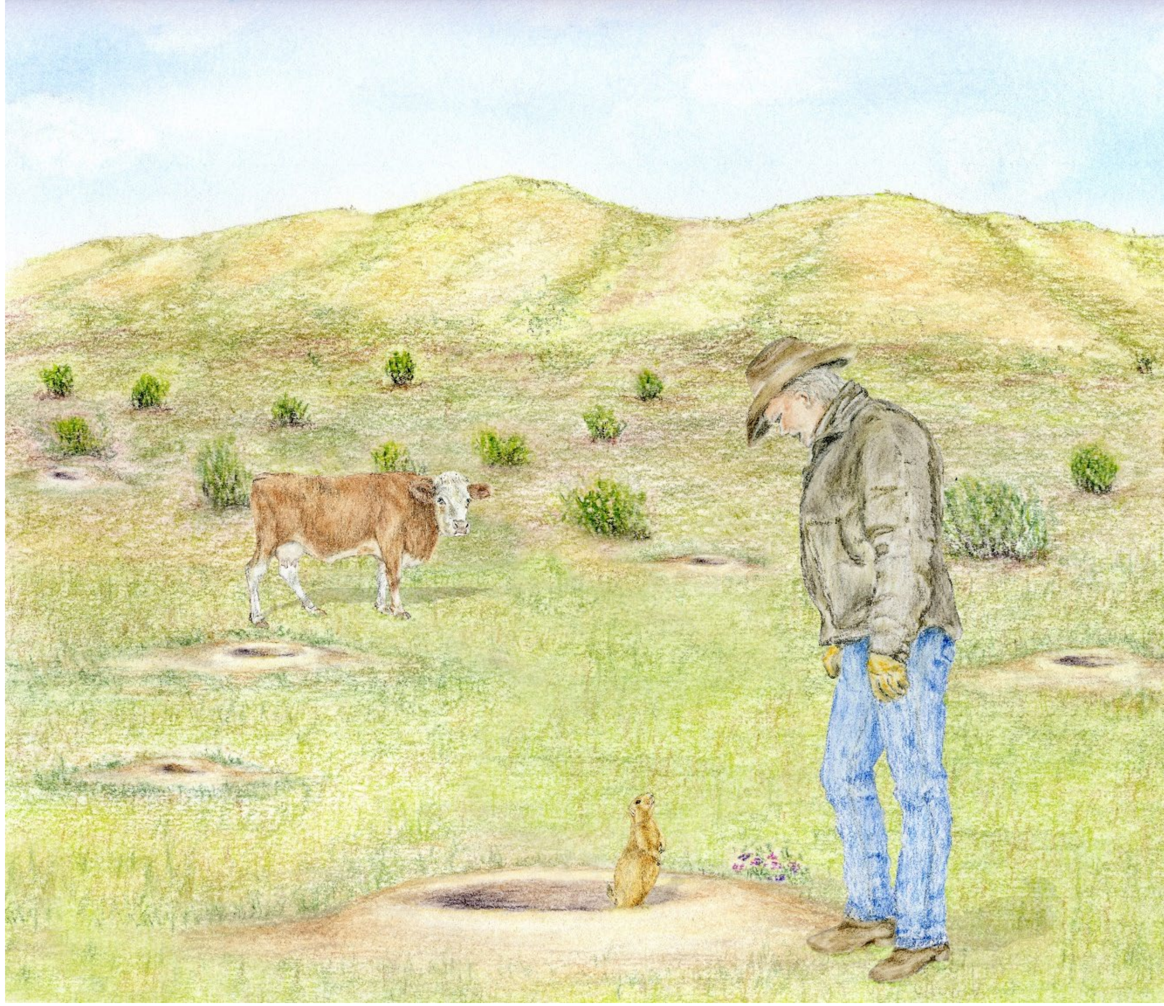

Drawing of prairie dog, cow, and rancher at Thunder Basin National Grassland by Sharyn Davidson

Management & conservation implications

- **Prairie Dog Ecosystem:** Understanding where and how prairie dogs are evolving resistance to plague valuable for management and conservation

- **Global:** Understanding the evolution of resistance to novel diseases and climates E.g., white nose syndrome, chytridiomycosis



Homes on the Range Project

Homes on the Range Objectives: Identify potential landscapes for grassland conservation

1) Identify priority conservation areas for the BTPD ecosystem

2) On-the-ground implementation

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journal homepage: www.elsevier.com/locate/biocon

Present and future suitable habitat for the black-tailed prairie dog ecosystem

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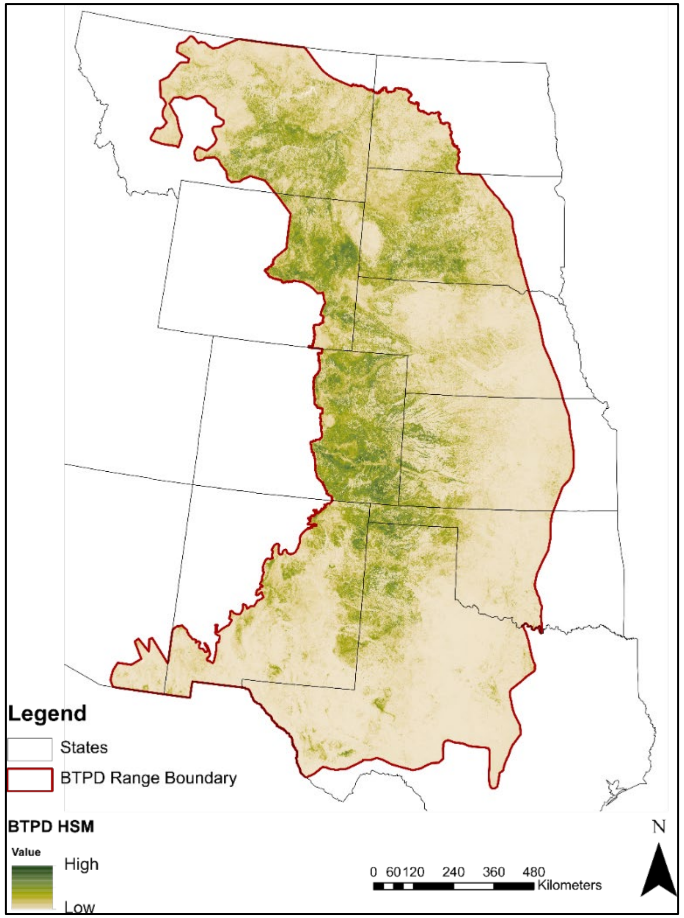
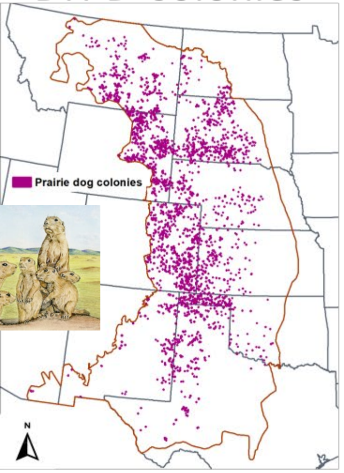
[a] Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO, USA
[b] Dept. of Fish, Wildlife and Conservation Biology, Colorado State University, Fort Collins, CO, USA
[c] Humane Society of the United States, Prairie Dog Coalition, Boulder, CO, USA
[d] Western Association of Fish and Wildlife Agencies, Phoenix, AZ, USA
[e] USDA-Agricultural Research Service, Fort Collins, CO, USA



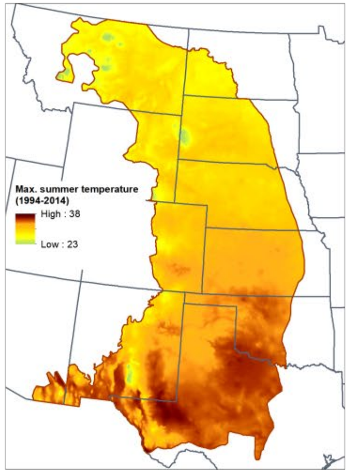
Methods (Part I): Habitat Suitability Model (HSM)

Variable	**Spatial data layer for Habitat Suitability Model**
BTPD colony occurrences	Prairie dog occurrences from WEST survey (McDonnald et al. 2015) 
Land Cover	USGS National Land Cover Database 2016
Soils	POLARIS 30-m resolution database Metrics: bulk density to 100cm, %Sand to 100cm, %Clay to 100cm, % organic matter to 100cm, pH to 100cm
Slope & elevation	National Elevation Dataset Metrics: Topographic Wetness Index, Topographic Ruggedness Index, slope, aspect
Climate – current	Current climate (1994-2014), using GridMet Metrics: Mean annual precipitation (mm), winter + spring & summer + fall precipitation, max summer temperature, potential evapotranspiration, growing degree days

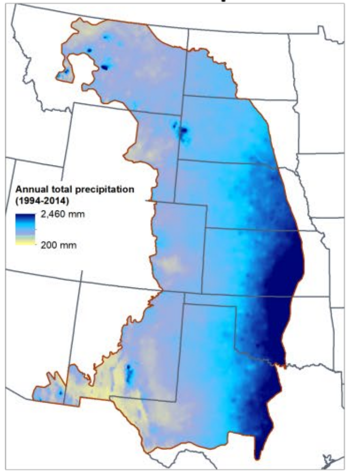
BTPD Colonies



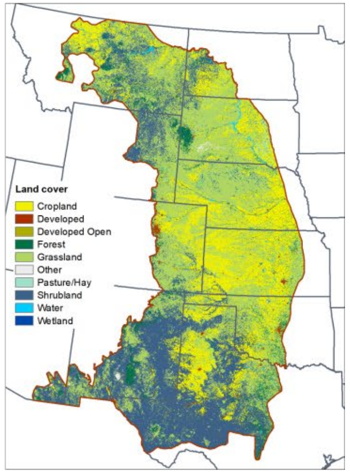
Max Temperature



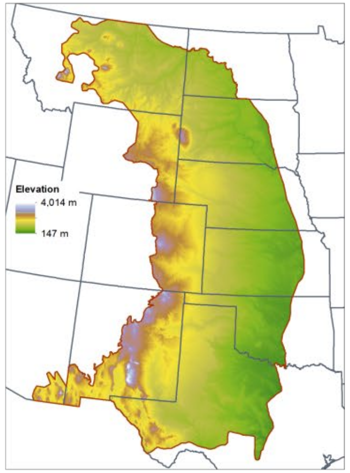
Annual Precipitation



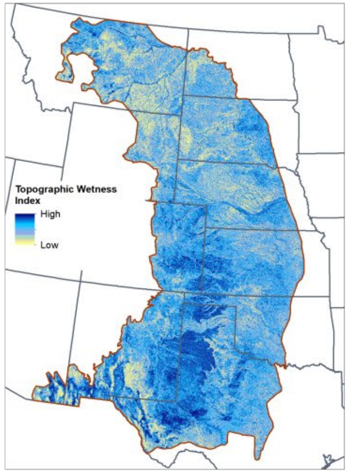
Land Cover



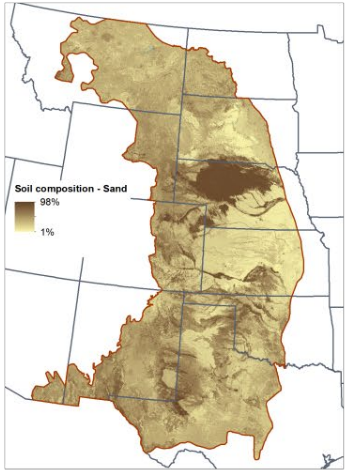
Elevation



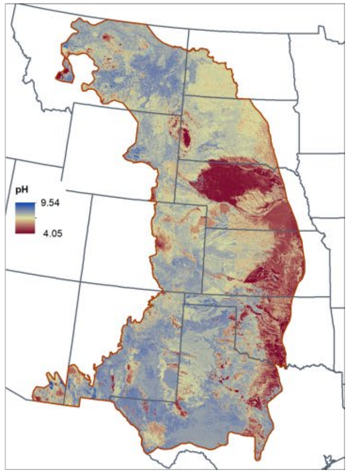
Topographic Wetness Index



Percent Sand



pH

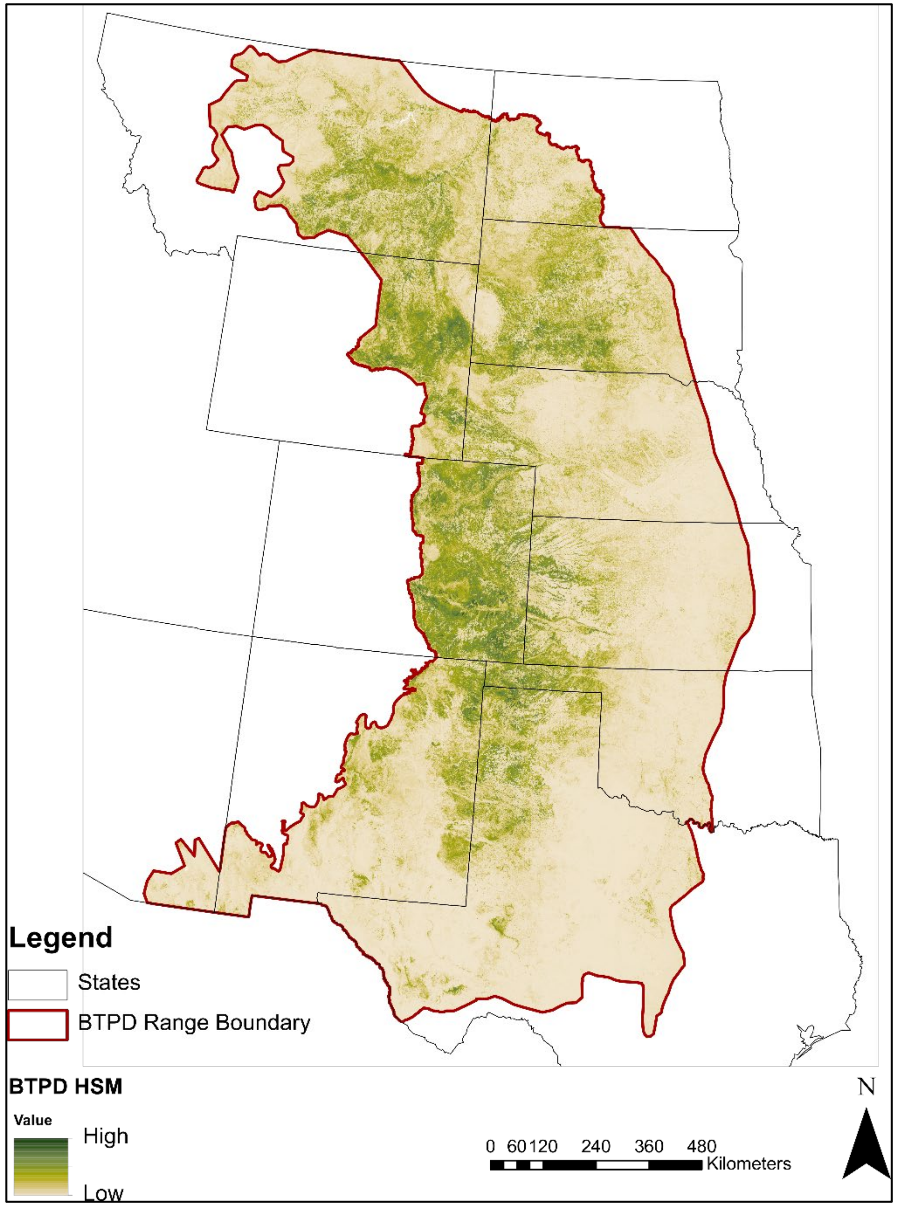


Davidson et al. 2023, *Biol. Cons.*

Results (Part I): Ensemble Habitat Suitability Model

HSM under **current climate**

- 20.8 million hectares of suitable grassland habitat
- only 1.9 million hectares (4%) are currently occupied by BTPDs
- States with the most suitable habitat: Colorado (5.8M ha), Wyoming (3M ha), Montana (2.9M ha), South Dakota (2.8M ha)

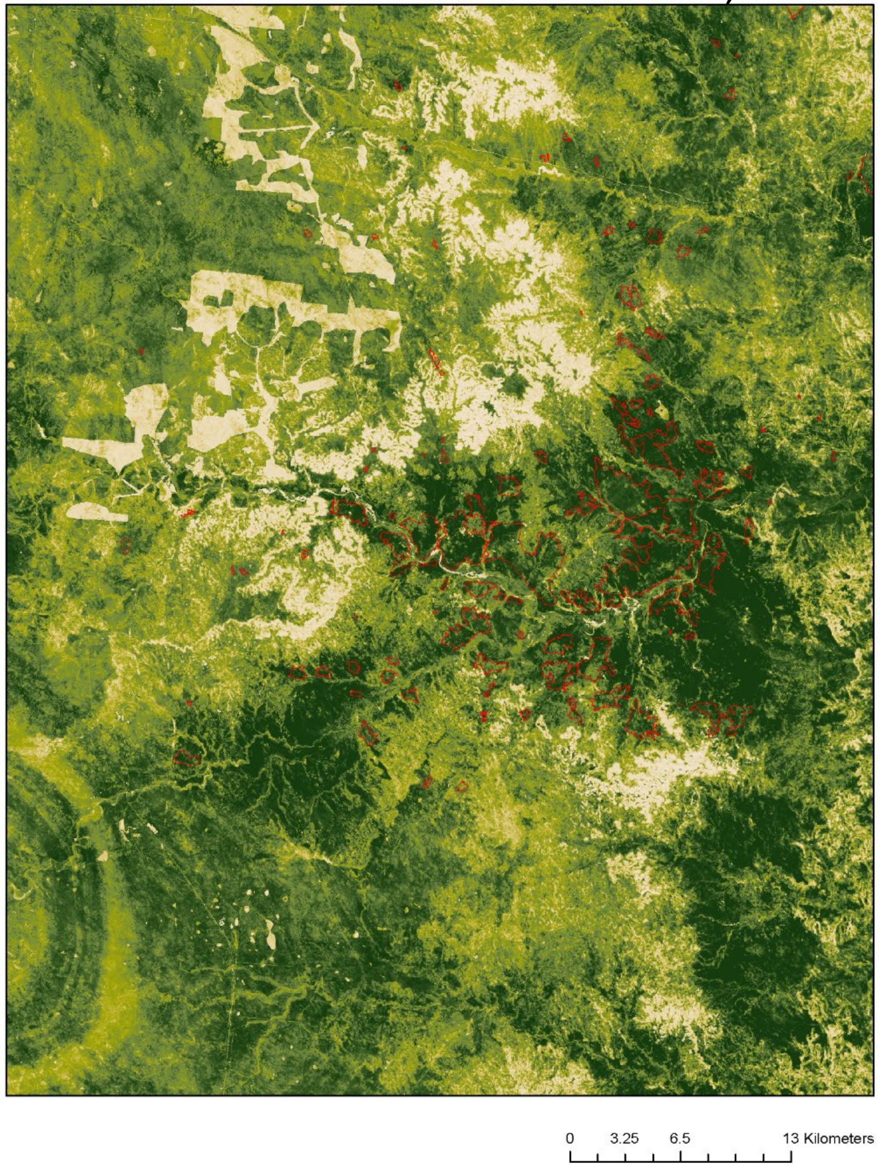


Davidson et al. 2023, *Biol. Cons.*

Results (Part I): Post-hoc analysis of HSM

Over **93%** of all ground-truthed colonies were in habitat predicted to be medium or high suitability

Thunder Basin National Grassland, WY



Comanche National Grassland, CO

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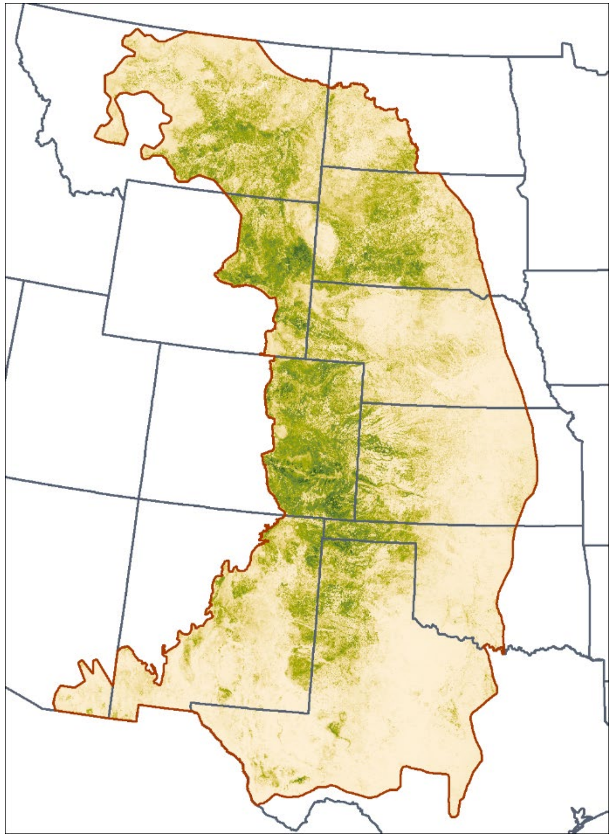
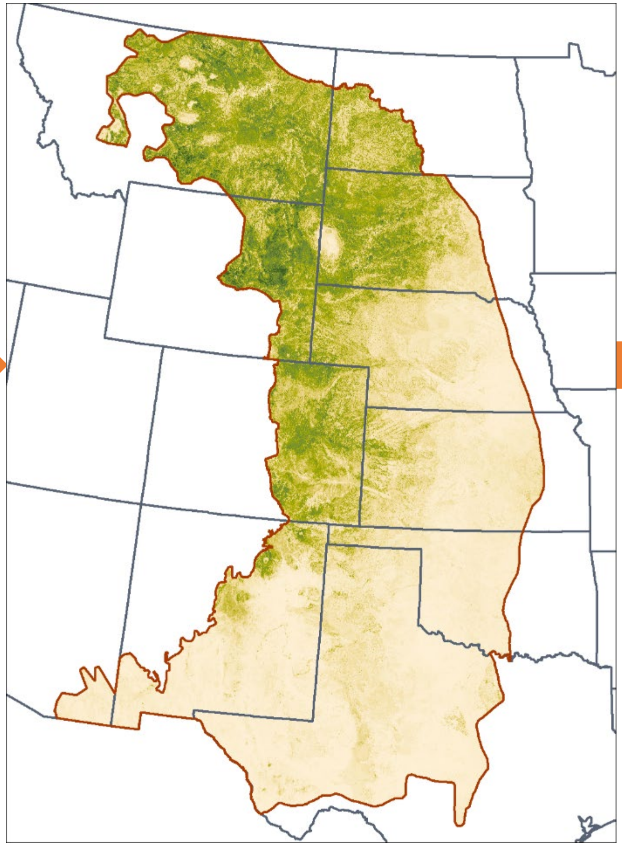
Results (Part I): BTPD Habitat Suitability Model

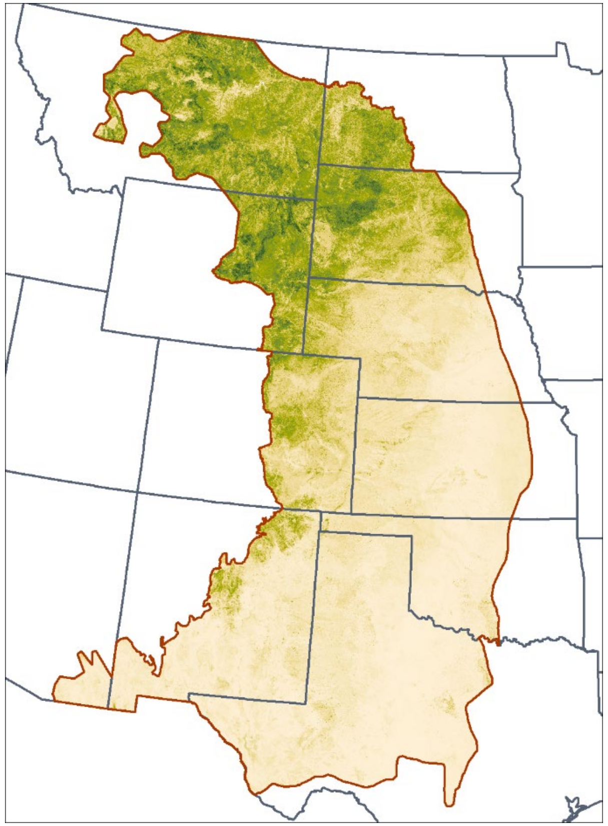
HSM under **Current Climate**



HSM under **Future Climate (warm & wet scenario)**



HSM under **Future Climate (hot & dry scenario)**



Legend

- State Boundaries
- BTPD Range Boundary

Habitat Suitability: High – Low

Davidson et al. 2023, *Biol. Cons.*

Methods (Part II): Identifying current & future landscapes for grassland conservation, within predicted suitable habitat

Goal: *Not only assess the suitability of the habitat for the prairie dog ecosystem, but also the social and political landscape, threats (such as development), habitat connectivity, and general ecological landscape (e.g., percent cover of grass)*


Drawing by Sharyn Davidson

Davidson et al. 2024, Diversity and Distributions

Diversity and Distributions

WILEY

Diversity and Distributions

RESEARCH ARTICLE OPEN ACCESS

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

Ana D. Davidson[1] | Fernanda Thiesen Brum[2] | Michael Houts[3] | Michael Menefee[4] | Matt Williamson[5] | Lindsey Sterling Krank[6] | Bill Van Pelt[7] | David J. Augustine[8]

[1]Colorado Natural Heritage Program & Department of Fish, Wildlife and Conservation Biology, Colorado State University, Fort Collins, Colorado, USA | [2]Universidade Federal do Paraná – Brazil & The Nature Conservancy, Curitiba, Parana, Brazil | [3]Kansas Biological Survey, University of Kansas, Lawrence, Kansas, USA | [4]Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado, USA | [5]Department of Human-Environment Systems, Boise State University, Boise, Idaho, USA | [6]Humane Society of the United States, Prairie Dog Coalition, Boulder, Colorado, USA | [7]Western Association of Fish and Wildlife Agencies, Phoenix, Arizona, USA | [8]USDA-Agricultural Research Service, Fort Collins, Colorado, USA

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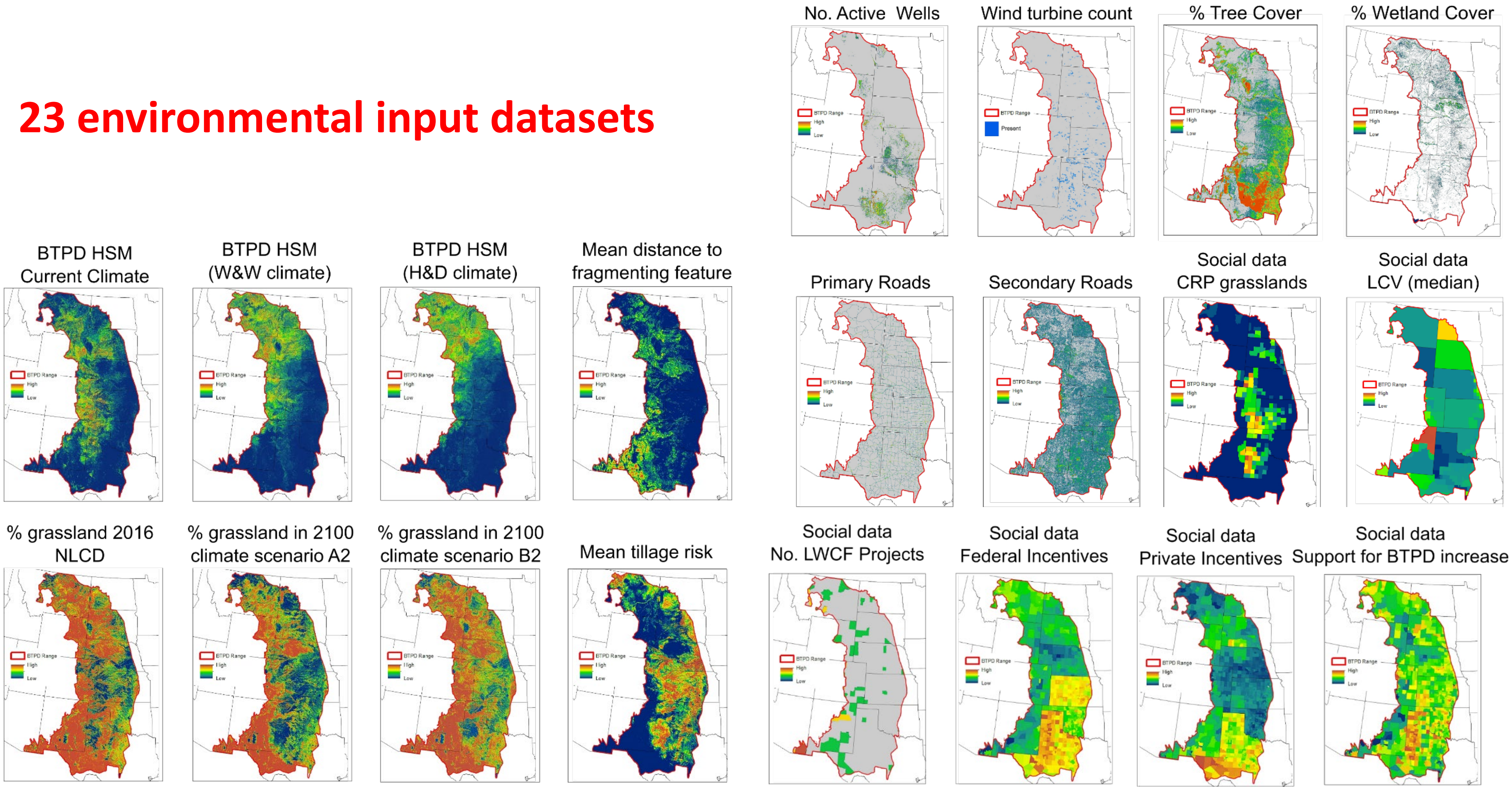
Methods (Part II): Incorporating landscape & social variables to determine conservation priorities

23 environmental input datasets

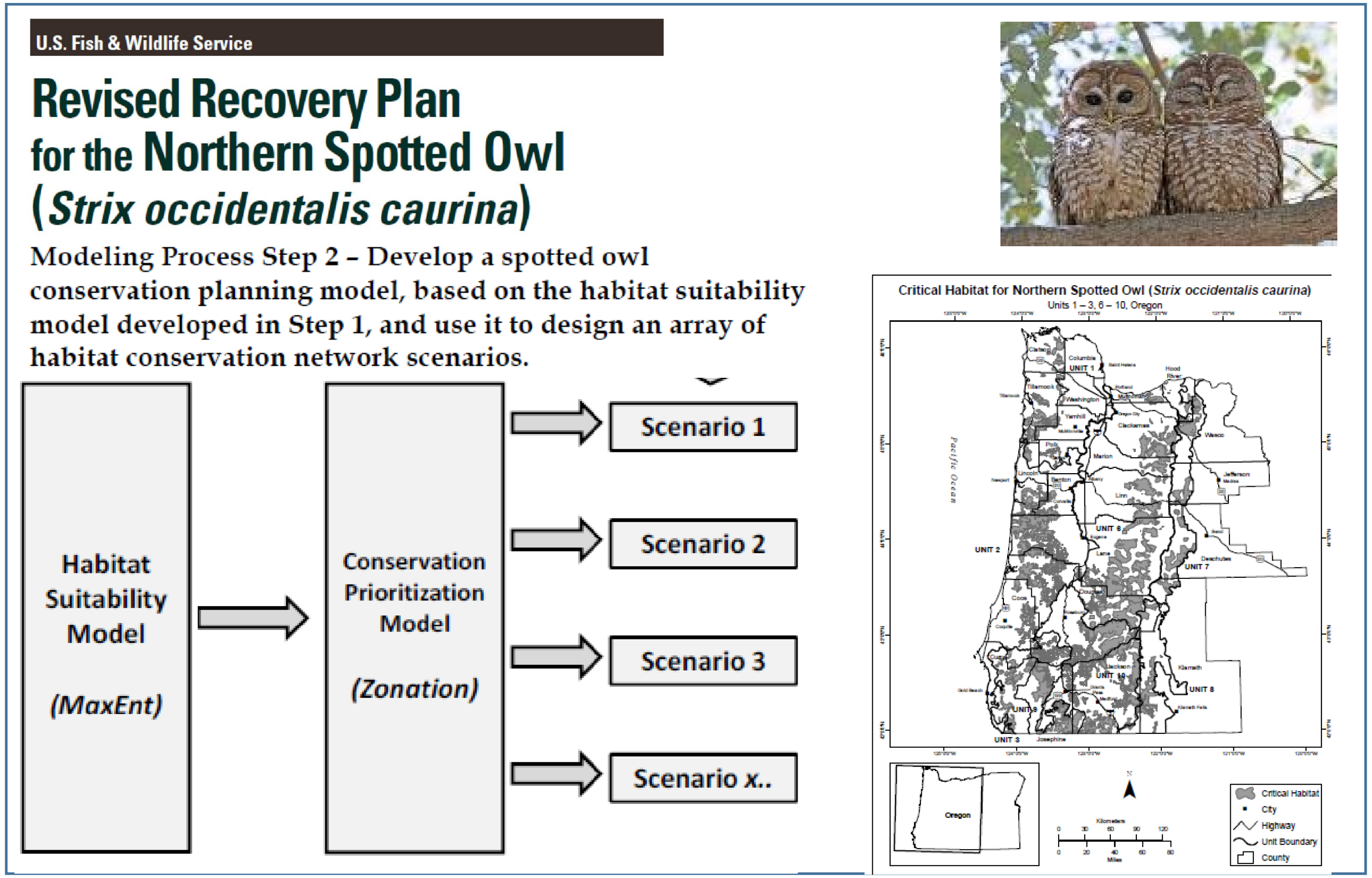


Davidson et al. 2024, Diversity and Distributions

Methods (Part II): Identifying current & future landscapes for grassland conservation, within predicted suitable habitat

Using Conservation planning tool (Zonation) to identify multiple scenarios based on varying assumptions

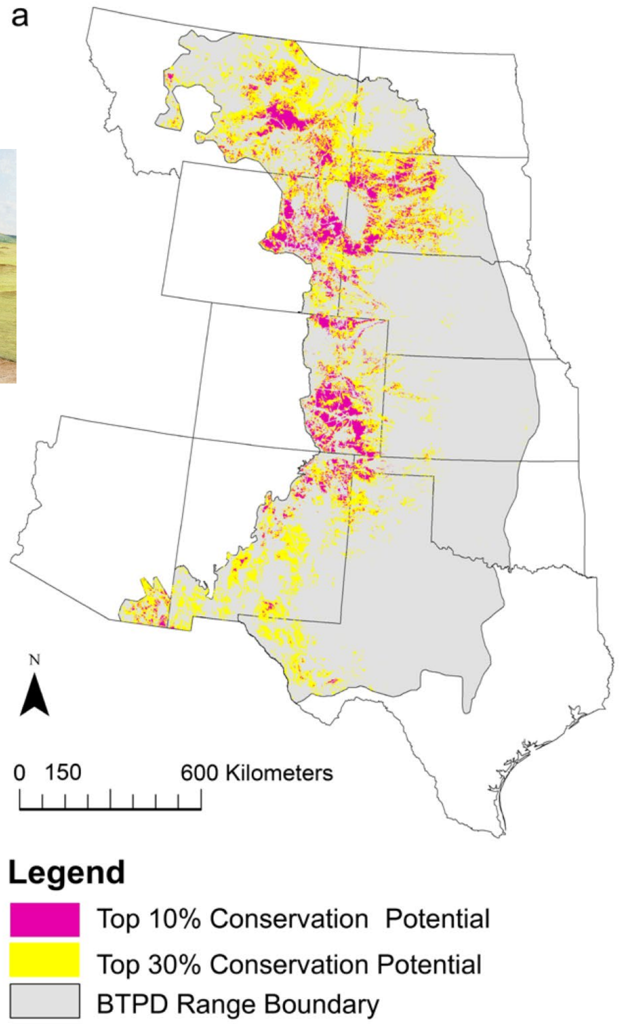
Zonation produces a hierarchical prioritization of the landscape based on the conservation value or "habitat value" of cells

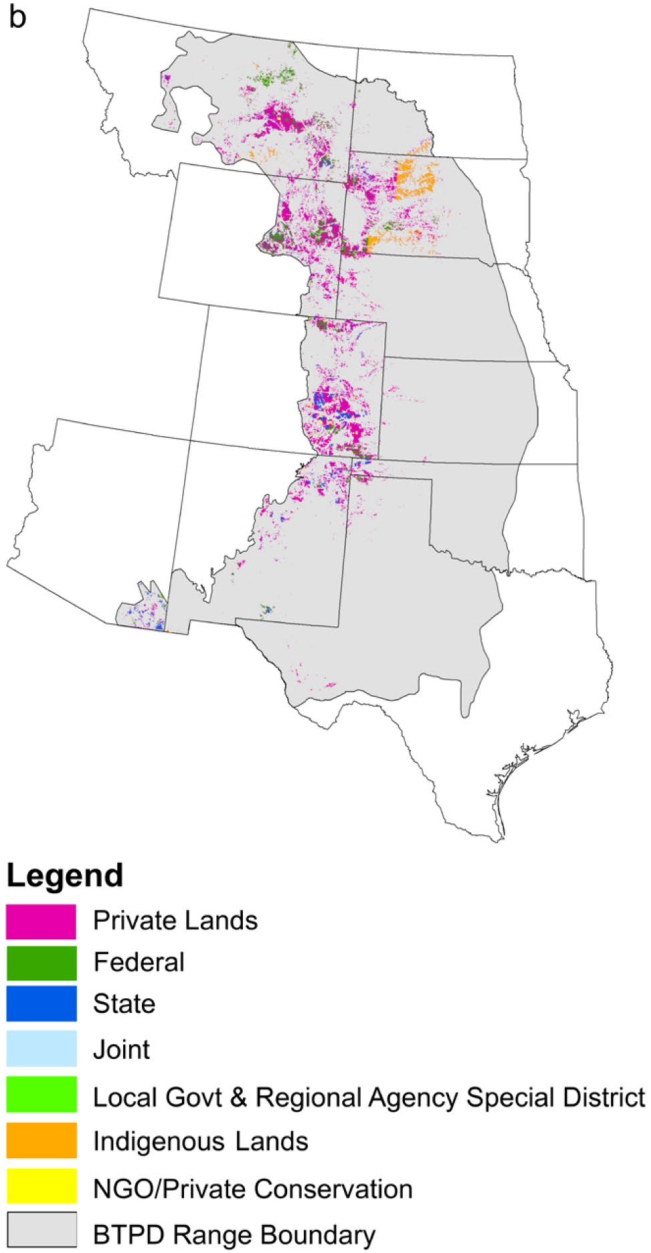


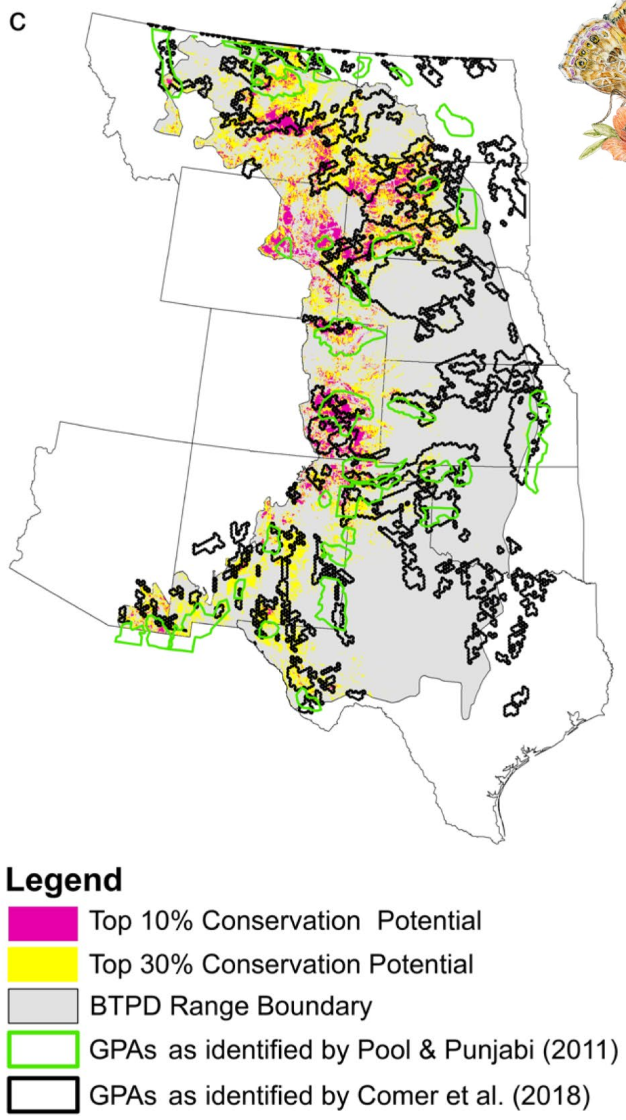
Our approach is similar to that used to identify scenario priority areas and inform the recovery plan for northern spotted owls

Davidson et al. 2024, Diversity and Distributions

Results: Landscapes with highest conservation potential



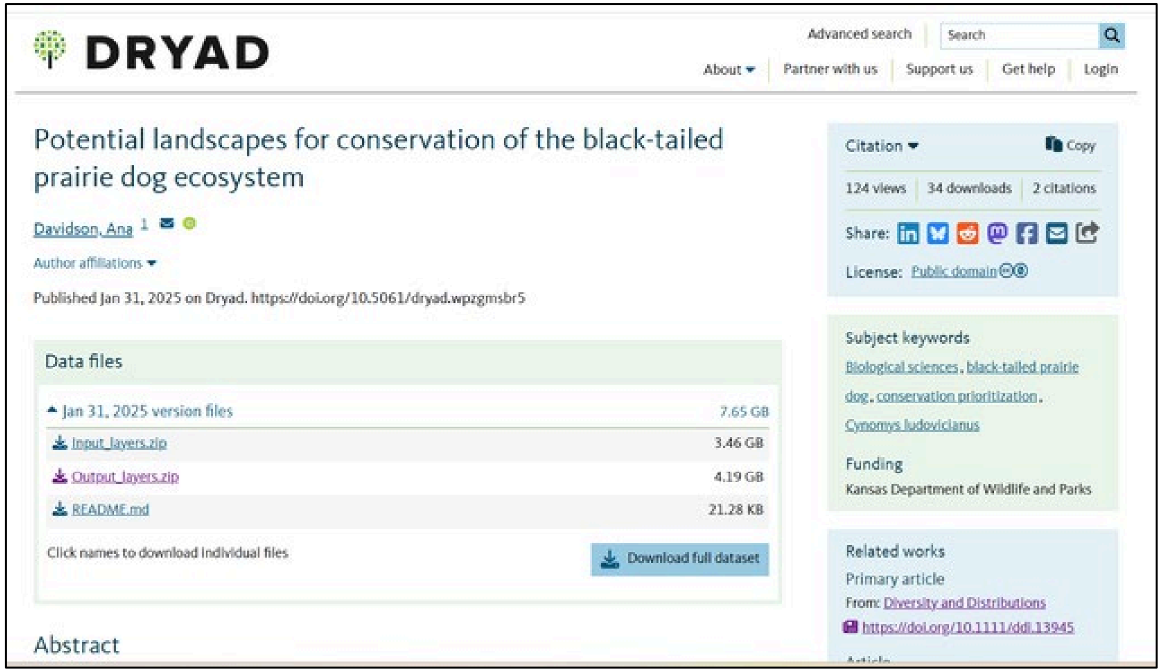




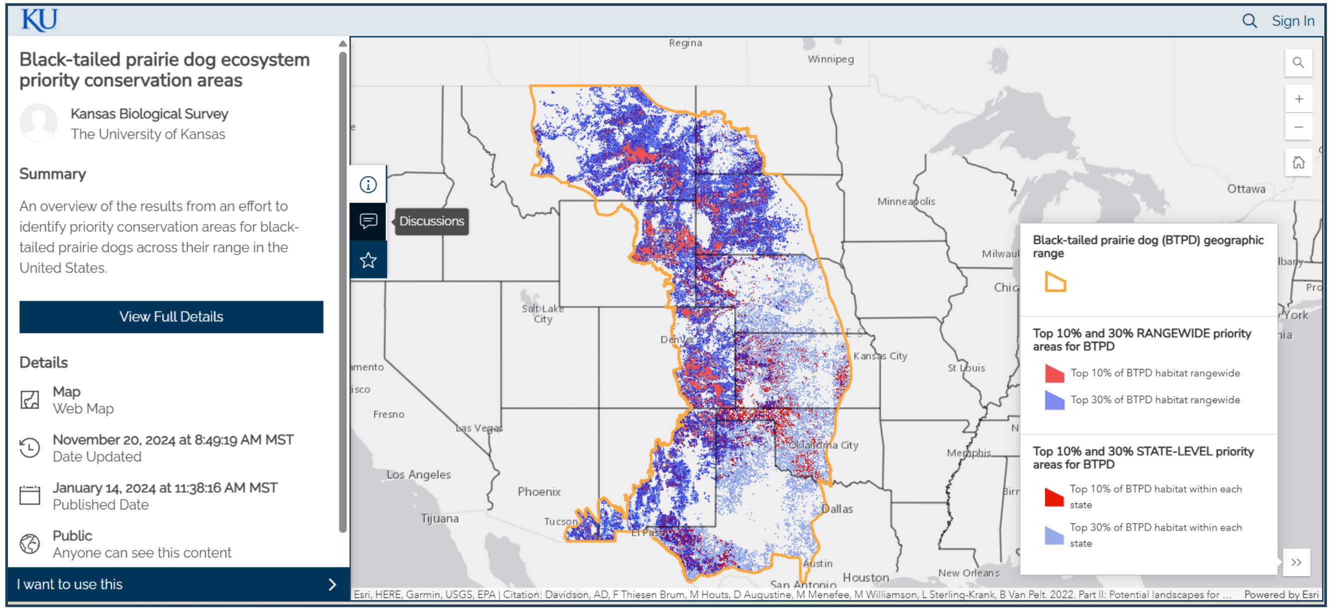
Davidson et al. 2024, Diversity and Distributions

Data available

Data Dryad



Interactive maps



Project web page with data and publications:
https://cnhp.colostate.edu/projects/hotr/

Davidson et al. 2025, Diversity and Distributions

Our Team!

David Augustine,
Research Ecologist,
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Grassland Coordinator,
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Conservation Biologist,
The Humane World of Animals

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Michelle Fink,
Landscape Ecologist,
Colorado Natural Heritage Program, CSU

Partners

Homes on the Range **is part of the WAFWA Grassland Initiative**

Natural Heritage Program Colorado

Colorado State University

WAFWA
Western Association of Fish & Wildlife Agencies

USDA Agricultural Research Service

The Humane Society of the United States

Kansas Wildlife & Parks

Kansas State University

UFPR
Universidade Federal do Paraná

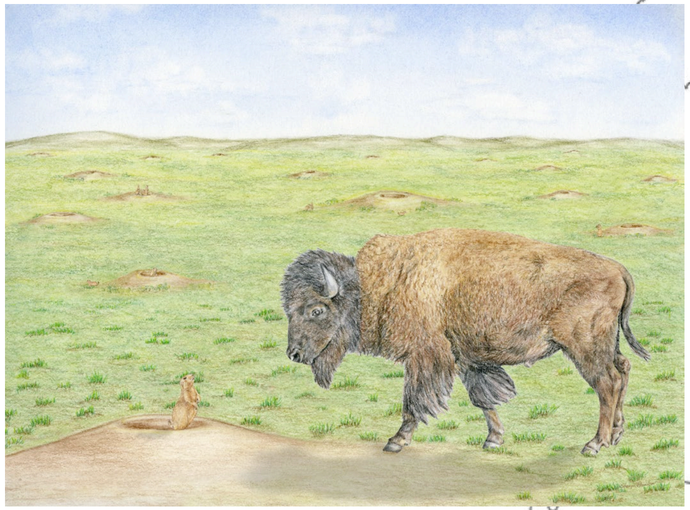
Boise State University

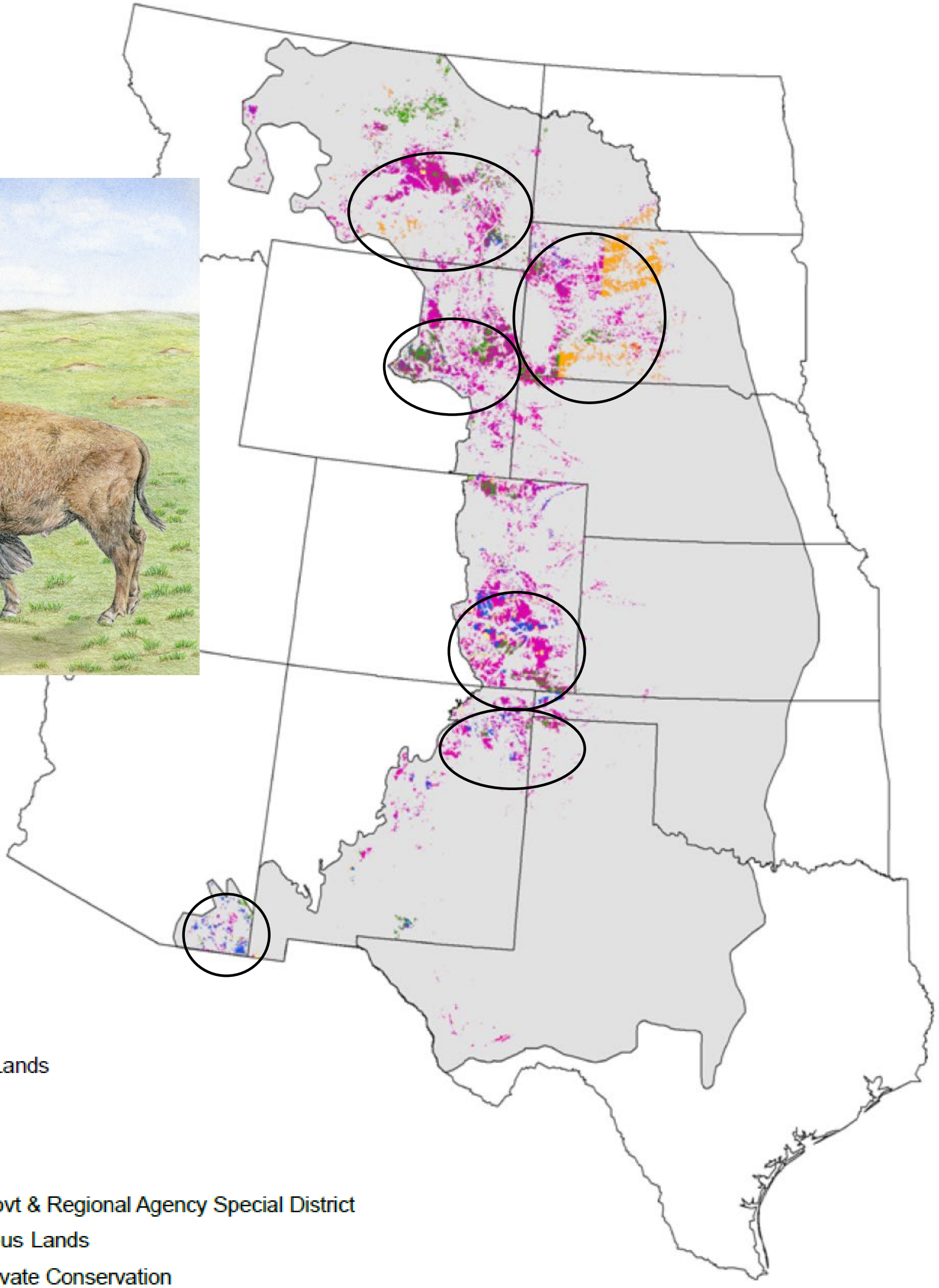
North Central Climate Adaptation Science Center

WAFWA Prairie Dog Conservation Team

Next Steps: Think Big!!

- Identification of local needs to facilitate conservation action in focal priority areas
- What will it take to support the conservation of the 5,000-10,000-50,000 acre colonies?
- What will it take to support the conservation of co-existing bison herds?
- **Large landscapes, connectivity, & corridors!**
- Seek funding to support local needs:
    - Capacity to support landowner outreach
    - Community outreach to understand sustainability issues
    - Capacity for states to develop conservation strategy among private and public lands
    - Facilitate coexistence with ranching community & economic sustainability
    - Landowner incentives, grassbank
    - Conservation easements
    - Climate adaptation
    - Monitoring and mapping of BTPD colonies
    - Plague management





Davidson et al. 2025, Diversity and Distributions

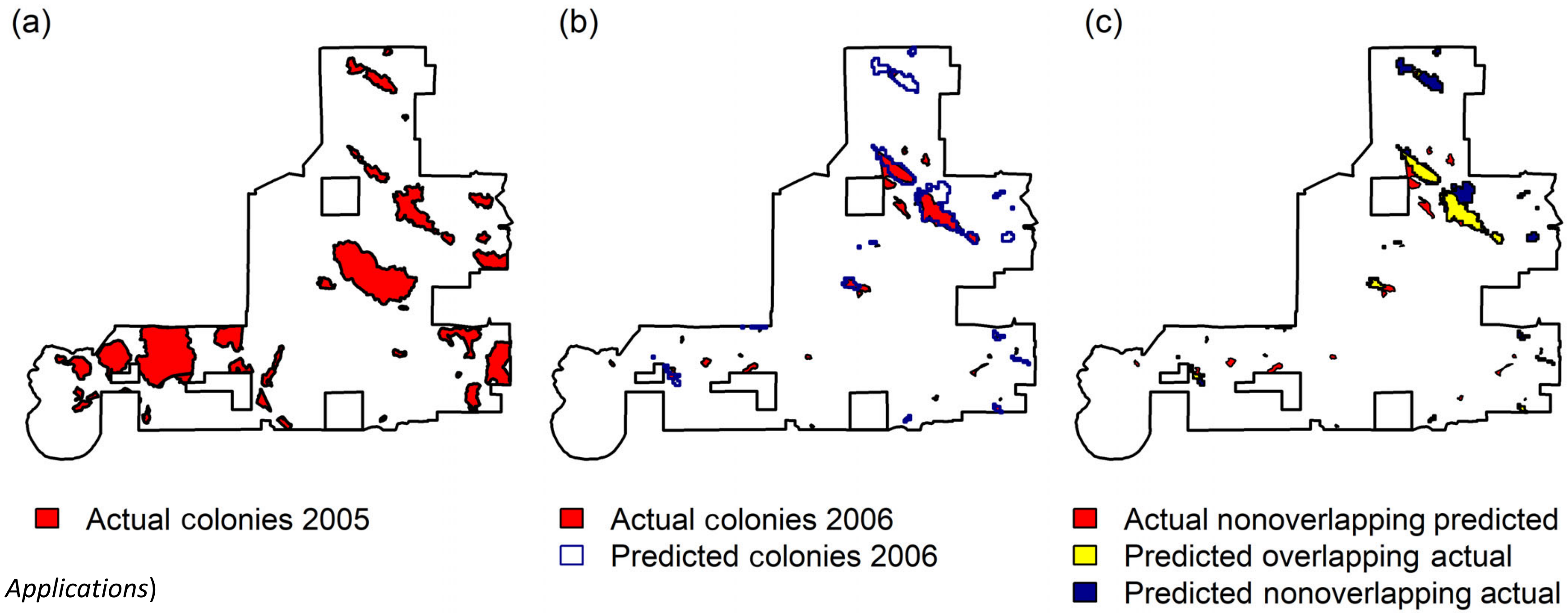
Informing management and facilitating co-existence

ARTICLE

ECOLOGICAL APPLICATIONS
ECOLOGICAL SOCIETY OF AMERICA

A big data–model integration approach for predicting epizootics and population recovery in a keystone species

Gabriel M. Barrile[1,2] | David J. Augustine[3] | Lauren M. Porensky[3] | Courtney J. Duchardt[4] | Kevin T. Shoemaker[5] | Cynthia R. Hartway[6] | Justin D. Derner[7] | Elizabeth A. Hunter[8] | Ana D. Davidson[1,2]



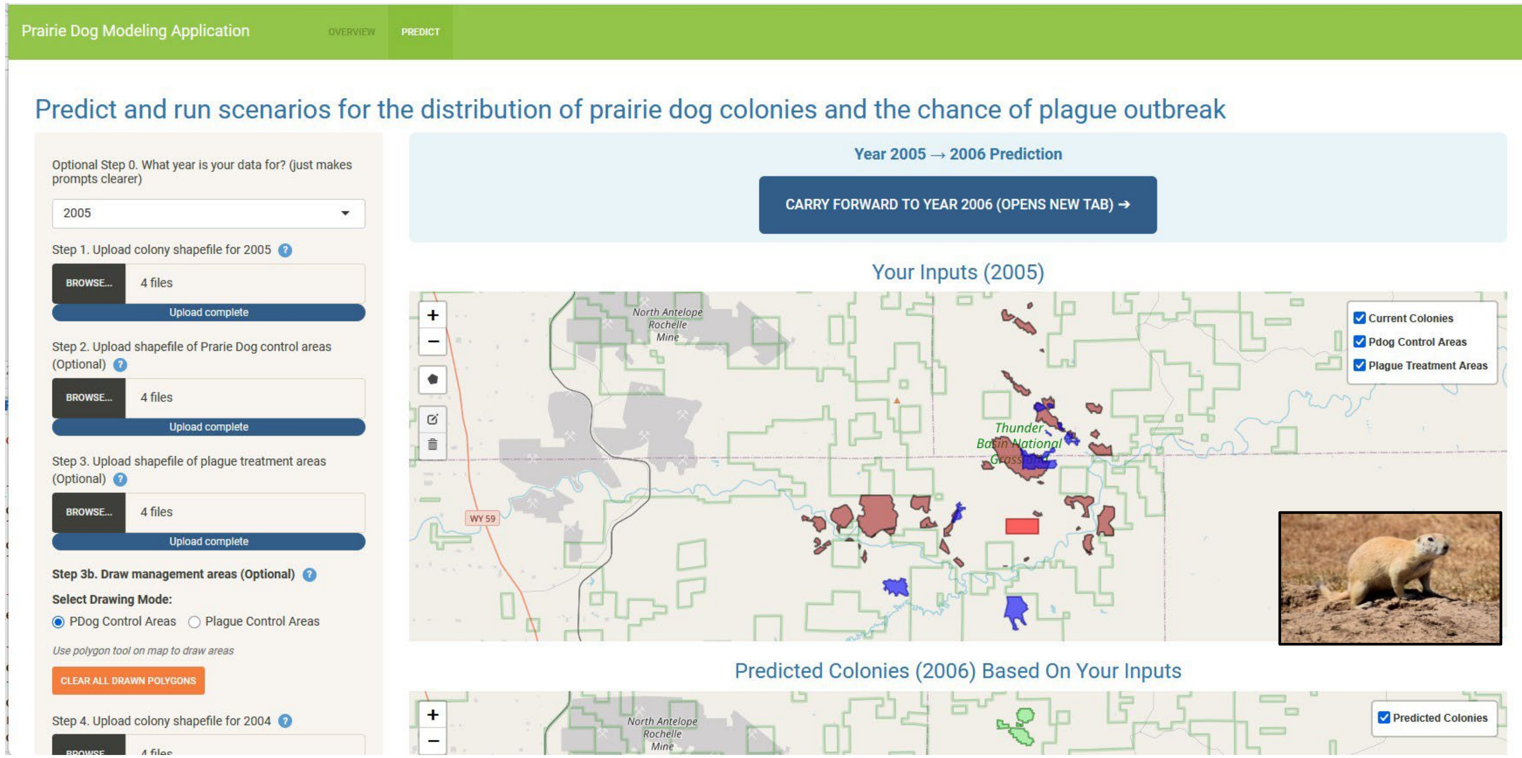
(Barrile et al. 2023, *Ecological Applications*)

PDOG MAPR An Interactive Web-Based Decision Support Tool to Inform Management of Prairie Dogs

NORTH CENTRAL Climate Adaptation Science Center

Team: Gabriel Barrile, UW; Bort Edwards, CNHP, CSU; Kevin Shoemaker, UNR; David Augustine, USDA-ARS; Courtney Duchardt, UA; Imtiaz Rangwala, CU Boulder & NC CASC; Maksim Sergeyev, CSU; Ana Davidson, CSU

- Simulate colony dynamics under user-defined management scenarios
- Predictions of future colony extent and risk of plague outbreak



https://moped.shinyapps.io/PDOGMAPR/

PDOG MAPR An Interactive Web-Based Decision Support Tool to Inform Management of Prairie Dogs

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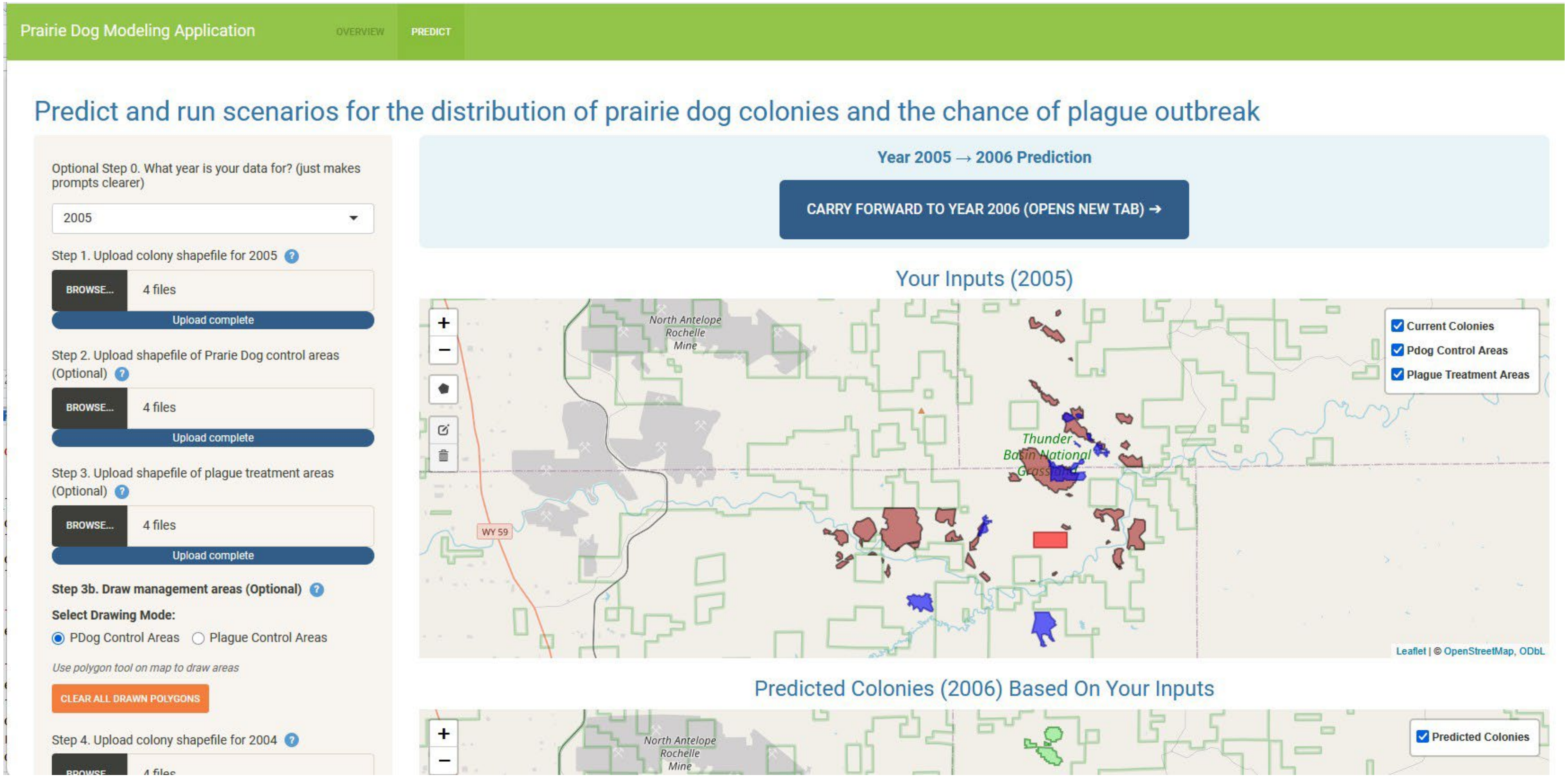

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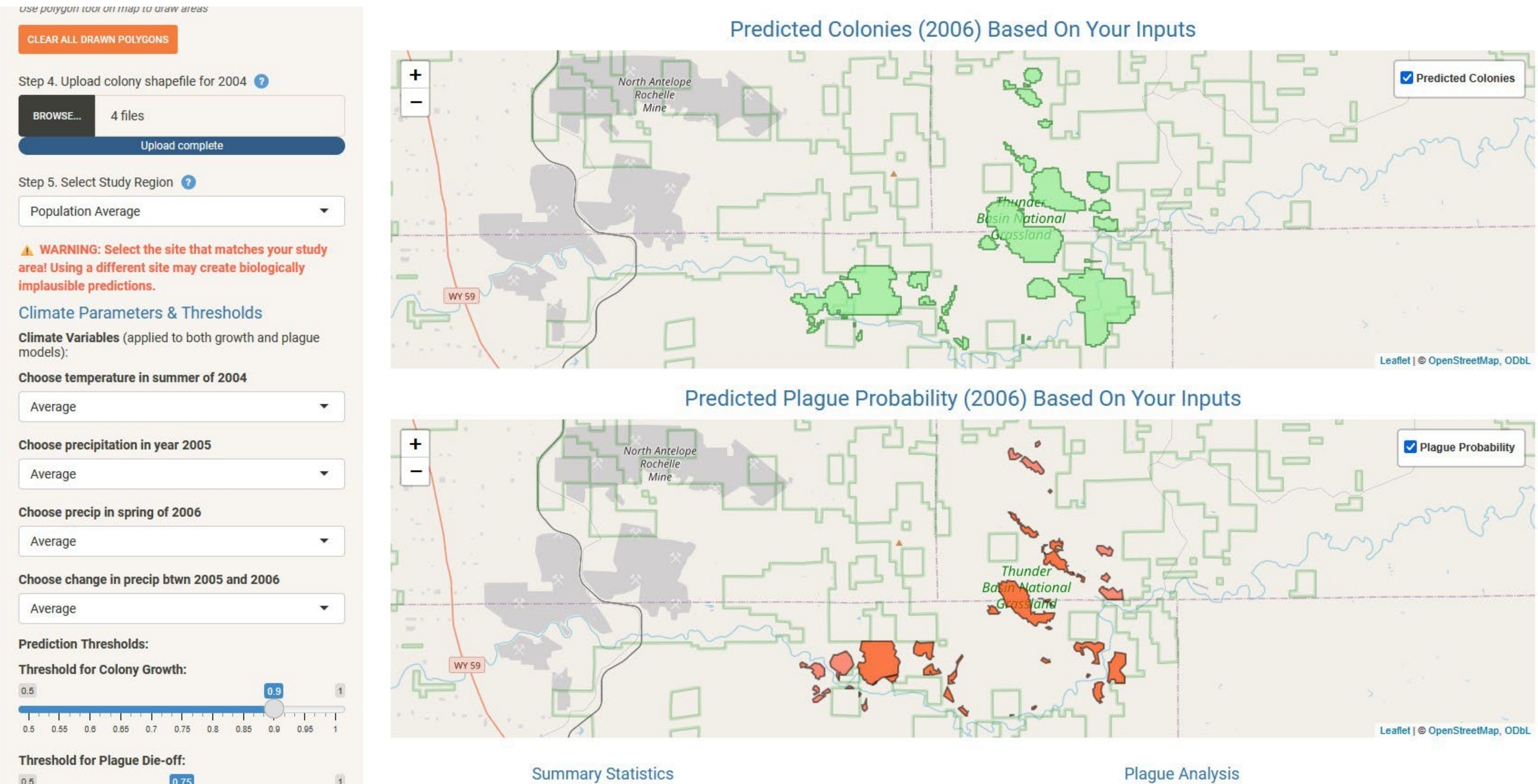
Climate Adaptation
Science Center



PDOG MAPR An Interactive Web-Based Decision Support Tool to Inform Management of Prairie Dogs

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$

Economic Analysis

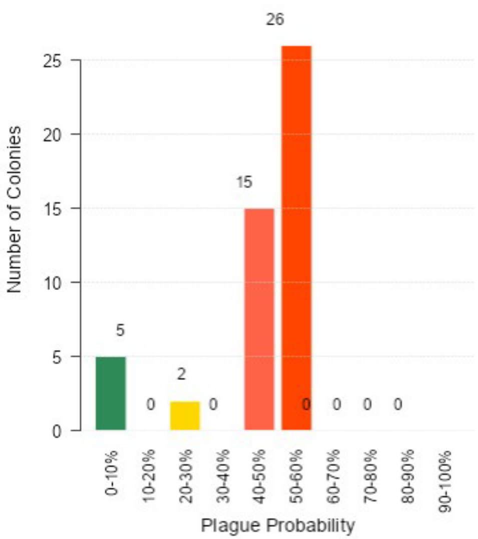
- How much forage gained
- Net Gain after poisoning costs considered

Summary Statistics

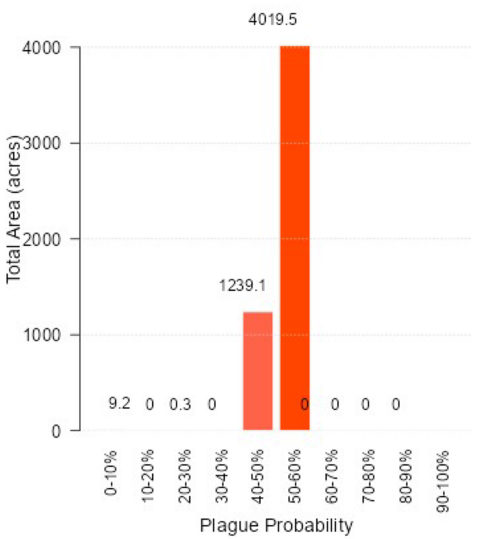
Metric	Value
Current Colonies	37
Predicted Colonies (2006)	32
Area Change (acres)	+6744.62
Area Change (%)	+118.7%
Max Plague Probability (%)	55.18
Mean Plague Probability (%)	44.61

Plague Analysis

Colony Count by Probability



Area by Probability



Economic Analysis - 4 Scenarios

CLICK TO RUN (OR UPDATE) ECONOMIC ANALYSIS

A: Average Pdog consumption values

Acres Pdog Control: 478.71

Acres Pdogs after colony prediction: 12426.92

Pdog density (per acre): 42

Control cost/Acre ($): 25

Change in forage on controlled land (lbs): -7,716,047

Change in forage on controlled land (lbs/acre): -16,118

Expenditure on Pdog control:

B: Pdogs have no influence on forage

Acres Pdog Control: 478.71

Acres Pdogs after colony prediction: 12426.92

Pdog control cost/Acre ($): 25

Change in forage on controlled land (lbs): +0

Change in forage on controlled land (lbs/acre): +0

Expenditure on Pdog control: $11,967.75

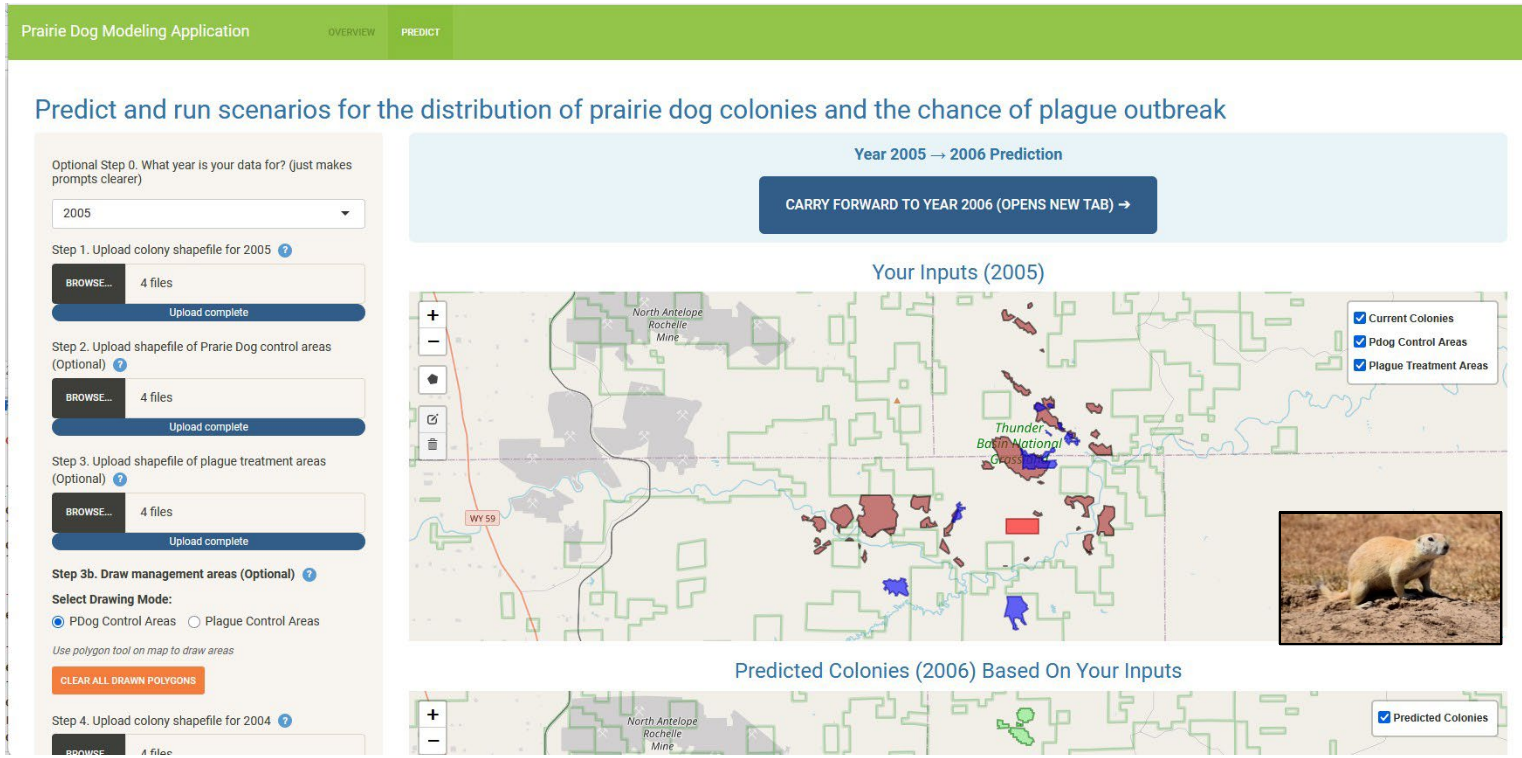
Economic Scenario Descriptions

	SCENARIO A: Average Prairie Dog Consumption Values	SCENARIO B: Prairie Dog Colonies Yield 100% Forage	SCENARIO C: Prairie Dog Colonies Yield 50% Forage	SCENARIO D: Prairie Dog Colonies Yield 0% Forage
Scenario	Average values for prairie dog/stock interactions are assumed.	It is assumed that areas occupied by prairie dogs yield the same forage as land unoccupied by prairie dogs (any change in colony area will result in no gain or loss of forage).	It is assumed that areas occupied by prairie dogs provide 50% forage value to stock, thus area modeled as being released from prairie dogs will result in a 50% gain in forage value.	It is assumed that area occupied by prairie dogs provide 0% forage value to stock, thus area modeled as being released from prairie dogs will result in an 100% gain in forage value.
Pdog control efficiency	100%	100%	100%	100%

PDOG MAPR Next Steps

Team: Gabriel Barrile, UW; Bort Edwards, CNHP, CSU; Kevin Shoemaker, UNR; David Augustine, USDA-ARS; Courtney Duchardt, UA; Imtiaz Rangwala, CU Boulder & NC CASC; Maksim Sergeyev, CSU; Ana Davidson, CSU

- Simulate colony dynamics under user-defined management scenarios
- Predictions of future colony extent and risk of plague outbreak
- Hold interactive webinars to receive stakeholder feedback and improve tool utility – This spring!



https://moped.shinyapps.io/PDOGMAPR/

Questions?

Photo by Rodrigo Sierra Corona