Methods for Determining Biodiversity Metrics, Focal Species, and Conservation Practices for Multi-scale Analysis in Support of the Conservation Effects Assessment Project (CEAP)

Informing Management for Grazing Lands in the Southwest

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By:

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Executive Summary

The Center for Applied Spatial Ecology (CASE) at New Mexico State University was contracted by the Natural Resources Conservation Service (NRCS) in support of the Conservation Effects Assessment Project (CEAP) to develop a process for identifying key species in a given management unit and determining the effects of conservation practices on those species. This process can be applied to many different management units and species, and is ultimately intended to inform rangeland management activities in the Western United States as they pertain to wildlife.

Biodiversity and species conservation priorities were identified using a broad-scale approach; conservation practice effects were assessed at the fine scale. At the broad-scale we revised and applied an existing method for assessing the importance and potential contributions that a particular management unit can make to regional conservation efforts. In particular, we compared the distributions of species and areas with higher levels of species richness within the management unit to those within different ecological contexts (i.e., areas surrounding the management unit) and selected both individual species and groups of species (e.g., riparian obligates) as conservation priorities. We applied this method to the Las Cruces District (LCD) of the Bureau of Land Management (BLM) in New Mexico. This method entails the use of species habitat distribution models from the Southwest Regional Gap Analysis Project.

We also compiled information on the relationship between land management practices and a prioritized list of focal species for the example study area (i.e., the LCD) that was identified via an extensive literature review and refined using stakeholder feedback. Our fine scale approach includes developing a Dynamic Systems Model using STELLA® to assess the effects of conservation practices on the wildlife species identified as priorities. This model is informed by state-and-transition vegetation dynamics; relationships among soil properties, water availability, and plant growth; and focal species habitat requirements. We focused on scaled quail (*Callipepla squamata*) and brush control techniques but the model could easily be extended to consider effects of other conservation practices on other species or suites of species with similar ecological requirements. The dynamic system model provides scenario runs that can assist with long-term management efforts. Our model indicates that tebuthiuron application can help managers restore scaled quail habitat on a temporal scale of 100 years if applied during above average precipitation. The extended time may give yucca the necessary time to establish and enhance scaled quail habitat.

We created ArcGIS models that work at the species or biodiversity metric level. The species model identifies the SWReGAP species and each specific land cover type (ecological system) found within the polygon. The model table also provides the area for each species * land combination and the predetermined impact for a conservation practice on that land based on % effectiveness. The CEAP Biodiversity Metrics provides the same information by based on species richness statistics for a given biodiversity metric within the polygon.

Information on habitat use patterns from the literature can be combined with output from the Dynamic Systems Model to identify whether and when post-application TEB treatment could be beneficial to Scaled Quail (*Callipepla squamata*). In particular, model output will allow for identification of the point at which a mixed shrub-grassland state is reached. The Dynamic Systems Model has potential use for other ecological systems.

This project has provided an initial effort to identify biodiversity metrics, species lists, and conservation practices of interest for a large and biodiverse management unit in the western US and assess the impacts of conservation practices on selected species. Collaboration with agencies and stakeholders, supplemented by thorough literature review, is necessary to determine conservation priorities and relevant management practices for a particular region. Analysis at the broad scale can be used to inform management activities at the fine scale. Fine scale dynamics can be extrapolated to a larger area and incorporated into a decision support tool that can be used to determine the holistic effects of conservation practices on wildlife populations. Conservation practices have varying effects on habitats and species utilization over time which should be considered in management planning.

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Acknowledgements

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Introduction

Biodiversity has been defined in many ways, but generally refers to the variety of life and the ecological processes that support life (Ridder 2008). More important is the general recognition that diversity of plants and animals in the natural world supports human interests ranging from basic food and fiber needs to medicinal products to recreation and purely appreciative aspects of nature. Thus, sheer biodiversity, regardless of our level of understanding of the ecology of individual species, has inherent value in terms of its impact on the quality of life of humans. West (1993) acknowledged the need to address biodiversity within rangeland management activities.

Coupling biodiversity perspectives with levels of conservation planning of natural systems has existed for many years (Burley 1988; Goldman and Tallis 2009). This concept has been developed broadly for biodiversity conservation purposes (Gap Analysis Program, GAP) in the continental United States (Scott et al. 1993, 1996; Prior-Magee et al. 2007). GAP provides a landscape-level process for assessing conservation of biological diversity (Scott et al. 1993, 1996). Gap analysis maps the distribution of plant communities and predicts suitable habitat for animal species and compares these distributions with land ownership and stewardship to identify biotic elements at potential risk of endangerment. The baseline datasets GAP provides are uniquely suited for use in biodiversity assessments at broad scales and an analysis of the ecological context and potential contribution to regional conservation planning that can be made by individual management units.

Identification of metrics that describe biodiversity is ongoing and researchers have used metrics such as species richness and vegetation diversity in prior biodiversity studies (Egoh et al. 2009). There are many ways that terrestrial vertebrates can be grouped to represent biodiversity. These groupings may include broad categories, such as: recreational or hunting, cultural, spiritual or intrinsic value, rarity, and association with particular land-cover types. More specific metrics include total species richness, richness of broad taxonomic groups, Threatened and Endangered (T&E) species richness, Species of Greatest Conservation Need richness (SGCN), and harvestable species richness (Boykin et al. 2013). Biodiversity metrics can provide information on more than the number of species found in a given area, or “alpha” diversity as defined by Whittaker (1960). Changes in biodiversity affect ecosystem structure and function and there is a relationship between biodiversity and the provisioning of ecosystem services (Chapin et al. 2000; Loreau et al. 2001; Duffy 2009; Thompson et al. 2011; Boykin et al. 2013). Biodiversity is associated with ecosystem stability and resilience (Chapin et al. 2000; Loreau et al. 2001). It is also associated with the provision of both market and non-market ecosystem services including crop pollination (Klein et al. 2003), wood production, fisheries’ yield stability, and carbon sequestration (Cardinale et al. 2012). Biodiversity metrics based on different groups of species can have varying connections to ecosystem services. For example, metrics based on harvestable species have a direct connection to local economies, while other metrics pertain to cultural values or ecosystem properties that are indirectly tied to biodiversity (Boykin et al. 2013). Many assessments related to biodiversity and ecosystem services have been performed globally and are being compiled for easy access and reference by the Intergovernmental Platform on Biodiversity and Ecosystem Services (http://catalog.ipbes.net/).

There are many approaches to identifying conservation and management priorities for geographic areas of interest that range from local to global scales (Dobson et al. 1997; Myers et al. 2000; Cardillo et al. 2006; Ribeiro et al. 2009; Schloss et al. 2011). These techniques can involve identification of specific areas (e.g. management units such as logging compartments or sub-watersheds) or broader geographic regions (e.g. counties or ecoregions) that should be protected (Dobson et al. 1997; Margules and Pressey 2000; Myers et al. 2000; Araújo et al. 2004; Burgess et al. 2006; Schloss et al. 2011; Lemes and Loyola 2013). They can also entail selection of species or habitats, either globally or within a focal area, that are the most important to protect (Hamazaki et al. 2003; Cardillo et al. 2004; Gastauer et al. 2013). Hamazaki et al. (2003) identified conservation priorities for a military base using an analysis that incorporates information on the base's ecological context (i.e. surroundings) as defined by buffers. This assessment led to the identification of species and vegetation types that were widespread within the study area but restricted within the region. This switch in priorities from locally rare to locally prevalent and regionally rare focuses conservation efforts on species that may be conserved more efficiently within the study area and ultimately contribute more to the biodiversity of the region. Extending the analytical approach presented by Hamazaki et al. (2003) to an evaluation of biodiversity metrics and the use of ecological context regions defined by political and ecological boundaries, rather than simple buffers, leads to a methodology that is easily applied to other geographic areas and considers context regions more relevant to the activities of many land managers. Incorporating ecological context into conservation planning allows managers to maximize the effects of on-site efforts while elucidating the impact of local conservation activities on the surrounding area (Hamazaki et al., 2003). Ecological context is defined here as the area surrounding a management unit of interest. Identifying conservation priorities using information on species distributions relative to both the area of interest and its ecological context can assist managers in selecting conservation practices that are locally beneficial and can contribute the most effectively to region-wide conservation efforts. For instance, if only 3% of a species total range overlaps a given management unit then that species would be of lower conservation priority, and thus less relevant to consider when selecting conservation practices, for that unit according to its ecological context than a species which has 90% of its range within the unit. Ecological context has been incorporated into environmental rehabilitation planning (Walz 2000; Pressey and Taffs 2001; Quon et al. 2001; Noss 2002).

Adaptive management is an important concept in conservation planning, and there are different approaches for its implementation (Gregory et al. 2006; Hockings et al. 2006; Williams and Brown 2013). The Natural Resources Conservation Service's (NRCS) Conservation Effects Assessment Project (CEAP) is one such approach. CEAP is a multi-agency effort to quantify the environmental effects of agricultural conservation practices and programs and develop the science base for managing agricultural landscapes for environmental quality (Maresch et al. 2008). The CEAP Grazing Lands component is intended to produce tools for the evaluation of the effects of conservation practices on the hydrology, soil, and ecosystem services provided by grazing lands, especially in the western US. CEAP tools allow for an assessment of the impacts of a variety of conservation practices, including brush and fire management and stock pond installation, on environmental variables such as runoff and sediment yield. This study was conducted to address biological resource concerns to complement these soil and water related assessments conducted under the CEAP Grazing Lands umbrella. Specifically, it is intended as a preliminary step towards determining the effects of conservation practices on individual species and different measures of biodiversity and associated ecosystem services (Weltz et al. 2011). As part of an adaptive management process, such evaluations can inform future application of conservation practices, especially with respect to their impacts on wildlife. At the international level, the International Union for Conservation of Nature has developed a framework for assessing the effectiveness of management activities in protected areas (Hockings et al. 2006). Context assessment, including identification of biological values such as biodiversity for the protected area, is listed as the first step in a broader adaptive management cycle.

Rangeland management activities or conservation practices can have multiple effects on habitat. Practices can cause type conversions, condition changes, or less tangible changes to the quality of the habitat. These changes are scale dependent and Bestelmeyer et al. (2011) suggested multi-scaled studies to uncover spatial processes. Our focus is on the larger and more readily measured changes within the community, principally type conversions and changes in quality or condition. Subtle changes are best studied under long-term site specific monitoring projects. Changes in vegetation community composition or structure or habitat quality can affect vertebrate species populations and ultimately overall biodiversity (Figure 1). Birds may be best suited as focal organisms for assessing conservation practice effects as the literature is replete with characterizations of different habitats suitable for birds.

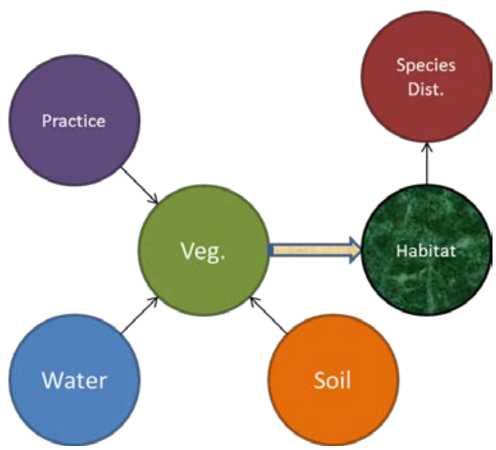

Figure 1. Connection between ecosystem processes, vegetation dynamics, species habitat, and conservation practices. These connections can be implemented in a dynamic systems model.

Ecological sites are areas with similar soils and landforms that are within a broader area of uniform climate (Bestelmeyer et al. 2011). These sites support similar ecosystems at their potential or reference state. Ecological sites have been defined by the variability of the system and the expected plant communities that may occur at these sites (Herrick et al. 2010). State-and-transition Model (STMs) have been developed using ecological sites as the framework (Briske et al. 2005). STMs identify vegetation communities as a series of states that are linked by some threshold (disturbance or management) to alternative states (Figure 1B. Bestelmeyer et al. 2011). The STM concept has been used by federal land management agencies in the United States to set reference conditions and recommend actions to achieve a predetermined condition in rangelands and forests (http://www.fs.fed.us/biology/soil/). The management actions and ecological processes described in STMs have potential to provide key components of scenarios necessary to test the impacts of the application of a conservation action on the habitat of a particular site (Figure 2). Scenario outcomes as determined by a Dynamic Systems Model can be validated through on the ground monitoring or by comparing past management actions with current conditions. However, STMs are not yet available for many of the ecological sites present within the western United States.

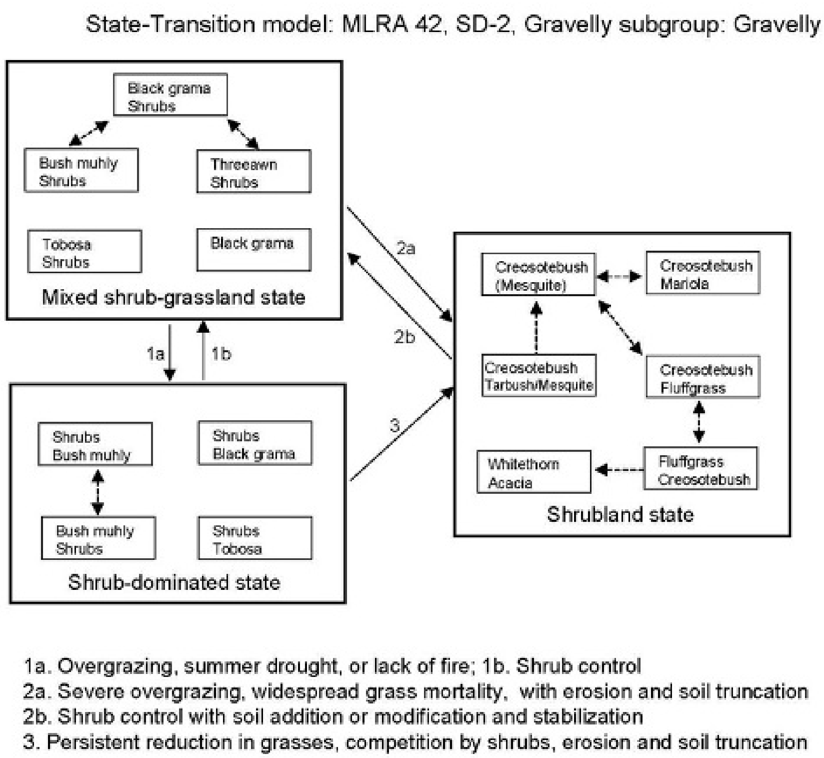

Figure 2. State-and-Transition Model Gravelly Ecological Site Description in Southern Desertic Basins, Plains, and Mountains (042).

Assessments of conservation practices are similar to risk assessments, only a species or habitat is analyzed for the potential benefit instead of risk from certain activities (i.e., conservation practices). Andersen et al. (2004) used a risk assessment protocol to identify steps for mitigation of the impacts of Department of Defense (DoD) activities on local species. This process used a list of programs, which were comprised of activities and associated impacts, to score the effect of management within defined areas on selected species. Scoring was dependent on individual species tolerance to impacts associated with each activity in each program. Similar information can be compiled regarding the effects of conservation practices, both positive and negative, on species of interest for a given management unit. If we select chemical brush control as an example conservation practice, a list of potential effects to an ecological system can be created. The effects could include change in shrub cover, change in vegetation height, or long term environmental chemical exposure. Each of these effects then could be given an impact score according to available literature and expert opinion on a species of interest. These impact scores could then be mapped out for potential chemical application sites across the management unit and compared to the geographic ranges of key species to determine the potential effects of brush control on the species.

We had two primary objectives for this project: 1) Develop a process for characterizing managed lands in an ecological context and identifying conservation priorities that were relevant to the broader landscape scale; and 2) Determine a method to quantify the effects of conservation practices on terrestrial vertebrate wildlife resources at the fine scale (Figure 3).

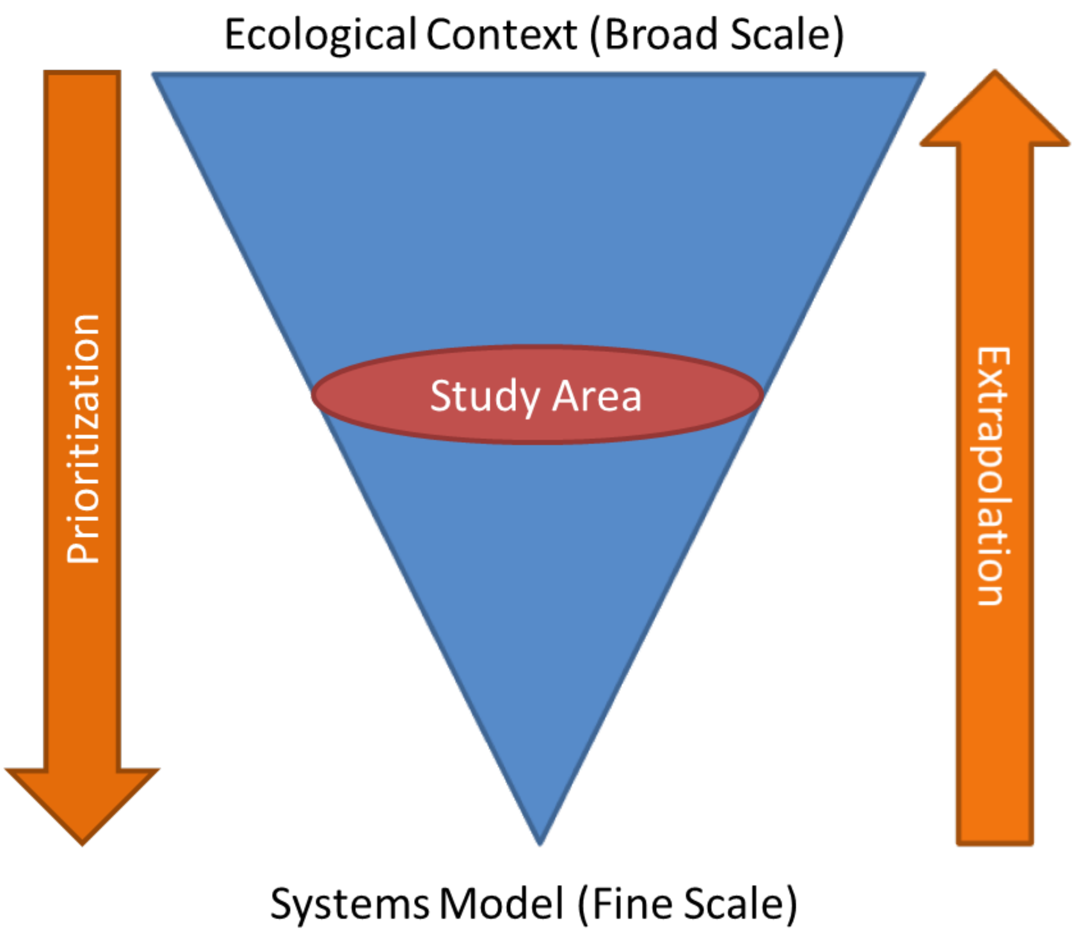

Figure 3. Schematic of a broad framework for the project. The diagram highlights the two spatial scales (broad and fine) considered and the connections between these two scales. The broad scale assessment can lead to prioritization of focal species for fine scale analysis and information from fine scale assessments of system dynamics can be extrapolated back to the broad scale.

We developed a detailed framework consisting of eight tasks. First, we identified biodiversity metrics consisting of various taxonomic groupings relevant to an example management unit (Task 1) and identified focal species and conservation priorities of interest (Task 2). Next we developed biodiversity metrics using gap analysis (Prior-Magee et al., 2007) data and characterized the example management unit in an ecological context and selected species and biodiversity metrics as conservation priorities (Task 3). The process used can ultimately be applied to any management unit anywhere in the United States and has the potential to be applied internationally as well. We compiled information on the effects of different conservation practices on focal species for the example management unit (Task 4). We developed a prototype tool [Dynamic Systems Model (DSM) in STELLA®] for assessing baseline vegetation dynamics (Task 5) and the effects of conservation practices on species selected as conservation priorities (Task 6). We reviewed the NRI data available within the study are and discussed with collaborators a process for validating the output from the DSM (Task 7). We have incorporated one of the basic components of the DSM into a GIS interface with SWReGAP data that can provide support for NRCS planning and field office personnel (Task 8).

Project Study Area

The focal area for both the broad scale and the fine scale effort for this study was the Bureau of Land Management's (BLM) Las Cruces District (LCD; Figure 4) in the southwestern US. The district encompasses over 64,900 km^2 and a total of six counties (Doña Ana, Grant, Hidalgo, Luna, Otero, and Sierra) in southwestern New Mexico. The district is bounded by the Arizona state line to the west, Otero County's eastern boundary to the east, and Mexico's northern boundary and the Texas state line to the south. There are 67 different land cover types found within the district, 62 of which are natural (National Gap Analysis Program Land Cover data; http://gapanalysis.usgs.gov/gaplandcover/data/download/). Twelve of the natural land cover types cover over 90% of the district's area and include two (Apacherian-Chihuahuan semi-desert grassland and steppe and Chihuahuan creosotebush, mixed desert and thorn scrub) that together cover over 50% of the study site. The Chihuahuan desert is a mosaic of soil patterns inferred from the Ecological Site Descriptions (ESD) provided by the Natural Resource Conservation Service (NRCS). Relevant species habitat distribution models were available from the Southwest Regional Gap Analysis Project (SWReGAP; Boykin et al. 2007). The study area provided an opportunity for extensive stakeholder involvement and the leveraging of existing connections and partnerships. The district encompasses a large portion of Fort Bliss Military Reservation (Fort Bliss), the area where conservation priorities were assessed by Hamazaki et al. (2003). In addition to lands managed by BLM and the Department of Defense, the district contains land managed by five federal agencies and land owned by private, state, and tribal entities (Figure 4). Finally, several types of land management practices widely used in the southwestern US, and of particular interest in the context of CEAP, are used in this district. The analysis performed for the LCD is ultimately intended for application to any area for which an assessment of ecological importance, and identification of conservation priorities and broader patterns of biodiversity, is desirable. The BLM was a willing partner to assist in the effort and had existing data that could be included in analysis. The New Mexico BLM is also undergoing a project called "Restore New Mexico" (http://www.blm.gov/nm/st/en/prog/restore_new_mexico.html) that is focused on placing landscape scale conservation practices on the ground.

For the fine scaled effort, this BLM district and associated agencies have conducted multiple surveys on vegetation and species that could be included within model building and model validation. Additionally the STMs for this area are better developed then in some areas of the US. The fine scaled model is meant to describe the vegetative dynamics on where shrub encroachment by creosotebush is expected to be most prolific, the gravelly soils of the bajadas in the Chihuahuan Desert. The most readily available data for this area is in the northern Chihuahuan Desert, where the Jornada Experimental Range (Jornada) conducts its research and where the Bureau of Land Management (BLM) has designated the Las Cruces District (LCD) for managing public lands. The specific Ecological Site Descriptions (ESD) provided by the Natural Resource Conservation Service (NRCS), specifically site ID R042XB010NM (R042XB010NM = Major Land Resource Area (MLRA) Region 42-2 (R042XB), soil type 10 (010), in the state of New Mexico (NM), soil type 10 is gravelly). Creosotebush has an affinity for gravelly soils, and has the ability to shift the soil type to gravelly.

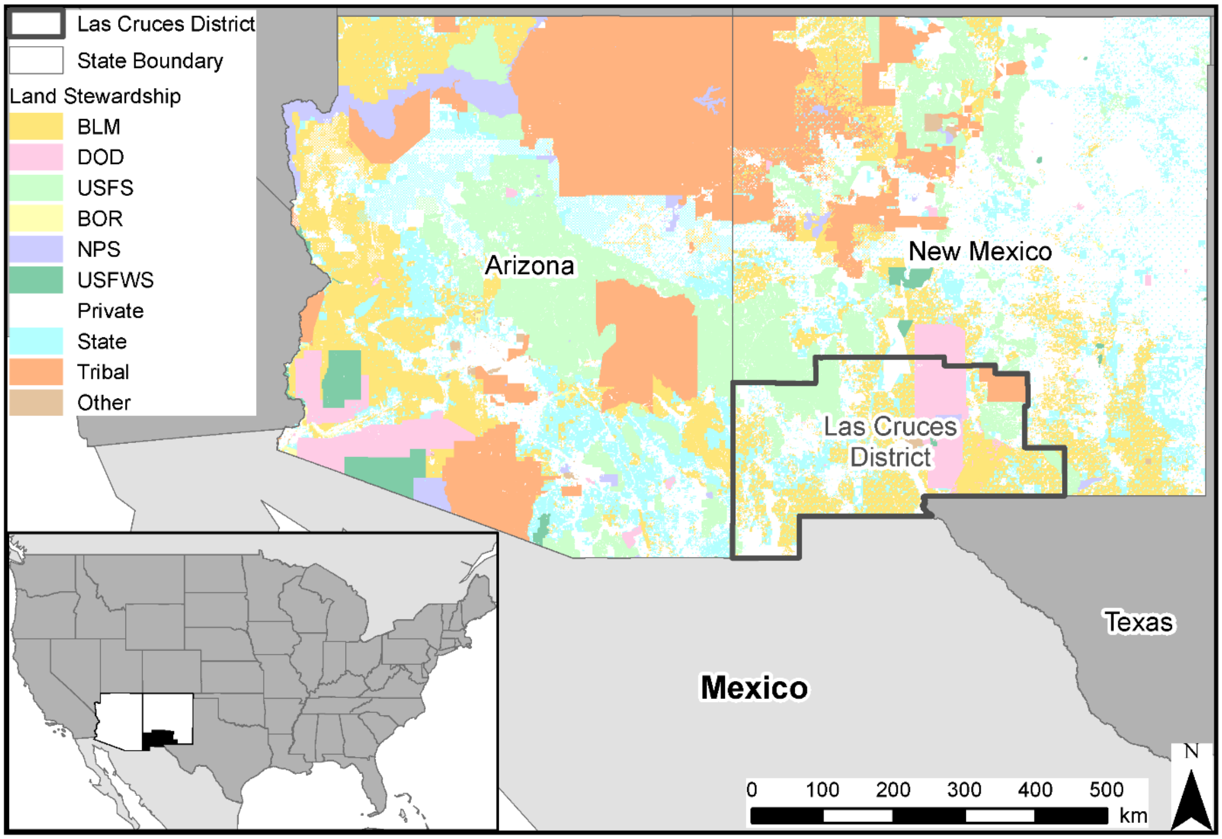

Figure 4. Land stewardship in and around the project focal area (i.e. Las Cruces District). BLM = Bureau of Land Management; BOR = Bureau of Reclamation; DOD = Department of Defense; NPS = National Park Service; USFS = United States Forest Service; and USFWS = United States Fish and Wildlife Service

Task 1-2: Biodiversity Metrics and Focal Species (Broad Scale)

We defined biodiversity metric as the sum of modeled distributions of every species within a group or taxon of interest, giving an estimation of that group's species richness over an area. These metrics can be rescaled in terms of the percentage of the maximum number of species found within the broader study area (i.e., Arizona and New Mexico combined; Figure 4). Project staff met with representatives from NRCS, the BLM, and other stakeholders to determine biodiversity metrics of interest for the BLM's LCD (Task 1). The biodiversity metrics identified are relevant to stakeholder interests and conservation concerns and were determined using existing species lists or information on species biology or taxonomy (e.g., riparian obligates, T&E species, Species of Greatest Conservation Need, mammals, etc.). Many metrics have direct or indirect connections to ecosystem services (e.g., harvestable species). Southwest Regional Gap Analysis Project (SWReGAP) models of predicted species habitat occurrence (Boykin et al. 2007; Lowry et al. 2007) were used to create each biodiversity metric (Task 2).

The set of biodiversity metrics and focal species used in the conservation priority identification process were determined based on two stakeholder workshops. An initial list of metrics and species was created based on author experience and scientific literature review to facilitate discussion at the first stakeholders meeting. Stakeholders at this first meeting included representatives from local, state, and federal agencies and conservation groups, as well as interested individuals (Table 1). The purpose of the first stakeholder meeting was to refine the initial list of metrics and focal species to align with stakeholder interests and responsibilities. Stakeholders made recommendations for new metrics and species to be added to the original list. At the second stakeholders meeting, participants rated each metric or species as low, medium, or high importance based on their agency's current management efforts or expert opinion. These scores were converted to numbers (low = 1; medium = 3; high = 5) and averaged to create a final ranking and determine which metrics and species were rated higher. Metrics and species were further assessed for their relevancy to the study area, extent to which they were expected to be impacted by conservation practices performed within the LCD (Appendix A), and availability of information. The list of metrics was further narrowed using stakeholder rankings and previously published recommendations (Boykin et al. 2013).

Thirty-one biodiversity metrics (Table 2) and 28 focal species (Table 3) were evaluated during the second stakeholder meeting. Twenty of the metrics were described in Boykin et al. (2013); they represent biodiversity, ecosystem services, or resources of conservation concern. More specifically, these metrics provide information on total species richness, richness within vertebrate taxa of interest (i.e. amphibians, bats, birds, mammals, and reptiles), richness of species identified in State Wildlife Action Plans (SWAPs; UDWR 2005; AGFD 2006; CDOW 2006; NDOW 2006; NMDGF 2006) as Species of Greatest Conservation Need (SGCN), and richness of federally threatened and endangered (T&E) species (USFWS 2011b). Several metrics relate to harvestable species and have a direct connection to local economics and ecosystem services (e.g. big game, small game, and furbearer richness). Metrics added to those from Boykin et al. (2013) pertain to sub-categories of taxonomic groups (e.g. birds protected under the Migratory Bird Treaty Act;
http://www.fws.gov/migratorybirds/RegulationsPolicies/mbta/mbtandx.html), species that are associated with particular habitat types (e.g. riparian obligate species [BLM 1998]), and species that are

not officially designated as needing conservation but are likely to be of conservation concern in the near future or are otherwise worthy of protection (e.g. richness of common but declining species [CDOW 2006; NMDGF 2006] or sensitive [i.e. candidate] species as defined in USFWS [2011a] and listed at USFWS [2011b])

The final set of 28 focal species were identified (Table 3). These species were well-studied, relevant to the study area, and likely to be impacted by conservation practices. Focal species were likely to be affected by land management practices including brush control (aplomado falcon [*Falco femoralis*] and scaled quail [*Callipepla squamata*]); and watering facilities (mule deer [*Odocoileus hemionus*] and pronghorn [*Antilocapra americana*]; Rautenstrauch and Krausman 1989; Clemente et al. 1995; Truett 2002; Bristow and Ockenfels 2006).

Table 1. List of individuals who participated in stakeholder workshops.

Participant Name	Affiliation
Jack Barnitz	Bureau of Land Management (Las Cruces District Office)
Leticia Lister	Bureau of Land Management (Las Cruces District Office)
Mark Hakkala	Bureau of Land Management (Las Cruces District Office)
Ray Hewitt	Bureau of Land Management (Las Cruces District Office)
Ray Lister	Bureau of Land Management (Las Cruces District Office)
Steve Torrez	Bureau of Land Management (Las Cruces District Office)
Brian Locke	Fort Bliss
David Griffin	Mesilla Valley Audubon Society
Donald Decker	Natural Resources Conservation Service
Marcus Miller	Natural Resources Conservation Service
Santiago Misquez	Natural Resources Conservation Service
George Farmer	New Mexico Department of Game and Fish

*Table 2. Rankings of biodiversity metrics from a stakeholder meeting of list priorities. Rankings ≥ 4.0 are shown in bold. SGCN = Species of Greatest Conservation Need and T&E = Threatened and Endangered. * indicates metrics considered in the process of selecting conservation priorities (from Seamster et al. in prep).*

Biodiversity Metric	Stakeholder Ranking
Amphibian richness*	3.8
Amphibian SGCN richness	3.8
Bat richness	3
Bat SGCN richness	3.4
Big game richness	3.8
Bird richness*	**4.2**
Bird SGCN richness	3.8
Breeding birds richness	**4**
Climate vulnerable species richness	**4.2**
Common-declining species richness	2.6
Culturally important species richness	1.8
Economic or recreationally important species richness	3.8
Ecosystem diversity	**4.6**
Furbearer richness	2.2
Grassland obligate richness	**4.6**
Harvestable species richness*	3.4
Keystone species richness	**5**
Mammal richness*	3.8
Mammal SGCN richness	3.8
Migratory Bird Treaty Act species richness	3.8
Reptile richness*	**4**
Reptile SGCN richness	**4**
Riparian obligate richness*	**4.6**
Sensitive species*	**4.6**
SGCN richness*	**4.2**
Small game richness	3
T&E richness*	**5**
Total species richness*	**4.2**
Upland game richness	3.5
Waterfowl richness*	2.2
Wintering birds richness	**4**

Table 3. Focal species used in characterizing the Las Cruces BLM district. "X" indicates the species is included in one of the following biodiversity metrics: Species of Greatest Conservation Need (SGCN) or Threatened and Endangered (T&E). Stakeholder rankings are based on the second stakeholder workshop and are average values. Rankings ≥ 4.0 are shown in bold (from Seamster et al. in prep).

Species Scientific Name	Species Common Name	SGCN	T and E	Stakeholder Ranking
Ammodramus bairdii	Baird's Sparrow	X		3.4
Ammodramus savannarum	Grasshopper Sparrow	X		3.3
Anthus spragueii	Sprague's Pipit	X		3.0
Antilocapra americana	Pronghorn	X	X	3.7
Athene cunicularia	Burrowing Owl	X		**4.7**
Buteo regalis	Ferruginous Hawk	X		3.0
Buteo swainsoni	Swainson's Hawk	X		2.6
Buteogallus anthracinus	Common Black Hawk	X		3.4
Calamospiza melanocorys	Lark Bunting	X		1.8
Callipepla squamata	Scaled Quail	X		**4.3**
Charadrius montanus	Mountain Plover	X		2.7
Coccyzus americanus	Yellow-billed Cuckoo	X		3.7
Crotalus willardi obscurus	New Mexico Ridge-nosed Rattlesnake	X	X	3.3
Dipodomys spectabilis	Banner-tailed Kangaroo Rat			**4.0**
Empidonax traillii extimus	Southwestern Willow Flycatcher	X	X	**5.0**
Eremophila alpestris	Horned Lark			1.8
Falco femoralis	Aplomado Falcon	X	X	**5.0**
Lanius ludovicianus	Loggerhead Shrike	X		2.3
Leptonycteris nivalis	Mexican Long-nosed Bat	X	X	**4.7**
Leptonycteris yerbabuenae	Lesser Long-nosed Bat	X		**4.3**
Lithobates chiricahuensis	Chiricahua Leopard Frog	X	X	**4.0**
Odocoileus hemionus	Mule Deer	X		**4.2**
Ovis canadensis	Bighorn Sheep	X		**4.7**
Pecari tajacu	Collared Peccary			2.3
Spizella atrogularis	Black-chinned Sparrow	X		2.6
Sturnella magna	Eastern Meadowlark			2.2
Sturnella neglecta	Western Meadowlark			1.8
Uta stansburiana	Common Side-blotched Lizard			1.8

Task 3: Baseline characterization of ecological context (Broad Scale)

(Excerpted from manuscript – Appendix D)

Local, state, and federal agencies conserve and manage natural resources at multiple spatial scales. Conservation and management priorities can be identified for single wildlife refuges (USFWS 2012), military installations (Hamazaki et al. 2003; Andersen et al. 2004), national forests (USFS 2010), national parks (Parks Canada 2010), an entire state (NMDGF 2006; Boykin et al. 2011), or a region that crosses state boundaries (Boykin et al. 2007; Boykin et al. 2008; USFWS 2009) or national boundaries (Schmeller et al. 2008). Efforts have been made to develop priorities for areas defined by ecological or hydrological features rather than land ownership or political boundaries. Such efforts help to make management and conservation activities relevant to the ecology or hydrology of the landscape, rather than to an area determined by political boundaries or under the jurisdiction of a single agency. An analysis that helps characterize the importance of land managed by a single entity in a regional context can facilitate stakeholder collaboration (Hamazaki et al. 2003). In particular, it can ensure that each stakeholder is maximizing their contribution to the management of resources in the region through more localized conservation efforts.

The ecological context for the LCD was defined in terms of ecoregions and state boundaries (Figure 5), which are more relevant to most managers than the buffers that were employed by Hamazaki et al. (2003). The Nature Conservancy's Terrestrial Ecoregions dataset (http://maps.tnc.org/gis_data.html) contains three ecoregions that intersect the LCD: Chihuahuan Desert (CHI), Apache Highlands (AH), and Arizona-New Mexico Mountains (MTN). In addition to these three ecoregion-based context regions, two more context regions were defined using the state boundary lines for New Mexico alone and then Arizona and New Mexico together. Use of these context regions ensured that the characteristics of the LCD were compared to those of an area that encompasses land managed by multiple major land stewards other than BLM (e.g. Department of Defense and White Sands Missile Range; US Forest Service and Gila National Forest; Figure 4; Figure 5).

Analysis of biodiversity metrics and species distributions at a broad scale allowed for identification of conservation priorities for the LCD that accounted for the district's ecological context (i.e., area surrounding the LCD; Task 3; Seamster et al. in prep). Hamazaki et al. (2003) provides a method to select species and land cover types as conservation priorities that considers the ecological context of a management unit of interest. We applied this method to the LCD for both species and biodiversity metrics, thus characterizing the LCD within the larger region. The method identified individual species and groups of species that are widespread and have relatively high richness within the LCD but are restricted within the LCD's ecological context. The individual species and groups of species identified using this approach can then be considered in further conservation planning efforts and fine scaled conservation practice assessment. This process for selecting conservation priorities is easily transferable to other geographic areas and management units of interest. Datasets similar to those used for our analysis will soon be available for the entire US. A manuscript describing the ecological context analysis (Seamster et al. in prep) is in progress.

Methods

Species habitat distribution models from SWReGAP (Boykin et al. 2007) were used to develop biodiversity metrics and identify metric and species conservation priorities for the BLM's LCD through an assessment of the district's ecological context. SWReGAP models were developed at 30 m resolution for 817 terrestrial vertebrate species found within one or more of five states in the southwestern US (Arizona, Colorado, Nevada, New Mexico, and Utah). The models are based on wildlife-habitat relationships that describe associations between species occurrence and environmental variables such as land cover, elevation, and proximity to water features. Biodiversity metrics were developed by summing the SWReGAP distribution models for all species within a given metric, thus determining the number of species distributions that intersected each 30 m pixel (Boykin et al. 2013). Biodiversity and species conservation priorities were identified using five context regions. The portions of the ecoregion-based context regions that extend into Texas and Mexico were excluded when identifying priority biodiversity metrics and species. This exclusion was necessary because biodiversity metrics and complete sets of species models were available only at the regional scale and are not being created for Mexico (Boykin et al. 2007; Aycrigg et al. 2010; Boykin et al. 2013).

Criteria for priority identification were based on Hamazaki et al. (2003). We determined whether areas with relatively high species richness for a given biodiversity metric, or with suitable habitat for a focal species were: 1) widespread within the LCD relative to the ecological context region; and 2) restricted within the ecological context region. The use of both criteria was intended to ensure the identification of entities of conservation interest that are prevalent within the LCD but relatively rare within the ecological context region (Hamazaki et al. 2003). These criteria were quantified using the following two formulas:

$$\mathrm{LCDP} = 100\left(\frac{\mathrm{ALCD}}{\mathrm{AEC}}\right) \quad (1)$$

where LCDP is the Las Cruces District Percentage; ALCD is the Area (in km^2) within the Las Cruces District with high species richness for a given biodiversity metric or that intersects the distribution of suitable habitat for a single focal species; and AEC is the Area (in km^2) within the ecological context region (i.e. ecoregion or state; see Figure 2) with high species richness for a given biodiversity metric or that intersects the distribution of suitable habitat for a single focal species.

$$\mathrm{ECP} = 100\left(\frac{\mathrm{AEC}}{\mathrm{TEC}}\right) \quad (2)$$

where ECP is the Ecological Context Percentage; and TEC is the Total area (in km^2) of the Ecological Context region. TEC values were based on the area of the polygon that defines the boundary of the context region. These percentages are easily modified to be relevant for other focal areas. Biodiversity metrics were developed, and area values used in calculating LCDP and ECP were extracted, using ArcGIS 10.1 (ESRI, Redlands, CA, USA).

Thresholds for LCDP were determined by calculating the percentage of the context region encompassed by the LCD (i.e. total area of the LCD or area of an ecoregion within the LCD divided by TEC and then multiplied by 100; Hamazaki et al. 2003). Biodiversity metrics or species that had calculated values for LCDP greater than these thresholds (Table 3) and an ECP < 50% were identified as conservation priorities for the BLM LCD. ECP thresholds of 30% and 10% were also applied in order to evaluate the sensitivity of the prioritization results to the value used for this threshold. These percentages (10, 30, and 50%) capture the variation in average conservation targets (i.e. percentage of the total area of a region of interest that should be protected) identified by a variety of both policy-driven and more scientific sources. The ECP thresholds thus represent the percentages of each ecological context region that a land manager may be interested in protecting in order to preserve local resources ranging from individual species to total biodiversity (Svancara et al. 2005).

Pixels found within the context region that contain at least 50% of the maximum number of species per pixel were considered to represent areas of “high” species richness. Values for ALCD and AEC for biodiversity metrics were calculated based on the number of pixels in the LCD (ALCD), or on the number of pixels in the ecological context region (AEC), with different percentages (i.e. 50, 60, 70, 80, and 90%) of the maximum number of species per pixel found within the context region. As an example, for the total species richness metric and the Chihuahuan Desert ecoregion (CHI), the maximum number of species per pixel found within the CHI was 265. To calculate the numerator (AEC) for ECP for 50% of this maximum species count, the total number of pixels with at least 133 (rounded up from 132.5) species in them was determined. This pixel count was then converted to km^2.

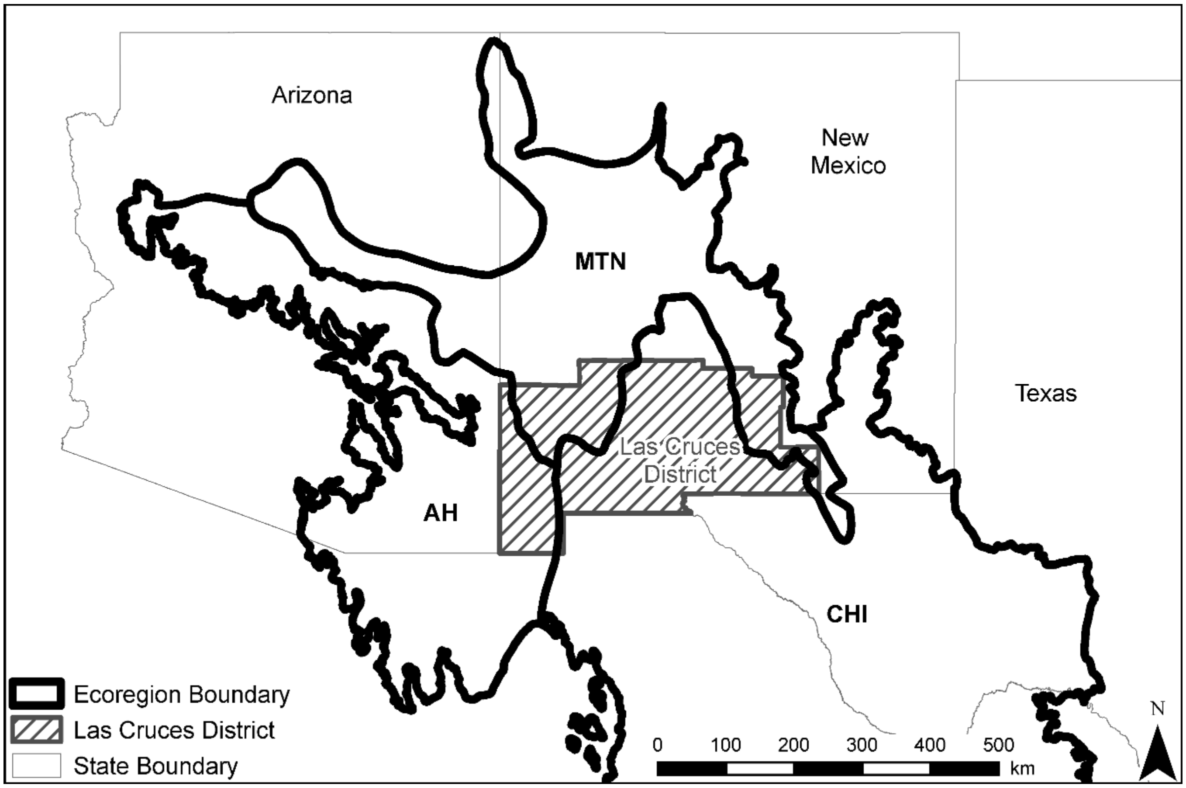

Figure 5. Map of the project focal area and the five ecological context regions used to assess the contribution that the Las Cruces District can make to species and biodiversity conservation with respect to the broader geographic region. Two regions are defined by state boundaries (New Mexico and Arizona and New Mexico). The remaining three are defined by the boundaries of the following ecoregions: Chihuahuan Desert (CHI), Apache Highlands (AH), and Arizona-New Mexico Mountains (MTN)

Results

Biodiversity metrics and focal species

Eleven metrics were chosen for inclusion in the assessment of conservation priorities (Table 4a-c). These metrics had higher average stakeholder ratings (≥ 4) and/or were recommended as not presenting information redundant to that provided by other metrics among the 20 presented by Boykin et al. (2013). In particular, these metrics were considered by Boykin et al. (2013) to represent total vertebrate diversity, diversity in both aquatic and terrestrial ecosystems, species of particular conservation concern, and species of interest to hunters and thus potential economic value. All 28 focal species (Table 2) were assessed to determine whether they represented conservation priorities for any of the five ecological context regions considered.

Conservation priorities: biodiversity and focal species

Based on the calculated values of LCDP and ECP, several biodiversity metrics and species were identified as conservation priorities for the different context regions considered. All 11 biodiversity metrics evaluated and 20 of the 28 focal species were identified as a conservation priority for at least one of the five context regions assessed (Tables 3a, 4). The four biodiversity metrics (excluding total species richness) that contained the largest number of the 20 species identified as conservation priorities (bird, mammal, SGCN, and sensitive richness) were all identified as priorities for all of the context regions (Table 4a). Similarly, seven of the eight metrics (excluding total species richness) identified as priorities for all five context regions (Table 3a) contained all of the priority species.

There was little variation between context regions defined by state boundaries in the number and specific biodiversity metrics or species identified as conservation priorities (Tables 4a, 5). In particular, nine of the 11 metrics considered, and 13 of the 18 species identified as a priority for at least one state-based context region were priorities for both state-based regions. The total number of priority species differed by only one between the two state-based ecoregions (15 for New Mexico; 16 for Arizona and New Mexico). The results for ecoregions were fairly consistent for biodiversity metrics; eight of the 11 evaluated were identified as priorities for all three ecoregions. Results varied more for species. Specifically, there was variation among ecoregions in the number of priority species (range 11 - 17). Additionally, two species were identified as priorities for only one ecoregion, and only four species were priorities for all three ecoregions.

The results of the conservation priority identification process varied with the ECP threshold used for both metrics and species (Tables 4a-c, 5). For the biodiversity metrics, results also varied with the percentage of the maximum number of species per pixel within the context region used in calculating LCDP and ECP. All biodiversity metrics were identified as a conservation priority for at least one ecological context region, regardless of ECP threshold used, when the highest levels of relative species richness (i.e. 90% of the maximum species per pixel) were considered (Table 4a-c). Conversely, when looking at 50% of the maximum species richness, seven metrics were identified as priorities for an ECP threshold of 50% and only three for ECP of 10% (Table 4b, c). For species, the total number of species identified as conservation priorities dropped from 20 to 19 (ECP < 30%) to 14 (ECP < 10%) as the ECP threshold was reduced from 50 to 10%. No species were identified as priorities for all five context regions when the most stringent (< 10%) ECP threshold was used (Table 5).

The assessment of biodiversity metrics in an ecological context leads to valuable information regarding general patterns of biodiversity across the study area. The LCD encompasses the converging point for three ecoregions (Figure 6) and contains an especially biodiverse portion of New Mexico, known colloquially as the “boot heel” (NMDGF 2006). This “boot heel” region covers the western portion of the LCD and is highlighted by multiple metrics as an area with relatively high (> 50% of maximum species per pixel) biodiversity (Figure 7).

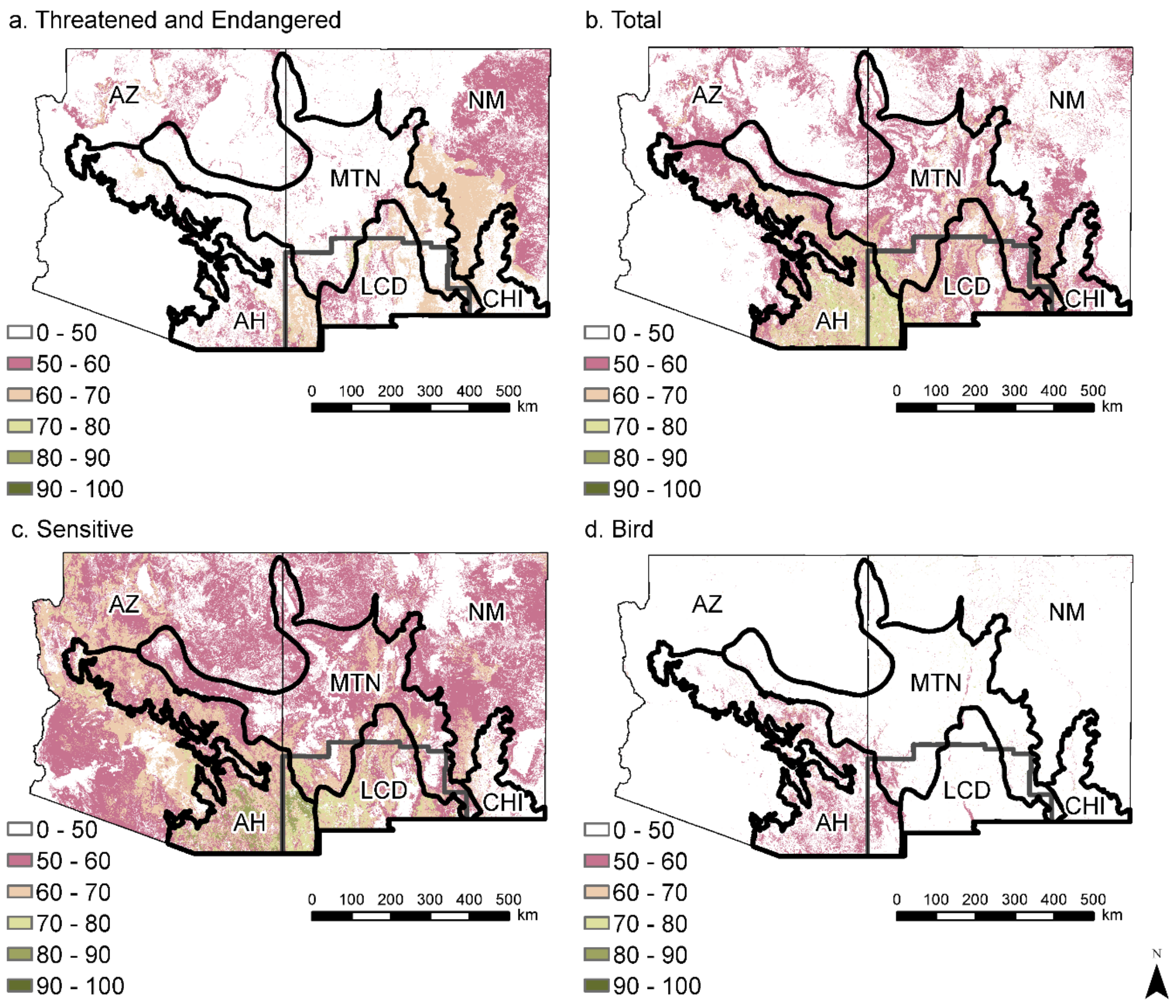

Figure 6. Percentage of maximum species richness within the Arizona-New Mexico context region relative to the Las Cruces District (LCD) and the four other ecological context regions considered for the biodiversity metrics (AH = Apache Highlands; AZ = Arizona; CHI = Chihuahuan Desert; MTN = Arizona-New Mexico Mountains; and NM = New Mexico). The subset of metrics shown was given higher ratings by stakeholder workshop participants (≥ 4.2; see Table 1) and is conducive to display across this large geographic area. Metrics shown are as follows: a) threatened and endangered richness; b) total richness; c) sensitive richness; and d) bird richness

Discussion

Comparison to other assessments of conservation priorities

There is general agreement between the conservation priorities we identified and priorities identified by state and federal wildlife agencies and project stakeholders. All biodiversity metrics evaluated using our criteria were identified as conservation priorities for at least one context region. Two of these metrics are composed of species that were identified as SGCN in SWAPs for the five southwestern states included in the SWReGAP (Arizona, Colorado, Nevada, New Mexico, and Utah; UDWR 2005; AGFD 2006; CDOW 2006; NDOW 2006; NMDGF 2006) or as T&E species by the USFWS (USFWS 2011b). Many (16 of 20) of the species identified as conservation priorities were included in either the SGCN or T&E biodiversity metrics (Tables 2, 3). With respect to project stakeholders, seven biodiversity metrics were rated highly by stakeholders (≥ 4.0) and include T&E, total, sensitive, and bird richness (Figure 6); as well as riparian obligate, SGCN, and reptile richness (Table 2). Six of these seven highly rated metrics were identified as conservation priorities for all context regions evaluated; riparian obligate richness was only identified as a priority for three regions (CHI and MTN ecoregions and the state of New Mexico; Table 4a). Across the different context regions, 40 - 70% of the 10 species with the highest average stakeholder ranking (≥ 4.0; Table 2) were identified as priorities (Table 5). This agreement with priorities identified by experts through other means provides support for our results and the methodology presented here.

This approach does lead to the identification of some priorities that differ from those presented by wildlife agencies and project stakeholders. In particular, there are four metrics identified here as priorities (including two pertaining to harvestable species) that were not highly rated by stakeholders or based on conservation priorities of state (i.e. SGCN richness) or federal (i.e. sensitive and T&E richness) agencies. Additionally, a low percentage of species identified as priorities were highly rated by stakeholders (35%). There are also species (7) we considered that were not identified as conservation priorities in this study but are listed as SGCN in recent SWAPs (NMDGF 2006; AGFD 2012). This indicates that this context analysis does more than just concur with lists of species identified by other sources and approaches; it helps to tailor the field of conservation priorities to groups of organisms and species that are especially important to protect in the focal area given the ecology of its surroundings. In particular, this analysis highlights species that are widely distributed within the focal area relative to the region (Figure 7a, b) and excludes many species that are more common outside the focal area (Figure 7c) or are found everywhere in the region (Figure 7d; Hamazaki et al. 2003). Focusing conservation efforts on organisms or groups of organisms that are widespread within the area being managed may be more cost effective than focusing solely on rare species with little suitable habitat in the managed area. Conversely, focusing on organisms that are rare in a regional context ensures that efforts are directed towards protecting ecological components that are not present elsewhere or may not be conserved as effectively by other land managers in the region (Hamazaki et al. 2003).

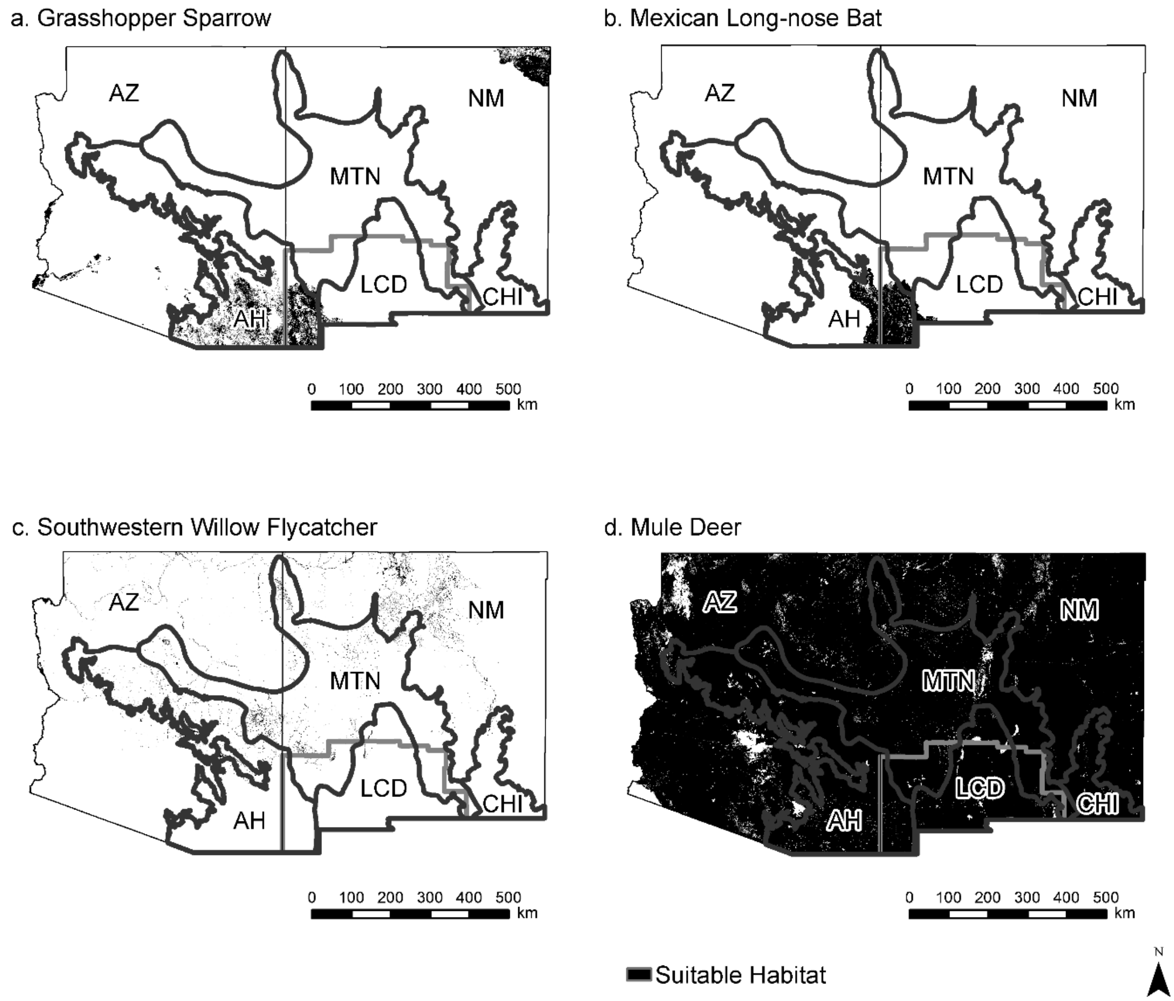

Figure 7. Examples of species that met priority identification criteria for all five ecological context regions (a and b) and species that were not identified as priorities for any of the regions (c and d). Maps display distributions of the following species in black: a) grasshopper sparrow (*Ammodramus savannarum*); b) Mexican long-nose bat (*Leptonycteris nivalis*); c) southwestern willow flycatcher (*Empidonax traillii extimus*); and d) mule deer (*Odocoileus hemionus*). AH = Apache Highlands; AZ = Arizona; CHI = Chihuahuan Desert; LCD = Las Cruces District; MTN = Arizona-New Mexico Mountains; and NM = New Mexico.

Application to land management

Some key benefits of the methodology demonstrated here are that it is easily replicated to other focal areas, both within the US and internationally, and results can be updated as new information becomes available or other context regions become of interest. At this time, biodiversity metrics and vertebrate species models are available for the southwestern and southeastern US and they will soon be available for the conterminous US (Aycrigg et al. 2010; Boykin et al. 2013). A national-scale version of one of the 11 biodiversity metrics evaluated here (i.e. reptile richness) is already displayed in the EnviroAtlas developed by the US Environmental Protection Agency, the US Geological Survey, the NRCS, and other entities (Boykin et al. 2013; http://www.epa.gov/research/enviroatlas/). These national datasets will help address the cross-state boundary issue encountered in this study regarding a lack of data for Texas. They will not however address the issue of international boundaries and missing data for Mexico and a significant portion of the Chihuahuan Desert ecoregion considered here. Such boundary issues are likely to arise in many parts of the world and thus the use of geopolitical boundaries (such as the state boundaries employed here) may be necessary.

Land managers can tailor the methodology presented here to fit their needs and interests. For example, selection of regions to consider can be based on the interests and needs of the entity performing the ecological context analysis. State-based regions that include adjacent states may be appropriate for a state agency interested in regional collaboration. Since ecoregions are nested within different biomes or major habitat types and their delineation considers measures of biodiversity and local species composition (Olson and Dinerstein 2002), focus on an ecoregion may be best for a land manager that applies land management practices suited to a particular vegetation type or biological community. Ecoregions may be especially important to consider in studies of other focal areas as they are often used in breaking out conservation priorities identified by state agencies (e.g. NMDGF 2006; Connally 2012a) and are more likely to have different management issues (Bailey 1980) and practices. In this study, there were two species identified as conservation priorities for the ecoregion-based context regions that weren't priorities for the state-based regions. Thus, consideration of ecoregions may provide a different perspective and final set of priorities.

The ecological context analysis presented here is best combined with other sources of information in order to devise a complete set of conservation priorities. The datasets employed here only provide information on terrestrial vertebrate species. Other datasets containing information on variables such as the distributions or diversity of invertebrates (Hamazaki et al. 2003) or aquatic vertebrates may be of interest and may complement the context analysis described here. As recommended by this study, information on conservation priorities gathered from relevant local experts, stakeholders, field surveys, and other sources can be used to determine which metrics and species are included in the analysis or to validate or refine analysis results. For example, as was accounted for in this study, several of the metrics initially considered may provide similar or redundant information on species richness patterns in the study area and it may be desirable to focus on a subset (Boykin et al. 2013). Further, it is likely that there will be metrics and species that are not identified using the criteria described here that are of vital interest to land managers and will have to be added to the list of conservation priorities. In this study, the riparian obligate richness metric only met priority identification criteria for three of the five context regions, yet this metric is of great interest to the stakeholders consulted for this study and riparian zones in general are highlighted as important habitats in SWAPs for multiple southwestern states, including New Mexico and Texas (NMDGF 2006; Connally et al. 2012a).

The general methodology presented here could be used as a preliminary screening tool in conservation assessments and as a component of an adaptive management process. It could also be used to evaluate and potentially revise existing lists of conservation priorities. The particular subsets of local biodiversity and species identified as conservation priorities in this study could be the foci of further assessments or management and monitoring activities. Identification of conservation priorities is often a first step to setting up monitoring programs or implementing management activities. This approach is relevant in the context of a conservation-oriented project like CEAP that facilitates an adaptive approach to management. Conservation priorities identified here could be used as the foci of an assessment of the benefits of a suite of rangeland conservation practices for important biological resources. For example, another study within CEAP analyzed the effect of 13 conservation practices on populations of five bird species of conservation priority across the western US (Casey 2013). Our results could inform a similar assessment performed at a much finer geographic scale. In particular, an analysis could focus on conservation practices most likely to affect species in one of the biodiversity metrics (e.g. riparian herbaceous cover [NRCS 2005] and riparian obligate richness) or on the effects of conservation practices on all of the 20 species identified here as priorities. The results of this assessment could then be used to inform future application of conservation practices in the focal area. Conservation practices are typically implemented for areas defined by the NRCS as Ecological Sites. These Ecological Sites typically have different plant communities, soil types, and various environmental factors and may respond differently to management activities (https://esis.sc.egov.usda.gov/About.aspx). Thus, a future application of the approach presented here to one or more Ecological Sites as focal management units and a NRCS Major Land Resource Area as a context region could further facilitate integration with CEAP.

Table 4. Percentages of the maximum species richness within the ecological context region at which the biodiversity metrics were identified as conservation priorities for ecoregion-based (left) or state-based (right) context regions for the following Ecological Context Percentage (ECP) thresholds: a) 50%; b) 30%: c) 10%.

a) Ecological Context Percentage (ECP) threshold = 50%	Ecoregion (AH, CHI, MTN)			State (NM, AZ-NM)		
Metric (%)	50	70	90	50	70	90
Total species richness		Black	Gray	Gray	Black	Black
Amphibian richness	Gray	Crosshatched	Crosshatched	Black		
Bird richness	Black		Gray	Black		Black
Mammal richness		Gray	Black		Black	Black
Reptile richness	Crosshatched	Black	Black	Black	Black	Black
SGCN richness		Black	Gray	Gray	Black	Crosshatched
T&E richness	Black	Black	Gray	Black	Black	Black
Harvestable species richness	Black		Crosshatched	Black		
Waterfowl richness			Gray			Crosshatched
Riparian obligate richness		Crosshatched	Crosshatched		Crosshatched	
Sensitive species richness		Black	Gray		Black	Crosshatched

b) ECP threshold = 30%	Ecoregion (AH, CHI, MTN)			State (NM, AZ-NM)		
Metric (%)	50	70	90	50	70	90
Total species richness		Black	Gray		Black	Black
Amphibian richness	Gray	Crosshatched	Crosshatched	Black		
Bird richness	Black		Gray	Black		Black
Mammal richness			Black		Black	Black
Reptile richness	Crosshatched	Black	Black		Black	Black
SGCN richness		Black	Gray		Black	Crosshatched
T&E richness	Crosshatched	Black	Gray	Gray	Black	Black
Harvestable species richness	Gray		Crosshatched	Black		
Waterfowl richness			Gray			Crosshatched
Riparian obligate richness		Crosshatched	Crosshatched		Crosshatched	
Sensitive species richness		Black	Gray		Black	Crosshatched

c) ECP threshold = 10%	Ecoregion (AH, CHI, MTN)				State (NM, AZ-NM)		
Metric (%)	50	70	80	90	50	70	90
Total species richness		Crosshatched	Black	Gray		Black	Black
Amphibian richness	Gray	Crosshatched	Crosshatched	Crosshatched	Black		
Bird richness	Gray		Crosshatched	Gray	Black		Black
Mammal richness			Crosshatched	Gray			Black
Reptile richness		Crosshatched	Black	Black		Black	Black
SGCN richness		Crosshatched	Black	Gray		Black	Crosshatched
T&E richness		Black	Gray	Gray		Black	Black
Harvestable species richness	Crosshatched		Crosshatched	Crosshatched	Gray		
Waterfowl richness			Crosshatched	Gray			Crosshatched
Riparian obligate richness		Crosshatched	Gray	Crosshatched		Crosshatched	
Sensitive species richness			Black	Gray		Gray	Crosshatched

Abbreviations as follows: AH = Apache Highlands; CHI = Chihuahuan Desert; MTN = Arizona-New Mexico Mountains; AZ = Arizona; NM = New Mexico; SGCN = Species of Greatest Conservation Need; and T&E = Threatened and Endangered. Black = identified as a priority for all three ecoregions/both state-based regions; gray = identified as a priority for two ecoregions /AZ-NM; crosshatched = identified for one ecoregion/NM. Fifty percent, 70% and 90% of the maximum species richness in the context region were selected for display here since intervening percentages did not change the set of context regions for which each metric was identified as a conservation priority. An intervening percentage (80%) was included in c as three metrics were only identified as priorities at that percentage for the AH ecoregion.

Table 5. Ecological context regions for which each of the 28 focal species were identified as conservation priorities. Priorities were evaluated for three different Ecological Context Percentage (ECP) thresholds.

Species Scientific Name	AH	CHI	MTN	NM	AZ-NM
Ammodramus bairdii	Gray	Black	Black	Black	Black
Ammodramus savannarum	Gray	Black	Black	Black	Black
Anthus spragueii		Gray	Black	Gray	Black
Antilocapra americana	Gray		Gray		Crosshatched
Athene cunicularia [a]					
Buteo regalis					
Buteo swainsoni					
Buteogallus anthracinus		Black	Black	Black	Black
Calamospiza melanocorys	Crosshatched		Black	Crosshatched	Gray
Callipepla squamata [a]			Crosshatched		Crosshatched
Charadrius montanus	Black				
Coccyzus americanus					
Crotalus willardi obscurus		Black	Black	Black	
Dipodomys spectabilis [a]	Gray		Gray	Crosshatched	Gray
Empidonax traillii extimus [a]					
Eremophila alpestris		Black			
Falco femoralis [a]	Gray		Gray	Gray	Gray
Lanius ludovicianus					
Leptonycteris nivalis [a]	Gray	Black	Black	Black	Black
Leptonycteris yerbabuenae [a]	Crosshatched	Black	Black	Black	Black
Lithobates chiricahuensis [a]		Black	Black	Black	Black
Odocoileus hemionus [a]					
Ovis canadensis [a]		Black	Gray	Gray	Gray
Pecari tajacu		Gray	Black	Black	Gray
Spizella atrogularis		Black	Gray	Black	
Sturnella magna	Crosshatched		Gray	Crosshatched	Gray
Sturnella neglecta	Gray	Crosshatched			Crosshatched
Uta stansburiana					

Black = identified as a priority for all three ECP thresholds (10%, 30%, 50%); gray = identified as a priority for the two largest ECP thresholds (30%, 50%); crosshatched = identified as a priority only for ECP < 50%. Abbreviations as follows: AH = Apache Highlands; CHI = Chihuahuan Desert; MTN = Arizona-New Mexico Mountains; AZ = Arizona; and NM = New Mexico. [a] indicates the species was highly ranked by stakeholders (average in second workshop ≥ 4.0)

Task 4: Relationship between Conservation Practices and Focal Species

A list of conservation practices relevant to the study area (Table 6) was compiled and refined using feedback from two stakeholder meetings (See Task 1-2). Information on the conservation practices was accessed in technical notes available through the USDA website (http://efotg.sc.egov.usda.gov/treemenuFS.aspx). The effects of various conservation practices on these species were then assessed using direct and indirect evidence provided within scientific literature and reports (Task 4). The effects of conservation practices were broken into short-term (< 1 year) and long-term (>1 year) effects, as we recognize the lag effect some practices impose on habitat suitability. The final version of species by practice matrix is presented in Appendix A. Gaps in the scientific literature are indicated within in the matrix by the phrases including, 'Unknown adverse effects' or 'Likely no response'.

Table 6. List of conservation practices and their rankings by project stakeholders. Practices presented in bold text were the focus of the current effort.

NRCS code	Conservation Practice	Stakeholder ranking
314	***Brush Control***	***4.6***
656	Constructed Wetland	1.4
382	***Fence Construction***	***3.4***
386	Field Border	2
595	Integrated Pest Management	2.6
378	***Pond***	***4***
338	***Prescribed Fire***	***3.4***
528	***Prescribed Grazing***	***3.4***
391	***Riparian Forest Buffer***	***3***
390	***Riparian Herbaceous Cover***	***4.2***
646	***Shallow Water Development***	***4***
381	Silvopasture Establishment	1
612	Tree/Shrub Establishment	2
601	Vegetative Barriers	1
614	***Watering Facility***	***4.6***

Task 5-6: Vegetation dynamics, conservation effects scenarios (Fine Scale)

Broad scale efforts are informative, but fine scaled effects provide land managers with vegetation dynamics and scenarios to assist with on the ground perspective of conservation practice effects. We developed a prototype tool using a Dynamic Systems Model for assessing baseline vegetation dynamics and the effects of conservation practices on a model species, both of which were selected as conservation priorities.

Structural Thinking Experimental Learning Laboratory with Animation (STELLA) is a software package published by isee systems designed to facilitate the construction and analysis of complex mathematical relationships. We used STELLA to construct a model that describes the changes of biomass through the interaction of black grama (*Bouteloua eriopoda*) (BOER) and creosotebush (*Larrea tridentata*) (LATR) across time in the Chihuahuan Desert (Task 5). The interactive effects of tebuthiuron (TEB) and grazing pressure were then incorporated (Task 6). Tebuthiuron application for brush control was selected as a focal conservation practice due to its widespread use in the project study area. We used scaled quail (*Callipepla squamata*) as the model wildlife species. For specific details on the model refer to Appendix D.

As with many North American birds, scaled quail are experiencing a steady long-term population decline (Cantu et al. 2006, Bristow and Ockenfels 2006). The decline of this upland game bird is due to habitat degradation (Kamees et al. 2008). The mechanism of this degradation remains debated with factors such as shrub encroachment, prolonged drought, fire suppression, and improper-grazing as likely causes (Van Auken 2000).

Scaled quail occur from east Arizona to Trans-Pecos Texas, to as far north as southern Colorado (Zornes 2008, BirdLife International, NatureServe 2014). Habitat preference for scaled quail includes a mosaic of grasses and shrubs characterized by high species richness (Saiwana et al. 2013). Thus, while the near monoculture of creosotebush brought about by shrub encroachment makes for poor scaled quail habitat, so would a homogeneous grassland. Habitat preference is from the bird's varying usages of different plant species and vegetative structures (Saiwana et al. 2013).

Shrub encroachment is a cause of habitat degradation in the northern Chihuahuan Desert. Shrub encroachment is the shift of vegetative dominance from grass to shrubs. This has been observed in arid lands across the globe (Van Auken 2000). Its presence can cause decline in the biodiversity and economic productivity of an area (Báez and Collins 2008, Coffman et al. 2014), but specific responses are dependent on shrub traits and location (Eldridge et al. 2011). Shrub encroachment displaces grassland obligates (Báez and Collins 2008).

In response to the degradation of the landscape via shrub encroachment and other processes, the Bureau of Land Management (BLM) implemented a collaborative effort in 2005 with local stakeholders called Restore New Mexico. While conservation practices to curtail shrub encroachment by creosotebush have been implemented since 1981 in the Las Cruces District (LCD), Restore New Mexico signifies a marked increase in organization and effort. The purpose of Restore New Mexico is to bring back the historical grasslands, woodlands, and riparian areas of all of New Mexico. As of 2012 Restore New Mexico had successfully restored over a million acres across the state, and from 2005 to 2009 over 116,000 acres of that was the restoration of grasslands from creosotebush treatment in the LCD.

Current treatment is the aerial application of the pelleted form of TEB, an herbicide that targets C4 plants such as creosotebush by interfering with the electron transport chain of photosynthesis. At the concentration used, TEB has an estimated 98% kill rate of creosotebush where it is applied, leaving most of any resident grasses intact.

A systems dynamic modeling approach was used to assess and project the potential effects of TEB use in controlling shrub encroachment, particularly in relation to scaled quail habitat. We constructed of a model that describes the effects of TEB on vegetative communities and give a measureable comparison between the results of the model and what is understood to be the habitat of scaled quail. This supports the wildlife component of CEAP by establishing a method for situations where results cannot be practically monitored due to extended response time or dynamic conditions.

Methods

Study Area

The model describes the vegetative dynamics of gravelly soils in The Chihuahuan Desert. Specifically within the Las Cruces District (LCD) of the Bureau of Land Management (BLM), consisting of Hidalgo, Grant, Luna, Sierra, Doña Ana, and Otero counties of southwest New Mexico. This area was chosen because shrub encroachment by creosotebush is common and relevant data are available for both the LCD BLM and the Jornada Experimental Range (JER).

The Chihuahuan desert of the LCD is a mosaic of soil patterns at multiple scales as described by Ecological Site Descriptions (ESD) available from the Natural Resource Conservation Service (NRCS). The site ID R042XB010NM, which translates to Major Land Resource Area (MLRA) Region 42-2 (R042XB), soil type 10 (010), in the state of New Mexico (NM), is the soil formation of interest where creosotebush dominance has become the most prolific.

Dynamic Systems Model

A dynamic system modeling approach was used to represent Chihuahuan Desert plant community interactions (Figure 8 model interface, Figure 9 model diagram), and how the different factors influence each other. Work by Stewart et al. (2014) was chosen as the foundation for model development. The vertical processes (infiltration and resource competition) of the Stewart et al. model were translated into STELLA. Horizontal processes (redistribution of resources and propagules across space), were set aside for future addition. For more detailed description of model development see Appendix D.

The output of the model is species biomass over one square meter. While percent cover is the standard vegetation measurement in the field, the mechanistic relationships of nutrients to plant growth lends itself naturally to an output of biomass. The broadly positive correlation between biomass and percent cover for each plant species was used to translate field measurements of percent cover and model output of biomass, though high variance and a lack of specific information necessitated a simple linear conversion rate. The max biomass as given in Stewart et al. (2014) was taken to be the equivalent of 100% cover for a square meter, 319g for black grama and 222g for creosotebush.

The primary mechanism of the translated model is the formula for change in biomass (3) from Stewart et al. 2014:

$$\Delta B_{j,i} = \left[\frac{R_{tot,i} - B_j M_{i,j}}{E_{i,j}}\right] \tag{3}$$

With $\Delta B_{j,i}$ being the change of biomass (*B*) of species *j* (black grama or creosotebush) given resource *i* (precipitation) as a function of the ratio between the difference of the total available resource ($R_{tot,i}$) and the maintenance cost of the current biomass ($B_j M_{i,j}$) to the efficiency of the species use of that resource ($E_{i,j}$). Once the available resource has been used to maintain the biomass, what is leftover is used to increase the biomass of the species at a rate determined by the efficiency term *E*. If the maintenance cost for the current biomass was greater than the available resource, the species would reduce biomass at the same rate of efficiency $E_{i,j}$.

Stewart et al. had two resource inputs (*i*): water and nitrogen. The effects of nitrogen were left out as it was found to be a limiting factor only when water was very high. Information on the rates of nitrogen cycling and infiltration are still limited, leading to nitrogen's effects being represented as a hard ceiling for the effects of water. This leaves water as the primary driver of biomass for this model.

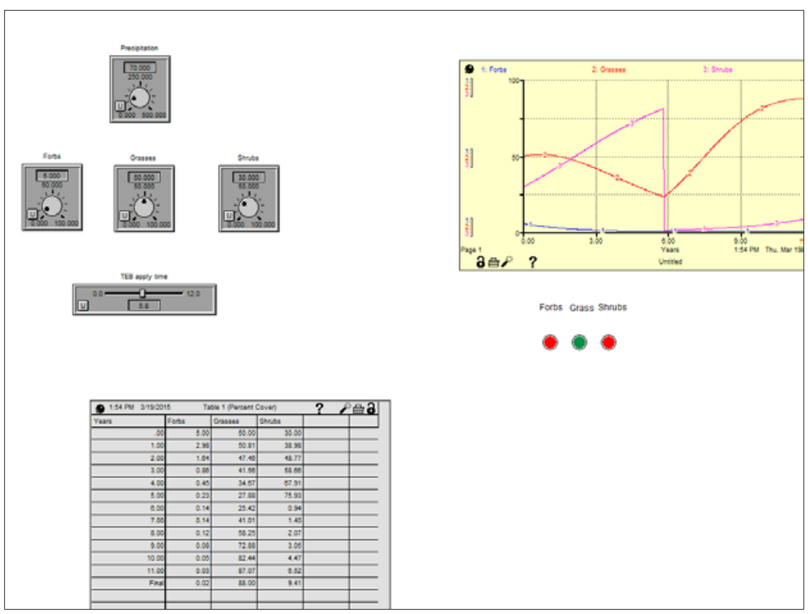

Figure 8. STELLA dynamic systems model interface

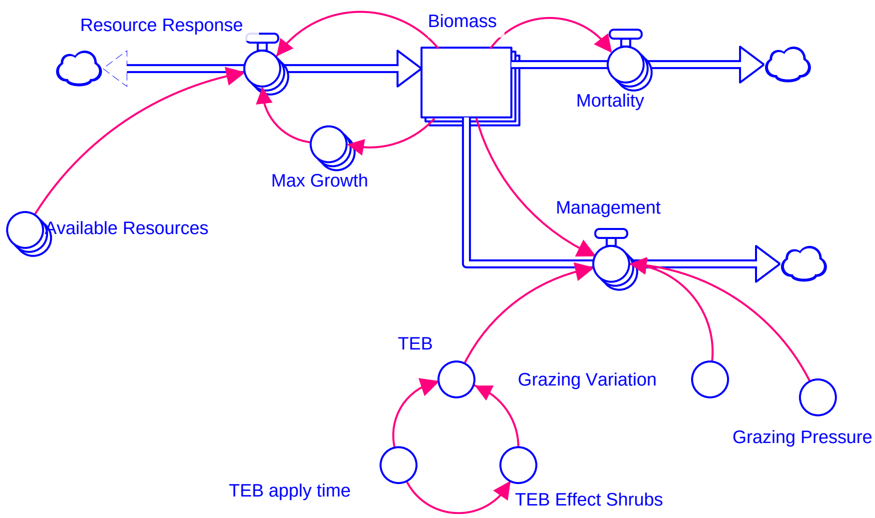

Figure 9. Vegetation components of the model, including biomass, resource input, mortality and management.

Precipitation factors (mean, variance, period, and magnitude) were estimated using precipitation data from the JER from 1980 to 2010. Mean was the average total annual precipitation in mm while variance showed how much the annual precipitation varied from year to year. Precipitation period and magnitude are based on the assumption that precipitation patterns go through regular cycles of flush and drought. While observed cycles are not regular, periods of drought do occur.

On an annual time scale, water availability in the soil stems from precipitation (total mm/year). When precipitation dynamics across years were simulated, the amount of any given year was determined by a stochastic distribution to simulate the unpredictability of precipitation. Precipitation patterns were inferred from an equation fitted to weather data from the JER. A regular repeating cycle of stable period and amplitude based on available data (JER) was used to establish the base results for the model. The water availability provided by the precipitation then becomes the source for soil-water available for each plant species.

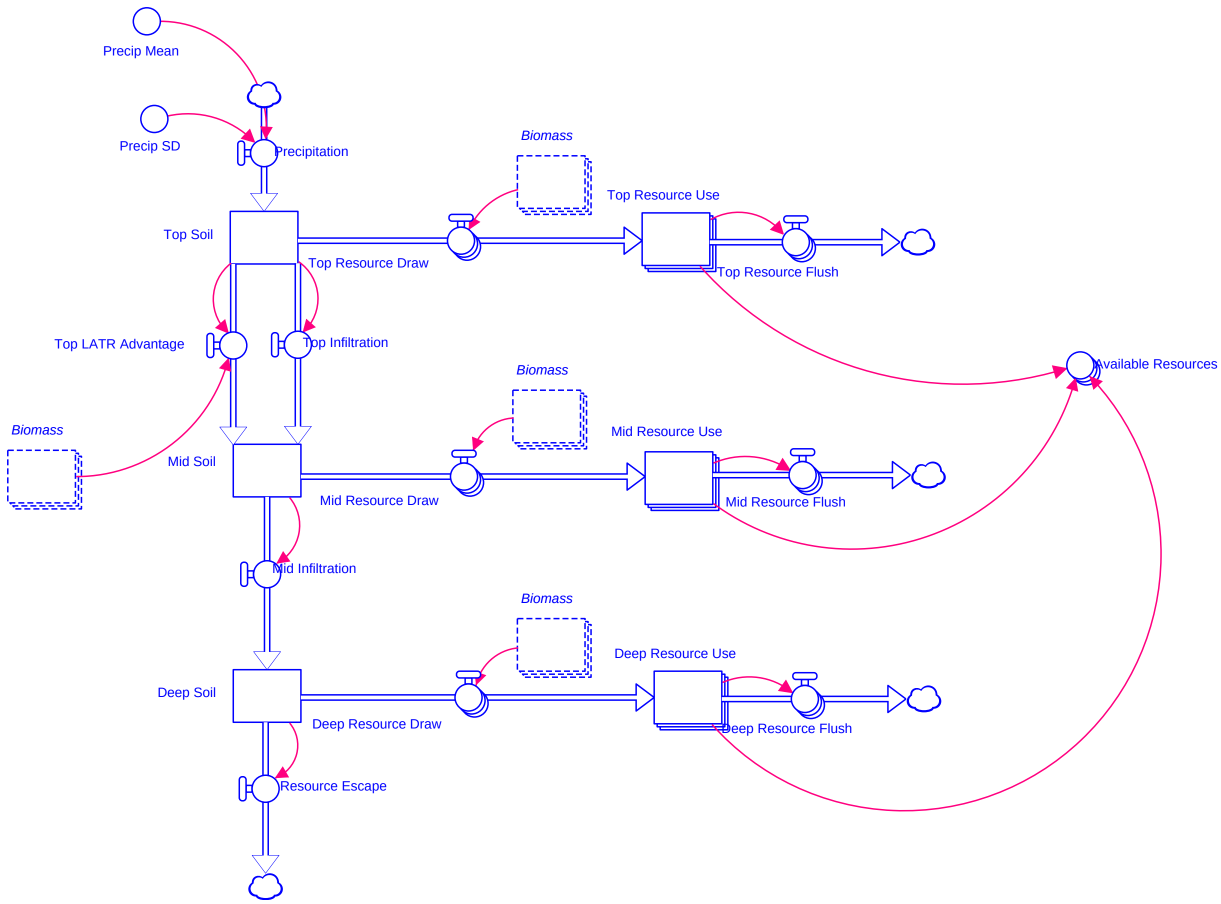

Figure 10. Resource components of the model including resource influx, soil layers, species roots distributions and inter-species competition.

The two species hold advantages over each other at different soil layers because of the concentration of the biomass of their roots. Black grama roots are shallower than creosotebush. As with Stewart et al. (2014), root allocation for black grama was set for 13.3% (top), 50.4% (middle), and 36.3% (deep) for corresponding soil layers. The allocation for creosotebush was set for 6.7% (top), 32.0% (middle), and 61.3% (deep). This influences the model (Figure 10) in that, for any time step, the maximum amount of water each species can consume, as given by its maximum rate * current biomass, is split among the three soil layers in terms of root distribution percentages. If a soil layer does not have enough resources for both plants, what is available is split evenly between the two species. The resources gathered from each soil layer is then totaled to give the available resource for that species and applied to the change in biomass equation (3) to begin calculation for the new biomass the following year.

The mechanism by which one species outcompetes the other in this model is resource competition (Hyder et al. 2002, Peters 2002, Stewart et al. 2014). Black grama has the advantage over creosotebush because the concentration of its roots is in the higher soil layers, allowing it to absorb the resources it needs before creosotebush. However, creosotebush creates feedback loops to create favorable conditions for itself by increasing the rate of infiltration of precipitation into the soil via stem flow.

Similar to Peters (2002) and Stewart et al. (2014), certain factors had necessary boundaries as a consequence of the overall setup. There is only so much of one plant that can fit into a one square meter space. Creosotebush and black grama, were given a maximum biomass of 222g and 319g respectively, though cumulative biomass was not limited, meaning a combined biomass of the two species could be greater than 319g. Plants were also given maximum growth rates of 9% (creosotebush) and 12.5% (black grama) of the species biomass. Mortality was included as a 1% reduction of biomass each year but was held at a constant rate throughout the model run.

The effect of TEB was integrated into the model as a sudden and semi-persistent reduction of creosotebush biomass to reflect shrub control. Little is published regarding the immediate effect of TEB on black grama, though studies have shown mixed results of black grama biomass following TEB treatment. A fixed rate of application and concentration of the chemical were assumed for the effects of the TEB.

Grazing effects were included as an annual percent reduction on black grama. Only black grama was affected because creosotebush is generally unpalatable to cattle. The effects of grazing were held without yearly variation for this analysis. The main values were used in Stewart et al. (2014), but stem from the assessment of Havstad et al. (2006). Values range from 0% to 14% reduction of total biomass of black grama every year. No grazing is indicated by 0%, while 3% indicates light, 6% moderate, and 12% heavy grazing. Grazing acts much like an extension of mortality applied to black grama, dampening reactions to changing resources and suppressing the overall biomass (see results of sensitivity analysis below). The time scale of the model was set to 500 years to capture multiple cycles of precipitation.

Characterizing Scaled Quail Habitat

The management recommendations provided by the New Mexico Department of Game and Fish (Kamees et al. 2008) were used as the benchmark for scaled quail habitat: 10-25% woody canopy cover and 30-50% grass canopy cover. This resource draws its measurements from a compilation of knowledge and experience. The results are given in terms of percent cover, which were translated into biomass as explained above.

Accuracy Assessment

Studies pertaining to a long term near monoculture (≥ 25% cover with≥ 50 bare ground) of the plant were assumed to be applicable to the gravelly soil type. This is because of the erosion feedback loop created by creosotebush in encouraging gravelly soil structure over time. The accuracy of the model was assessed by comparing those of Perkins et al. (2006). Perkins' study acquired data from TEB treatments of 20, 10, and 5 years prior to 2001, as well as paired untreated plots. The untreated plots were used as a measure of the climax community. Precipitation data from the nearby JER was used to approximate precipitation over the same time period of Perkins' study sites, which are in similar ecosystems and geographic areas. The model was then run with and without the application of TEB.

Perkin's study sites excluded cattle grazing and so grazing was set to zero in the model. Perkins' measurements were given in percent cover, which were converted to biomass. The output of the model was fitted through linear regression and compared to the results from Perkins' measurements to test for R^2. Initial biomass for the model was taken from the climax community of Perkins instead of the default provided by Stewart et al. (2014). Finally, when used, TEB was assumed to be applied immediately at the first time step. Perkins' did not measure black grama, so the measurement for total percent grass cover (incorporating all measured grasses) was used.

Sensitivity Analysis

Sensitivity analysis of the model was performed in STELLA for starting biomass, precipitation, grazing pressure, and TEB timing. Each of these factors was assessed in terms of the magnitude of their effect on the model output: biomass per square meter over time for both creosotebush and black grama. Variables were changed at regular intervals from the minimum to the maximum limits observed or defined. While one variable was being tested, the remaining variables were held constant. For further detail see Appendix D.

Results

Sensitivity Analysis

Variation in the starting biomass of either black grama or creosotebush had little impact on the results of the model, affecting only the time it took for the system to reach equilibrium under static conditions. Creosotebush was more responsive to other parameters than initial biomass and so took less time than black grama to reach equilibrium: approximately 30 years for creosotebush to the 80 years of black grama. It took an estimated 100 years for the system to reach complete equilibrium. When initial black grama biomass was set very low, < $5g*m^{-2}$, creosotebush biomass results took longer, about 80 years, to reach equilibrium. An initial biomass of zero for either species resulted in no growth for that species under this setup of the model, where the calculation for each time step is predicated on the last as given in equation (3).

Precipitation directly affected both species, increasing and decreasing biomass with rise and fall respectively. When precipitation was set to zero, the biomass of both species rapidly approaches zero. Interactive effects of precipitation and grazing gave complex results. Black grama was sensitive to constant grazing pressure at all levels, acting as a direct suppressor to black grama biomass (Figure 11). For all values of precipitation > 0, there was a grazing level that acted as a release for creosotebush, whereby creosotebush would begin to cycle with precipitation (Figure 12). At 240mm annual average precipitation, creosotebush begins to react to precipitation at the 5% grazing level and reaches a high at the 6% grazing level (Figure 13). Somewhat counterintuitively, the lower the precipitation, the higher the grazing pressure had to be before creosotebush was released.

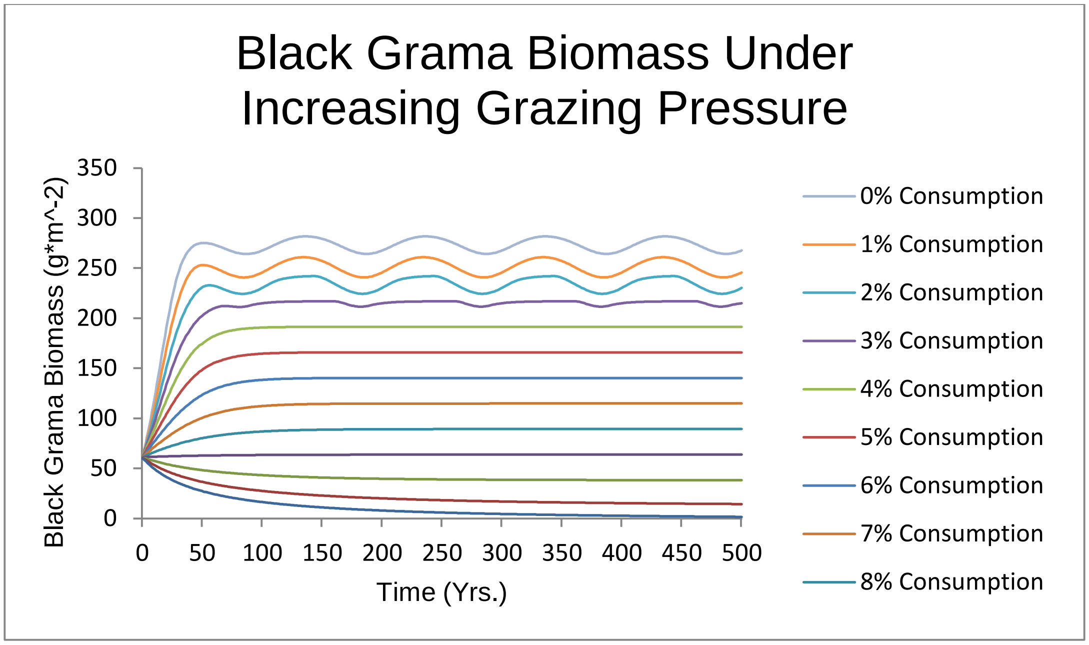

Figure 11. Black Grama response to increased grazing pressure in 1% increments at 240mm annual precipitation and no TEB treatment. Black Grama is decreased with every interval. The legend to the right increases from top to bottom to reflect this.

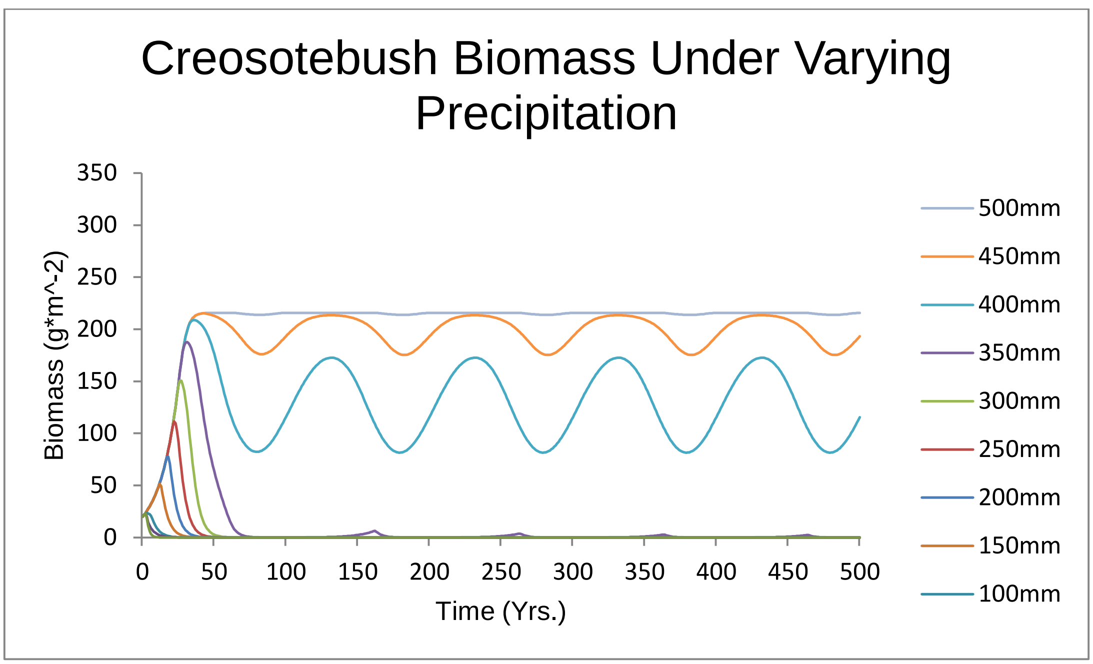

Figure 12. LATR response to increasing precipitation from 100mm to 500mm in 50mm increments with no grazing or TEB treatment.

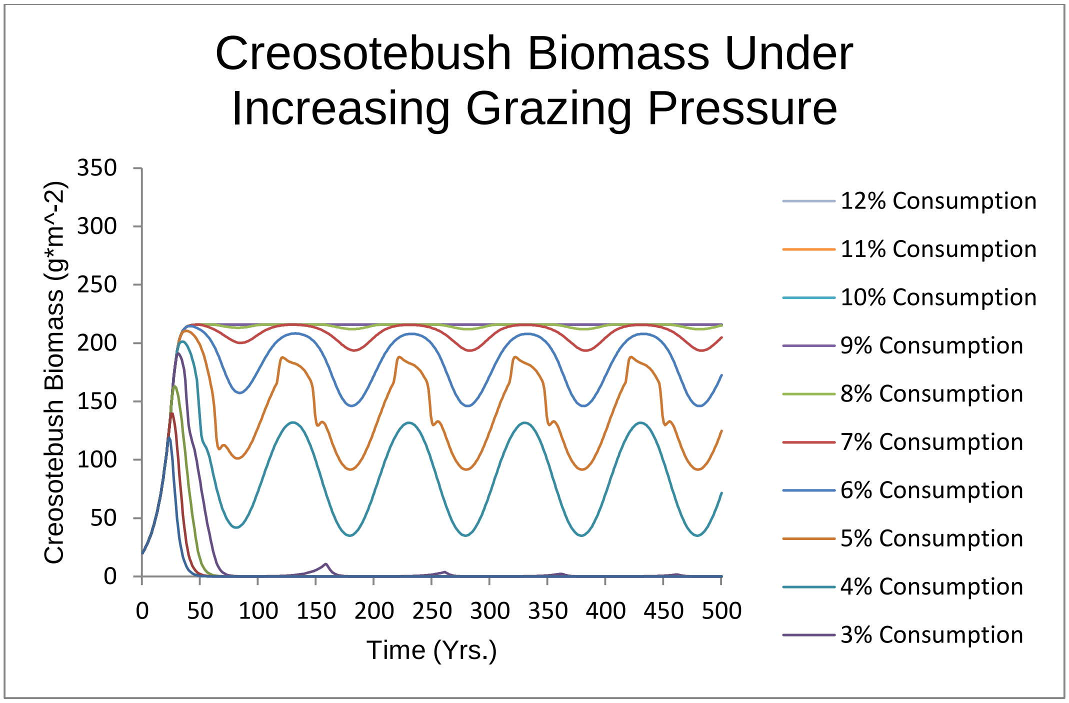

Figure 13. Creosotebush response to increasing grazing pressure in 1% increments at 240mm annual precipitation and no TEB treatment. Creosotebush shifts from minimum to maximum biomass from 3% grazing to 8% grazing consumption. The legend to the right increases from bottom to top to reflect this.

System Output

The inputs for the model are presented in Table 7. Figure 14 shows the results of the model under these specifications. Grazing pressure was initially set at 6% to represent moderate grazing, but was adjusted to 5.5% as per the sensitivity analysis to allow for more distinction in the results. The application time of TEB was then adjusted to create the longest period of time where the results are the closest to the target numbers representing scaled quail habitat. Because the input of precipitation was abstracted into a periodic cycle, and because the variation of black grama becomes muted with constant grazing pressure, the maximization of the effectiveness of TEB becomes periodic as well, following the cycle of creosotebush response to the cycling precipitation. In this case, TEB is most effective at restoring scaled quail habitat for the longest period of time when applied just before creosotebush gains the competitive advantage over black grama, in this case, every 100 years following the initiation of the simulation.

Table 7. Starting inputs for STELLA model

Variables	Value
black grama biomass	60 g*m^{-2}
Creosotebush biomass	20 g*m^{-2}
average total annual precipitation	260 mm
year to year precipitation variance	0
precipitation cycle magnitude	25 mm over 100 years
constant grazing pressure	5.5% annually
TEB apply date	200 years post simulation start

Creosotebush has a competitive advantage embedded within the model, water usage for the mid and deep soil layers increases dramatically when creosotebush biomass is greater than black grama biomass. As such, the amount of water in these layers is less, leading to the pattern seen in Figure 15. The large spike of resource availability for all layers coincides with the application of TEB. This makes sense due to the living biomass of creosotebush being reduced so rapidly and the limitations on black grama growth rate. Still, it is somewhat surprising that the surplus of resource does not allow black grama to overcome the effect of constant grazing pressure. Future scenarios may include grazing as a pulse, which would be more representative of rotational grazing practices.

Figure 16 shows the average distance of the two species from the characterization of scaled quail habitat, an emulation of the technique for calculating mean square error (MSE) in an Analysis of Variance (ANOVA). The closer to zero the distance is, the closer both species come to the recommended percentage of shrubs and grasses. Creosotebush is depicted as closely correlated to the precipitation cycle, and that grazing pressure has suppressed black grama to a level close to its target. This means that the near elimination of creosotebush by TEB causes the model to read that scaled quail habitat is closely approximated nearly immediately after, and continues to do so until the population recovers.

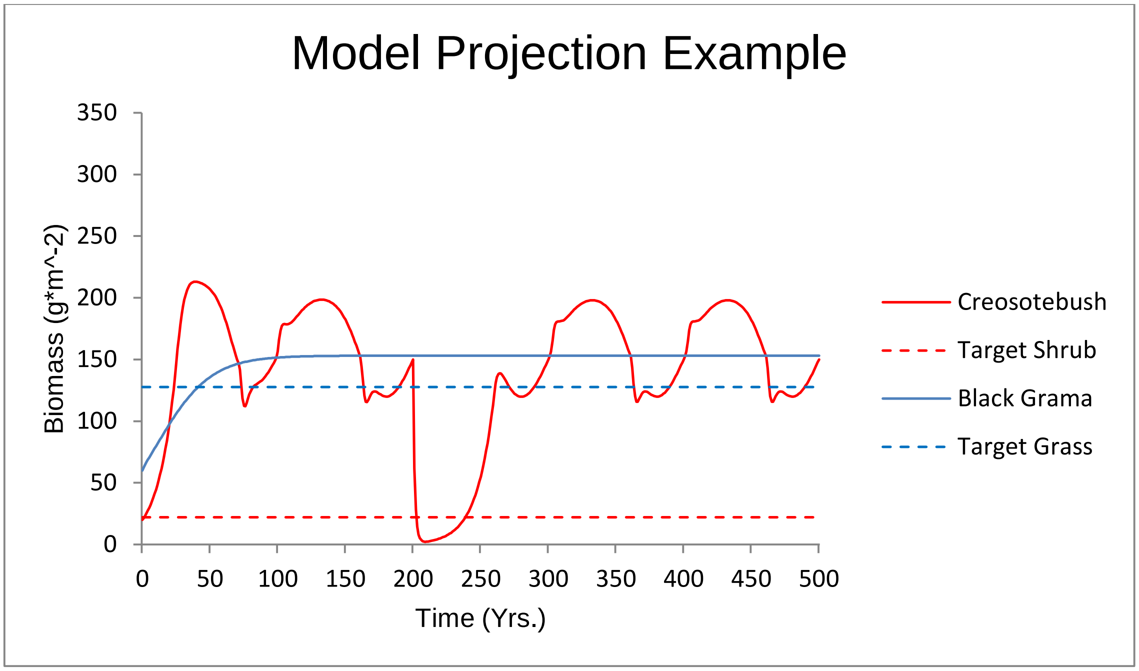

Figure 14. Comparison of black grama (BOER) and creosotebush (LATR) biomass under normal precipitation conditions over 500 years.

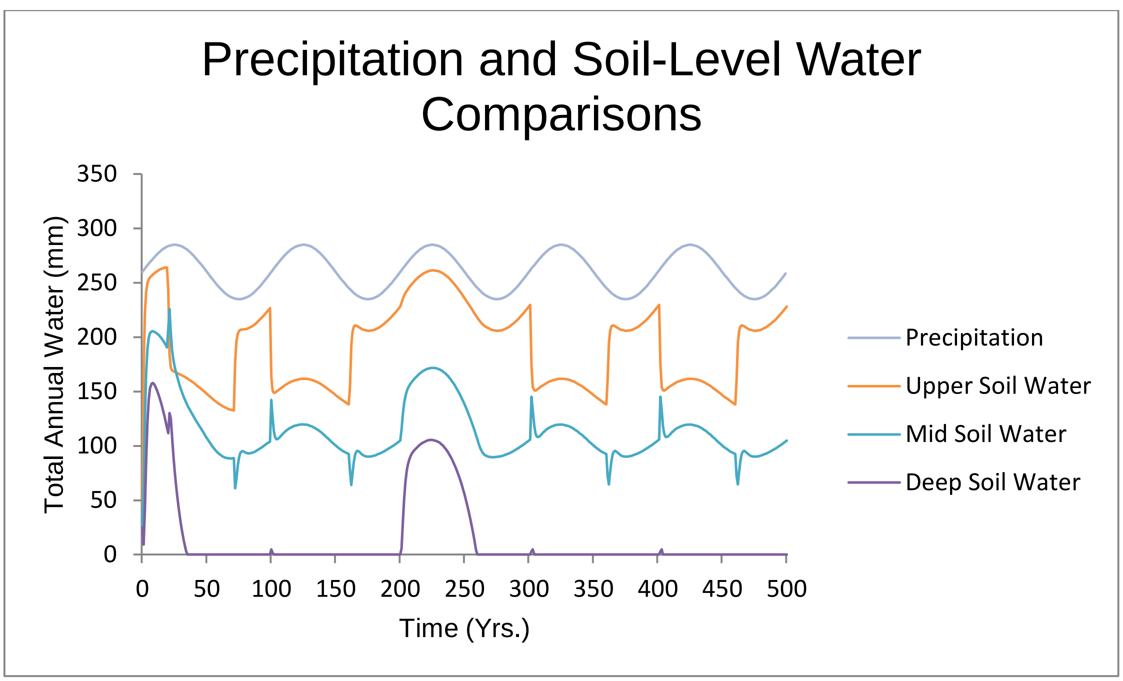

Figure 15. Comparison between precipitation and soil layer depth (top, middle and deep soils) over time (0-500 years).

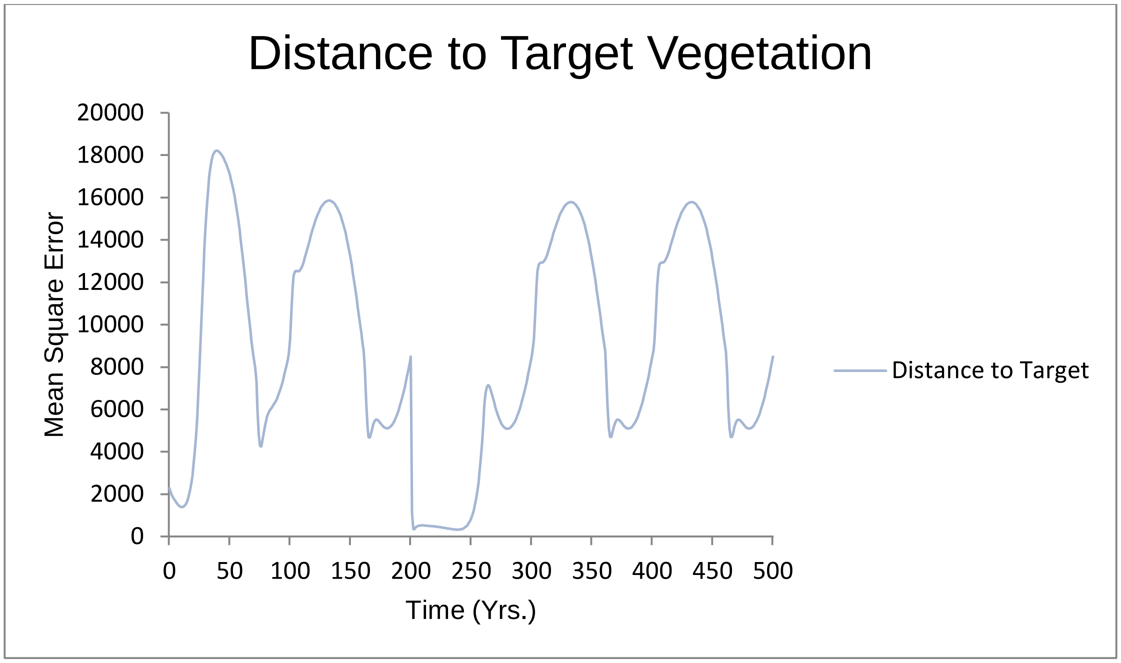

Figure 16. Mean squared distance of the results from Figure 1 to the target numbers of 127.6 g*m^-2 BOER and 22.2 g*m^-2 LATR. The lower the result, the closer the two species are to scaled quail habitat target values.

Accuracy Assessment

The addition of TEB allowed for higher soil-water in all three layers of soil (Figure 17; Figure 18), ostensibly from less consumption by creosotebush. TEB had an immediate effect on the biomass of creosotebush; however, TEB did not affect the growth rate of black grama within this scenario (Table 8). Linear regression analysis was significant for all growth rates except creosotebush without TEB treatment (Table 8; Figure 19; Figure 20).

The comparison between the model results and Perkins' data shows similarities along certain segments. The only relationship without an R^2 above 90% is creosotebush response to TEB, which exhibit slopes from 5 to 15 years with an R^2 of 15%. The comparison of black grama response to TEB yields similar results over the entire run of the model.

Table 8. Analysis using linear regression for creosotebush and black grama. Analysis included growth with tebuthiuron and without tebuthiuron.

Species	With TEB	R^2	No TEB	R^2
Creosotebush (LATR)	-0.233x+6.012	0.153	6.880x+7.529	0.972*
Black grama (BOER)	1.967x-3.273	0.928*	1.967x-3.273	0.928*

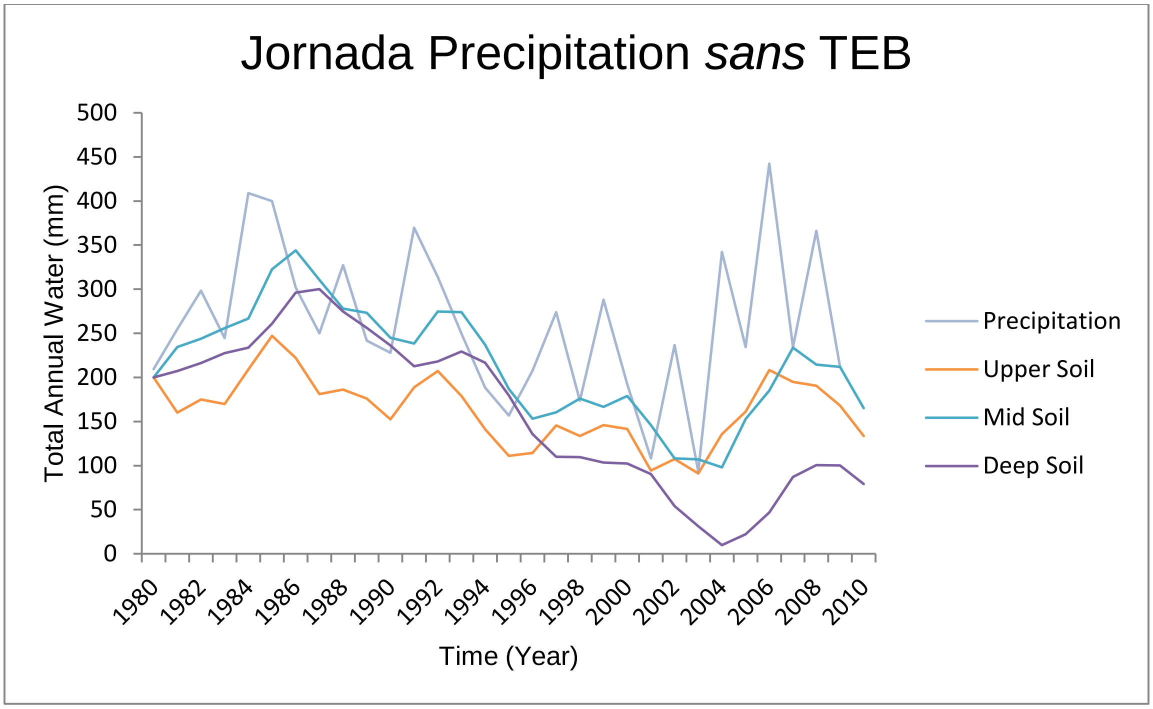

Figure 17. Timeline analysis of Jornada Experimental Range precipitation data with the three soil layers of upper, middle and deep soils in the absence of tebuthiuron treatment.

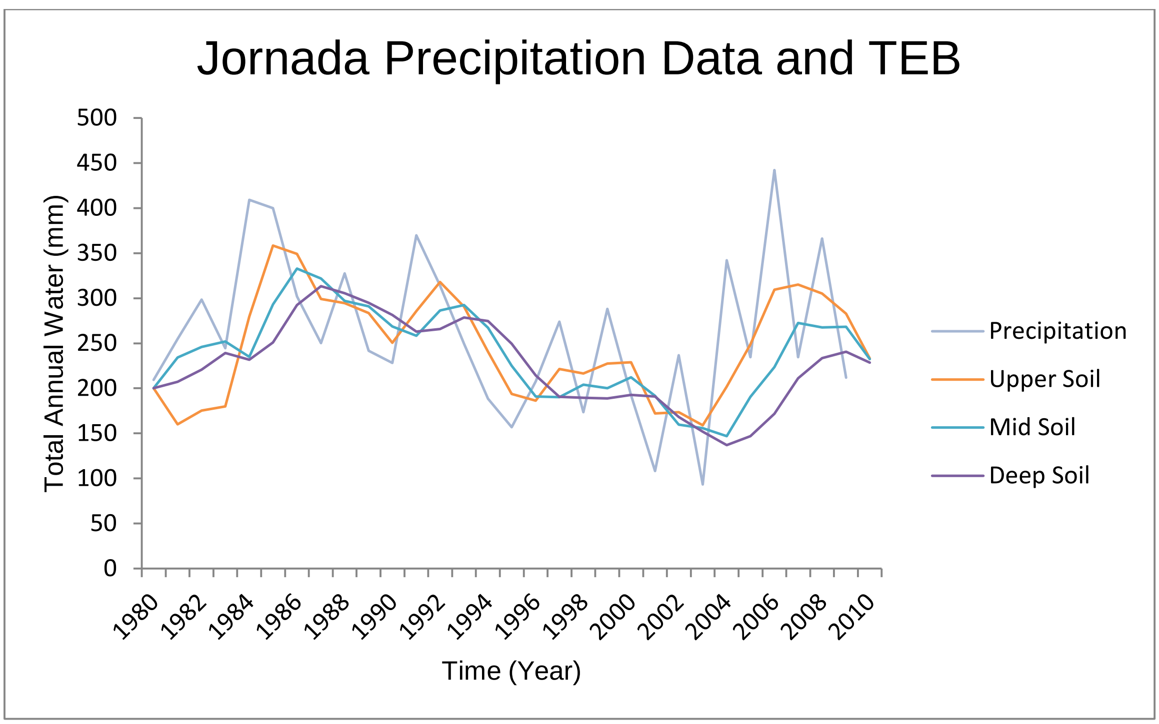

Figure 18. Timeline analysis of Jornada Experimental Range precipitation data with the three soil layers of upper, middle and deep soils in the presence of tebuthiuron treatment.

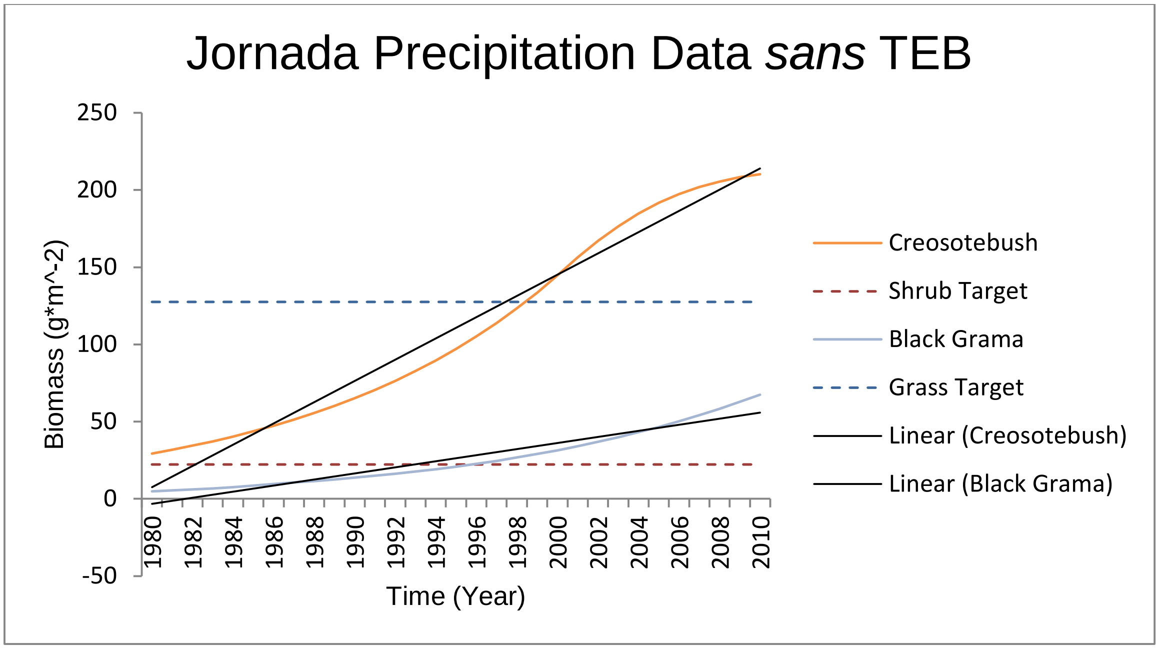

Figure 19. Timeline analysis of Jornada Experimental Range precipitation data and resultant creosotebush and black grama biomass increases in the absence of tebuthiuron.

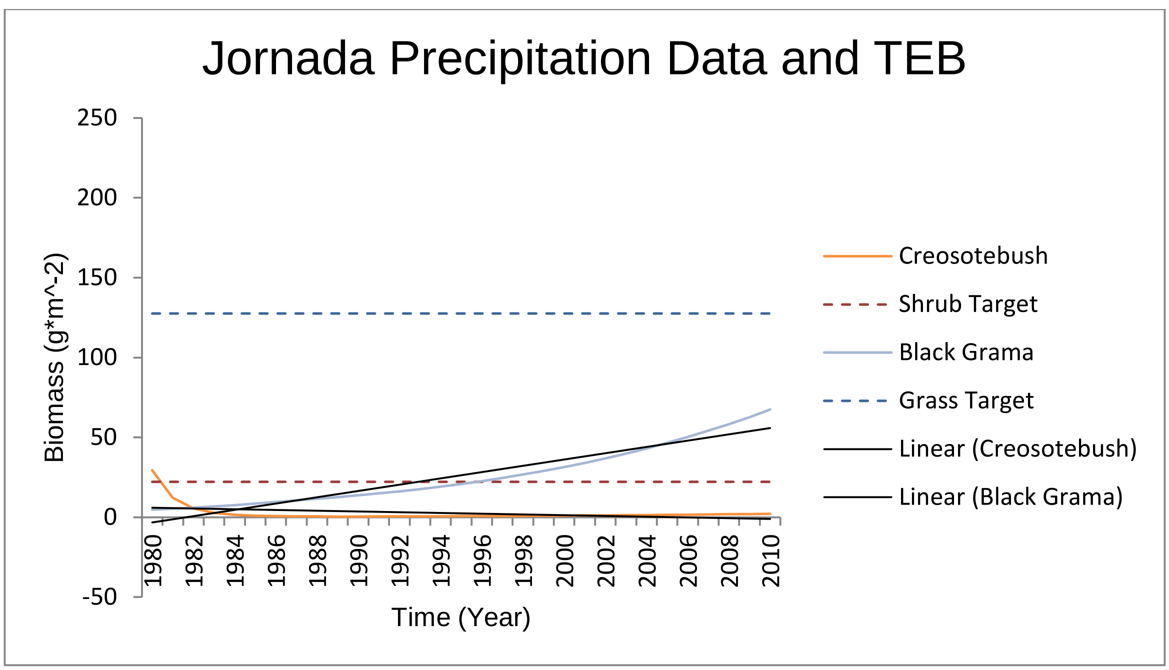

Figure 20. Timeline analysis of Jornada Experimental Range precipitation data and resultant creosotebush and black grama biomass increases in the presence of tebuthiuron.

Discussion

Model results indicate that tebuthiuron (TEB) application can help managers restore scaled quail habitat on a scale of around one century when applied during a surplus of precipitation. Tebuthiuron controls creosotebush through elimination and should be applied when conditions are ideal for the C3 plants leftover after treatment. Grazing pressure of the treated area may also need to be addressed if it is too high for grasses to recover. The time of grass dominance can be extended by TEB treatment, and would give yucca time to establish itself and provide scaled quail habitat. However the system may return to a shrub dominated state, as the model returns to equilibrium after approximately 100 years.

Without grazing pressure, black grama oscillates with precipitation. Within the model, black grama suppresses the growth of creosotebush. When black grama biomass is removed at > 5% grazing pressure, the oscillations become muted and creosotebush biomass is released. When it is released, creosotebush biomass becomes sensitive to precipitation. In this scenario, the difference between the model and the target range of scaled quail habitat becomes dependent on creosotebush biomass. Because the target number for creosotebush is low, and as TEB reduces creosotebush biomass effectively, the analysis shows TEB treatment as restoring scaled quail habitat.

While the model addresses two species of plants, scaled quail correlate with plant species diversity; the addition of species can address this. Scaled quail are often associated with soaptree yucca (*Yucca elegans*). If the treatment area is not disturbed, and yucca establishes itself, a modification of the model may better predict when scaled quail habitat is optimized.

Further testing of the strength of relationships between all environmental factors would allow a more rigorous selection of factors controlling vegetation dynamics without the model becoming over-parameterized. Likewise, there are too few field data points for a conclusive accuracy analysis at this time. The time frame for this phenomenon is too large for it to have been studied long enough for all the factors to have been assessed. Bayesian techniques in decisions and analysis may address these uncertainties until the body of knowledge expands.

It may be possible, if the landscape of ownership and management allow it, to create rotating “pulses” of scaled quail habitat, where adjacent plots of land are managed in succession to allow for scaled quail movement and persistence, similar to sustainable harvest for logging. Like with logging though, these practices must have incentive to exist on a time scale that exceeds the average human life span, in addition to dealing with the stochastic nature of the desert. In this way, the consequences of the application of TEB in the restoration of scaled quail habitat could be accounted for, temporally and spatially, maximizing corridors and habitat patches.

Task 7: Monitor biodiversity metrics and conservation effects (fine scale)

Project limitations prevented us from monitoring both the biodiversity metrics and conservation effects. We examined the Natural Resources Inventory (NRI) data protocols to see if they were appropriate to provide baseline habitat information and to monitor change and provide trend information within the study area. Herrick et al. (2010) showed NRI data can be incorporated into a national ecosystem assessment. NRI data may also be used to validate conservation effects of selected conservation practices. During project meetings it was determined that the NRI was not a sufficient database for pre-conservation practice and post conservation practice to assess habitat change within our study area range. Thus we began the aforementioned dynamic systems modeling using the conceptual STM descriptions with conservation practice by species matrix. Simulation was determined to be best to incorporate to illustrate usefulness of long-term monitoring. The use of monitoring data, was identified as extremely valuable in Tasks 5-6, as this information provided an accuracy check of the SDM model outputs.

Task 8: Technology transfer

Technology transfer is always a challenge across agencies, department, and disparate field offices. We focused on utilizing common technology available in most federal and state offices to allow field personnel to gain access to some of the previously described analyses and datasets.

We created several ArcGIS models that are connected to a MS Access database. The full description is provided in Appendix C. The models work at the species or biodiversity metric level. The species model identifies the SWReGAP species and each specific land cover type (ecological system) found within the polygon. The model table also provides the area for each species * land combination and the predetermined impact for a conservation practice on that land based on % effectiveness. The CEAP Biodiversity Metrics provides the same information by based on species richness statistics for a given biodiversity metric within the polygon.

Conclusions

Our effort presents a general methodology for identifying a set of conservation priorities for a management unit that accounts for the broader geopolitical and ecological context. This methodology highlights areas of high relative species richness within the focal management unit. A large and highly biodiverse portion of New Mexico in the Southwestern US was used as an example focal management unit. This methodology is easily applied to other areas. The methods described herein identify multiple biodiversity and species-level conservation priorities for the focal management unit. These priorities vary depending on the broader context considered and the criterion thresholds used in the assessment. They also highlight the western portion of the focal area as containing exceptionally high biodiversity; an observation confirmed by other sources. The methods used here are highly flexible and can be modified to suit the needs of a variety of land and natural resource managers. The species richness datasets applied here, and national-scale data that will soon be available, potentially allow for a top down approach that starts with identification of broad groups of organisms that are well-represented in a given area, then identifies individual species that are important to conserve. The priorities identified using the spatial techniques applied here are best supplemented and refined using information from a variety of sources, including agency-generated priorities and expertise. These priorities can then be used to inform further analyses and activities related to the conservation and management of local biodiversity and individual species. They can also be used to assess or revise existing priorities for the focal management unit.

The list of conservation practices by species matrix should be a dynamic effort. Knowledge is gained every year and growth of knowledge of individual species is increasing at an exponential rate. The practice by species matrix is a start that is specific to the focal species identified within this study. When using this type of information, managers should take care to review the details and geography of the study. Geographical differences may strengthen or lesson the practice effect. USDA already provides excellent information on the conservation practices through the USDA website (http://efotg.sc.egov.usda.gov/treemenuFS.aspx).

Conservation practices effects on these species were then assessed using direct and indirect evidence provided within scientific literature and reports. Providing a temporal scale on the effectiveness of practices provides managers with a time-dependent response. We used short-term (< 1 year) and long-term (> 1 year) effects, however the temporal span could be expanded much more. For example, results from the dynamic system modeling provide a longer term perspective on TEB effects on black grama and creosotebush. As noted, there will always be gaps in the scientific literature where we do not currently know what the effect and concomitant species response will be.

The dynamic system modeling provides scenario runs that can assist with long-term management efforts. Our SDM model indicates that TEB application can help managers restore scaled quail habitat on a temporal scale of 100 years if applied during above average precipitation. We included grazing in the model, to test the effect of resting the treated area to provide insight into the amount of grazing pressure that can allow grasses to recover. In the model simulations, grassland dominance can be extended by TEB treatment. The extended time may give yucca the necessary time to establish and enhance scaled quail habitat. The scenario suggests that the system may return to a shrub dominated state after 100 years. With no grazing, black grama increases or decreases with precipitation, but when grazing pressure increases above 5% black grama biomass increases dampened and creosotebush biomass is released. When it is released, creosotebush biomass becomes sensitive to precipitation. In this scenario, the difference between the model and the target range of scaled quail habitat becomes dependent on creosotebush biomass. Our model, based on low target number for creosotebush and TEB reducing creosotebush biomass effectively, shows TEB treatment as restoring scaled quail habitat.

The model provides support for managers to create a rotating “pulse” of scaled quail habitat. Conceptually, this is where adjacent plots of land are managed in succession to allow for scaled quail movement and persistence. Similar to sustainable logging, this concept must have incentives to continue over long periods of time. Additionally managers will have to make adjustments for the stochastic nature of the desert. In this way, the consequences of the application of TEB in the restoration of scaled quail habitat could be accounted for, temporally and spatially, maximizing corridors and habitat patches.

This project has provided an initial effort to identify biodiversity metrics, species lists, and conservation practices of interest for a large and biodiverse management unit in the western US and assess the impacts of conservation practices on selected species. Collaboration with agencies and stakeholders, supplemented by thorough literature review, is necessary to determine conservation priorities and relevant management practices for a particular region. Analysis at the broad scale can be used to inform management activities at the fine scale. Fine scale dynamics can be extrapolated to a larger area and incorporated into a decision support tool that can be used to determine the holistic effects of conservation practices on wildlife populations. Conservation practices have varying effects on habitats and species utilization over time which should be considered in management planning.

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Appendices

Appendix A. Species by Practice Matrix with Short-term and Long-term Effects.

Effects in Green = positive, Yellow = mixed, Pink = negative, and White = neutral. Superscripts indicate references which are listed below the table.

Scientific Name	Common Name	Short-term Effect	Long-term Effect
Falco femoralis	**Aplomado Falcon**		
	Brush Control (*herbicide*)	If pesticides/herbicides present in prey (-), likely cause of their decline[1]	Prefer grassland/savanna-like habitat where trees and shrubs are widely spaced[2,3]; successful reintroductions are rare; Indirect food recovery[2]
	Watering Facility	Raptor use to drink, bathe, perch, nest, and forage where prey concentrations occur)[4] Mourning doves (falcon prey) benefit from water catchments[5]	Likely positive if high water quality
	Riparian Herbaceous Cover	NA	NA
	Prescribed Fire	Immediate negative effects[6]	Short grasslands restored are optimal for nesting[3,6] Grass/savanna promote greater diversification[7]
	Fence Construction	Likely no response	Likely no response
	Prescribed Grazing	Can improve quality of foraging habitat by reducing stature of grass (<60 cm)[2]	Overgrazed areas reduce available foraging habitat and enhance shrub encroachment[2]
Empidonax traillii extimus	**Southwestern Willow Flycatcher**		
	Brush Control (*herbicide*)	Use Tamarisk for habitat; targeted for herbicide use[8]	Use Tamarisk for habitat; targeted for herbicide use[8]
	Watering Facility	Likely no response	Likely no response
	Riparian Herbaceous Cover	Riparian obligate species[1,8]	Riparian obligate species[1,8]
	Prescribed Fire	Fire may isolate species[9]	Fire may isolate species[9]
	Fence Construction	Likely no response	Likely no response
	Prescribed Grazing	Reduces understory habitat (Damon Peterson, personal comm.)	Reduces understory habitat (Damon Peterson, personal comm.)

Scientific Name	Common Name	Short-term Effect	Long-term Effect
Leptnycteris nivalis	**Mexican Long-nosed Bat**		
	Brush Control (*herbicide*)	May reduce Agave[10]	May reduce Agave[10]
	Watering Facility	Likely used for drinking, but not for foraging (eat nectar and pollen)[4]	May expand distribution, especially near roosts[4]
	Riparian Herbaceous Cover	Minimal habitat overlap	Minimal habitat overlap
	Prescribed Fire	Agave not fire tolerant[11]	Agave not fire tolerant[11]
	Fence Construction	Likely no response	Likely no response
	Prescribed Grazing	US DOI say no significant effects foreseen	Degrades Agave[11] Low nutrition for cattle[12]
Athene cunicularia	**Burrowing Owl**		
	Brush Control (*herbicide*)	Prefer reduced grass cover height[9]	Food increase
	Watering Facility	Raptor use to drink, bathe, perch, nest, and forage where prey concentrations occur[4,13,14]	Raptor use to drink, bathe, perch, nest, and forage where prey concentrations occur[4,13,14]
	Riparian Herbaceous Cover	Minimal habitat overlap	Minimal habitat overlap
	Prescribed Fire	Select for reduced grass cover, but can lead to greater predation[10,13]	Select for reduced grass cover, but can lead to greater predation[10,13] Likely long-term benefits for potential prey
	Fence Construction	Likely no response	Likely no response
	Prescribed Grazing	Nesting pairs select grazed sites[13,15,16]	Absent from areas with greater than 40% cover of perennial grasses[15]

Scientific Name	Common Name	Short-term Effect	Long-term Effect
Ovis canadensis	**Bighorn Sheep**		
	Brush Control (*herbicide*)	Unknown adverse effects	Food increase[17]
	Watering Facility	Readily use surface water; obtain sufficient water from succulents[4] Likely no effect[18]	Food increase[17] Habitat use correlated with proximity to water, including developments; benefit some, not all populations[19]
	Riparian Herbaceous Cover	Minimal habitat overlap	Minimal habitat overlap
	Prescribed Fire	Reintroductions after prescribed fire[20]	Food increase[15] Prefer open habitat[21]
	Fence Construction	Barrier	Barrier
	Prescribed Grazing	Competition[21,22]	Competition[21,22]
Callipepla squamata	**Scaled Quail**		
	Brush Control (*herbicide*)	Associated with bare ground/most detected at sites with 3.5% woody plant cover[23] - Higher occurrence in treated areas[24] Mesquite seeds a food source[25]	Habitat recovery/Grassland birds that require habitat diversity[26]
	Watering Facility	Resource availability	
	Riparian Herbaceous Cover	Minimal habitat overlap	Minimal habitat overlap
	Prescribed Fire	Generally positive grass recovery[6]	Generally positive grass recovery[6] Require habitat diversity[26]
	Fence Construction	Likely no response	Likely no response
	Prescribed Grazing	Grassland birds that require habitat diversity[26]	Cover/food removal

Scientific Name	Common Name	Short-term Effect	Long-term Effect
Leptonycteris yerbabuenae	**Lesser Long-nosed Bat**		
	Brush Control (*herbicide*)	May reduce Agave[10]	May reduce Agave[10]
	Watering Facility	Likely used for drinking, but not for foraging since not insectivorous (eat nectar and pollen)[4]	May expand distribution, especially near roosts[4]
	Riparian Herbaceous Cover	Likely no response	Likely no response
	Prescribed Fire	Agave not fire tolerant[11]	Agave not fire tolerant[11]
	Fence Construction	Likely no response	Likely no response
	Prescribed Grazing	No significant effects foreseen[22]	Degrades Agave[10] Low nutrition for cattle[12]
Lithobates chiricahuensis	**Chiricahua Leopard Frog**		
	Brush Control (*herbicide*)	Negative if in close proximity to an aquatic habitat [27] Restores habitat health[28]	Negative if in close proximity to an aquatic habitat[27] Restores habitat health[28]
	Watering Facility	Earthen tanks can provide valuable refugia for amphibians[4] Jack Barnitz (BLM) used taller stock tanks for CLF restoration; Livestock can have negative effects[17]	Earthen tanks can provide valuable refugia for amphibians[4] Jack Barnitz (BLM) used taller stock tanks for CLF restoration; Livestock can have negative effects[17]
	Riparian Herbaceous Cover	Restores habitat health[28] Likely improve corridors for movement[27]	Restores habitat health[28] Likely improve corridors for movement[27]
	Prescribed Fire	May have immediate adverse effects (azrangelands.org)	Fire suppression (-)[28] Rehab projects on prescribe burned areas[20]
	Fence Construction	Likely no response; Construction of could interfere with dispersal[27]	Likely no response; Construction of could interfere with dispersal[27]
	Prescribed Grazing	Habitat removal[22]	Habitat removal[22]

Scientific Name	Common Name	Short-term Effect	Long-term Effect
Odocoileus hemionus	**Mule Deer**		
	Brush Control (*herbicide*)	Depends on remaining resources for food and cover[21]	Generally positive grass recovery[6]
	Watering Facility	Found in close proximity to water source; population increase (+)[4]	Can become dependent on water catchments (-)[4]
	Riparian Herbaceous Cover	Resource availability	Resource availability
	Prescribed Fire	Depends on remaining resources for food and cover[21]	Generally positive grass recovery[6]
	Fence Construction	Permeable barrier; Some mortality[29]	Permeable barrier; Some mortality[29]
	Prescribed Grazing	Little evidence of competition with cattle[30,31]	Little evidence of competition with cattle[30,31]
Dipodomys spectabilis	**Banner-tailed Kangaroo Rat**		
	Brush Control (*herbicide*)	Unknown direct effects	Brush control generally positive; >20% shrub cover detrimental[32,33]
	Watering Facility	Minimal habitat overlap	Minimal habitat overlap
	Riparian Herbaceous Cover	Avoid tall grasses[32]	Avoid tall grasses[32]
	Prescribed Fire	Lag in response to grassland restoration[32,33]	Disappear when invasive shrub cover exceeds 20%; presence is an indicator desert grassland health[32,33,34]
	Fence Construction	Fencing can be used as exclosures for experiments[35]	Likely no long-term effects since they build underground tunnels
	Prescribed Grazing	Heteromyid rodents abundant on grazed plots (Banner-tailed not included in this study)[36]	Livestock grazing considered driver of shrub encroachment, although evidence is anecdotal or confounded by other factors[37]

Scientific Name	Common Name	Short-term Effect	Long-term Effect
Coccyzus americanus	**Yellow-billed Cuckoo**		
	Brush Control (*herbicide*)	Unknown direct effects	Minimal habitat overlap; occupy large areas of willow-cottonwood or mesquite (prefer high canopy)[38]
	Watering Facility	Minimal habitat response	Minimal habitat response
	Riparian Herbaceous Cover	Habitat recovery[39]	Habitat restoration (Cottonwood)[39,40]
	Prescribed Fire	Likely no response if outside of breeding season[41]	Minimal habitat overlap
	Fence Construction	Likely no response	Likely no response
	Prescribed Grazing	Likely no response; associated with savanna-woodland[42]	Likely no response
Antilocapra americana	**Pronghorn**		
	Brush Control (*herbicide*)	Recommend treating <450 ha; Pesticides negatively influence food[20]	Likely no response
	Watering Facility	Support greater densities of pronghorn in most studies, but not determining factor[4]	Especially beneficial during drought or when succulents are unavailable[4] Water availability does not affect distribution[43]
	Riparian Herbaceous Cover	Minimal habitat overlap	Minimal habitat overlap
	Prescribed Fire	Resource availability[21]Autumn patch burns are valuable[44]	Minimizes loss of native plants[22]
	Fence Construction	Semi-barrier/some mortality	Likely no significant response
	Prescribed Grazing	Competition[45]	Competition, particularly during drought conditions[45]

Scientific Name	Common Name	Short-term Effect	Long-term Effect
Ammodramus savannarum	**Grasshopper Sparrow**		
	Brush Control (*herbicide*)	Negative correlation with woody cover; territory density decreased 2-5 yrs. following hexazinone (4kg/ha) application[46]	Habitat restoration[20] Grass-dependent; negative correlation with woody cover[46,47] Habitat requirements differ for dependent and independent juveniles[48]
	Watering Facility	Resource availability	Resource availability
	Riparian Herbaceous Cover	Minimal habitat overlap	Minimal habitat overlap
	Prescribed Fire	Possible decline[5] Least abundant in breeding season immediately after burn[41] Lag effects when outside breeding season[47] Lowers nest predation by snakes[49]	Negative correlation with woody cover[46,47] Open grassland species[50]
	Fence Construction	Likely no response	Likely no response
	Prescribed Grazing	Bison increased abundance[46] Cattle reduced nesting success, reduced invertebrate prey, increased predation[51] Greater forb cover around nest reduces predation[49]	Bison increased abundance[46] Cattle reduced nesting success, reduced invertebrate prey, increased predation[51]
Buteogallus anthracinus	**Common Black Hawk**		
	Brush Control (*herbicide*)	Unknown direct effects/Minimal habitat overlap	Minimal habitat overlap
	Watering Facility	Drink, bathe, perch, use for nest substrates, and foraging areas with concentrations of prey[4]	Drink, bathe, perch, use for nest substrates, and foraging areas with concentrations of prey[4]
	Riparian Herbaceous Cover	Restore summer habitat[19]	Prefer established/mature riparian habitat[52]
	Prescribed Fire	Likely no response outside of breeding season	Minimal habitat overlap
	Fence Construction	Likely no response	Likely no response
	Prescribed Grazing	Likely no response	Likely no response

Scientific Name	Common Name	Short-term Effect	Long-term Effect
Ammodramus bairdii	**Baird's Sparrow**		
	Brush Control (*herbicide*)	Unknown direct effects	Habitat recovery[21] Require grasslands[53]
	Watering Facility	Likely no response	Likely no response
	Riparian Herbaceous Cover	Minimal habitat overlap	Minimal habitat overlap
	Prescribed Fire	Likely no response if outside of breeding season	Likely no response[4] Habitat recovery causing increased use[54]
	Fence Construction	Likely no response	Likely no response
	Prescribed Grazing	Prefer ungrazed, mixed prairie (tall and dense)[55]	Prefer ungrazed, mixed prairie (tall and dense)[55]
Anthus spragueii	**Sprague's Pipit**		
	Brush Control (*herbicide*)	Complete shrub removal[56]	Complete shrub removal[56]
	Watering Facility	Likely no response	Likely no response
	Riparian Herbaceous Cover	Minimal habitat overlap	Minimal habitat overlap
	Prescribed Fire	Likely no response if outside of breeding season	Habitat recovery[53,56]
	Fence Construction	Likely no response	Likely no response
	Prescribed Grazing	Prefer ungrazed, mixed prairie (tall and dense)[55] Light to moderate optimal[56]	Prefer ungrazed, mixed prairie (tall and dense)[55] Light to moderate optimal[56]
Buteo regalis	**Ferruginous Hawk**		
	Brush Control (*herbicide*)	Prairie dog response[57]	Prairie dog response[57]
	Watering Facility	Drink, bathe, perch, use for nest substrates, and foraging areas with concentrations of prey[4]	Drink, bathe, perch, use for nest substrates, and foraging areas with concentrations of prey[4]
	Riparian Herbaceous Cover	Restore habitat health[21]	Restore habitat health[21]
	Prescribed Fire	Prairie dog response[58]	Prairie dog response[58]
	Fence Construction	Likely no response	Likely no response
	Prescribed Grazing	Prairie dog response[57,59]	

Scientific Name	Common Name	Short-term Effect	Long-term Effect
Crotalus willardi obscurus	**NM Ridge-nosed Rattlesnake**		
	Brush Control (*herbicide*)	Unknown direct effects	Likely no response
	Watering Facility	Will drink from earthen tank water, but not detrimental. In NM, snakes more abundant at watered sites[4]	Likely no response
	Riparian Herbaceous Cover	Minimal habitat overlap	Minimal habitat overlap
	Prescribed Fire	Low-intensity fire survivable, high intensity fire causes mortality[22,60]	Low-intensity fire survivable, high intensity fire causes mortality[22,60]
	Fence Construction	Likely no response	Likely no response
	Prescribed Grazing	Likely no response[22]	Likely no response[22]
Charadrius montanus	**Mountain Plover**		
	Brush Control (*herbicide*)	Restore prairie dog habitat[59,61]	Restore prairie dog habitat[59,61] Will nest in cultivated fields[62]
	Watering Facility	Likely no response	Likely no response
	Riparian Herbaceous Cover	Minimal habitat overlap	Minimal habitat overlap
	Prescribed Fire	Restore prairie dog habitat[59,61]	Restore prairie dog habitat[59,61]
	Fence Construction	Likely no response	Likely no response
	Prescribed Grazing	Restore prairie dog habitat[59,61]	Restore prairie dog habitat[59,61]
Buteo swainsoni	**Swainson's Hawk**		
	Brush Control (*herbicide*)	Depends on prey (rodent/insect) response	Depends on prey (rodent/insect) response
	Watering Facility	Drink, bathe, perch, nest, and forage where prey concentrated[4] Drinking may not be required for survival[63]	Drink, bathe, perch, nest, and forage where prey concentrated[4] Drinking may not be required for survival[63]
	Riparian Herbaceous Cover	Trees for nesting[64]	Trees for nesting[64]
	Prescribed Fire	Consume insect or rodent prey driven out by fire[64]	Likely no response if outside of breeding season; grasslands preferred breeding habitat[65]
	Fence Construction	Likely no response	Likely no response
	Prescribed Grazing	Unknown; depends on prey (rodent/insect) response	Rodent response

Scientific Name	Common Name	Short-term Effect	Long-term Effect
Spizella atrogularis	**Black-chinned Sparrow**		
	Brush Control (*herbicide*)	Unknown direct effects/reduces shrub habitat (unless dead shrubs remain)[66]	Reduces shrub habitat[66]
	Watering Facility	Resource availability[67]	Resource availability[67]
	Riparian Herbaceous Cover	Minimal habitat overlap	Minimal habitat overlap
	Prescribed Fire	Likely no response outside of breeding season	As shrubs are restored in post-fire succession[66]
	Fence Construction	Likely no response	Likely no response
	Prescribed Grazing	Prefer undisturbed chaparral or successional scrub[66]	Prefer undisturbed chaparral or successional scrub[66]
Peccari tajacu	**Javalina**		
	Brush Control (*herbicide*)	Unknown direct effects	Long-term food increase[68]
	Watering Facility	If low enough, resources availability	If low enough, resources availability
	Riparian Herbaceous Cover	Resource availability[68]	Resource availability[68]
	Prescribed Fire	Unknown direct effects	Long-term food increase[68]
	Fence Construction	Permeable barrier[69]	Permeable barrier[69]
	Prescribed Grazing	Competition (where mesquite food occurs)[69]	Competition (where mesquite food occurs)[69]
Sturnella magna	**Eastern Meadowlark**		
	Brush Control (*herbicide*)	Negative correlation with woody cover[23] Higher occurrence in treated areas[24] Open grassland species[50]	Negative correlation with woody cover[25] Open grassland species[50]
	Watering Facility	Resource availability[67]	Resource availability[67]
	Riparian Herbaceous Cover	Minimal habitat overlap	Minimal habitat overlap
	Prescribed Fire	Rare at breeding sites immediately post-burn[54]	Habitat recovery[5]; Open grassland species[50]
	Fence Construction	Likely no response	Likely no response
	Prescribed Grazing	Risk of nest destruction[70]	Risk of nest destruction[70]

Scientific Name	Common Name	Short-term Effect	Long-term Effect
Lanius ludovicianus	**Loggerhead Shrike**		
	Brush Control (*herbicide*)	May be negatively impacted by shrub removal via herbicide[24] Shrub dependent[50]	Shrub dependent[50] Loss of foraging habitat and hunting perches implicated in population declines[71]
	Watering Facility	Resource availability	Resource availability
	Riparian Herbaceous Cover	Minimal habitat overlap	Minimal habitat overlap
	Prescribed Fire	Likely no response outside of breeding season/unless intense fire[6,50.72]	Likely no response outside of breeding season/unless intense fire[6,50.72]
	Fence Construction	More abundant and more nesting sites in fenced areas[73] Nest in trees/shrubs along fence lines in agricultural areas[74]	More abundant and more nesting sites in fenced areas[73] Nest in trees/shrubs along fence lines in agricultural areas[74]
	Prescribed Grazing	Grazing encourages shrub growth/appeared to forage more where grass was undisturbed[75]	Grazing encourages shrub growth/appeared to forage more where grass was undisturbed[75]
Eremophila alpestris	**Horned Lark**		
	Brush Control (*herbicide*)	Initial creation of bare ground[5,76,77]	Positive relationship with grass cover[23] Higher occurrence in treated areas[24]
	Watering Facility	Resource availability[67]	Resource availability[67]
	Riparian Herbaceous Cover	Shies from woodlands[77]	Shies from woodlands[77]
	Prescribed Fire	Habitat recovery, including seeds[6,67,76]	Habitat recovery, feed on weed and grass seeds[6,67,76] use grass in nest cavities[78]
	Fence Construction	Likely no response	Likely no response
	Prescribed Grazing	Detected more often on grazed transects[67] Creation of bare ground[6,77]	Positive relationship with grass cover[23] Grassland specialist[24]

Scientific Name	Common Name	Short-term Effect	Long-term Effect
Sternella neglecta	**Western Meadowlark**		
	Brush Control (*herbicide*)	No effects due to shrub removal[76]	No effects due to shrub removal[76]
	Watering Facility	Resource availability[67]	Resource availability[67]
	Riparian Herbaceous Cover	Shies from woodlands[40]	Shies from woodlands[40]
	Prescribed Fire	Likely no response if outside of breeding season	Habitat recovery[6]
	Fence Construction	Used for basking[79]	Used for basking[79]
	Prescribed Grazing	Grasses for nesting material[79]	Removal of grasses[79]
Calamospiza melanocorys	**Lark Bunting**		
	Brush Control (*herbicide*)	Shrub removal[80]	Shrub removal[80]
	Watering Facility	Resource availability[40,67]	Resource availability[40,67]
	Riparian Herbaceous Cover	Minimal habitat overlap	Minimal habitat overlap
	Prescribed Fire	Likely no negative response outside of breeding season/removal of shrubs[40]	Removal of shrubs[40]
	Fence Construction	Likely no response	Likely no response
	Prescribed Grazing	Detected more often on grazed transects[67] Association with risks[23]	Detected more often on grazed transects[67]
Uta stansburiana	**Side-blotched Lizard**		
	Brush Control (*herbicide*)	Unknown direct effects	Likely no response
	Watering Facility	Will drink from earthen tank water, not detrimental; In NM, lizards more abundant at watered sites[4]	Likely no response
	Riparian Herbaceous Cover	Minimal habitat overlap[81]	Minimal habitat overlap[81]
	Prescribed Fire	Shrub cover influenced occupancy, but grasses/forbs and bare ground also show empirical support[82]	Greatest abundance in grasses and shrubs; fire suppression indirectly leads to shrub encroachment[83]
	Fence Construction	Likely no response	Likely no response
	Prescribed Grazing	Decreases lizard abundance[84]	Decreases lizard abundance[84]

References for Appendix A

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Appendix B. CEAP ArgGIS Model Documentation

Any updates will be posted at http://case.nmsu.edu/case/Projects/CEAP/Documents/Appendix_B.pdf

CEAP Model Documentation

The process uses both MS Access databases (CEAP.mdb and CEAPToolbox.mdb) and an ArcGIS Toolbox.

To install, unzip the file CEAP.zip. All datasets necessary to run are included within this zip file. The data is specific to the Southwestern United states of Arizona, Colorado, New Mexico, Nevada, and Utah.

There are two MS Access Databases used in the analysis. The CEAP.mdb is the front-end database with forms and tabular output. The CEAPToolbox.mdb is the working database where most temporary files are contained.

Opening the database will open the below form.

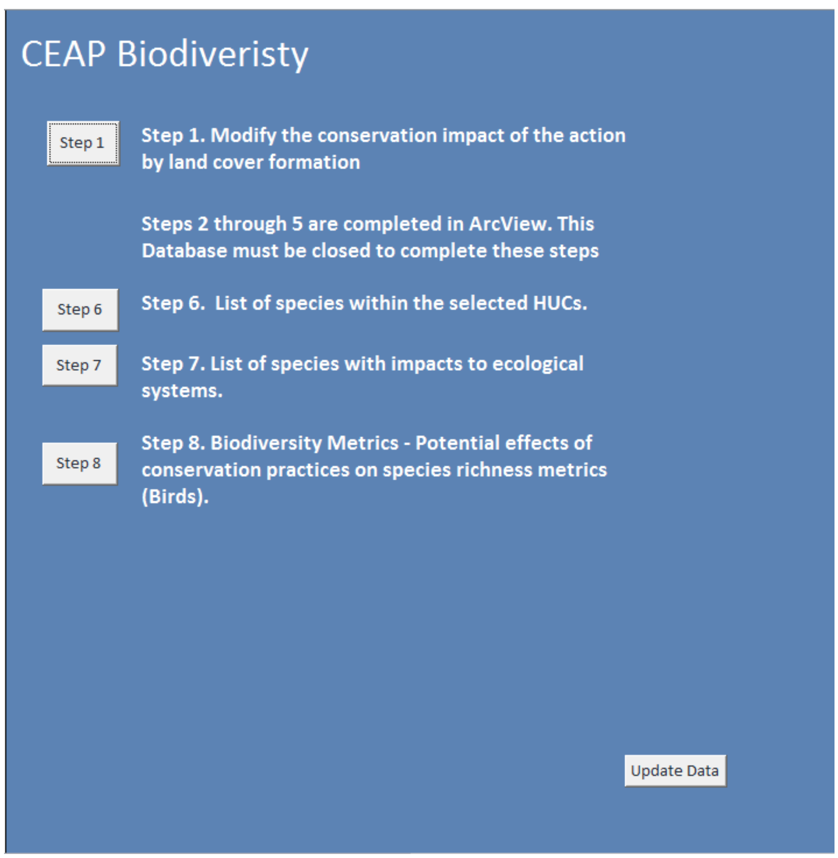
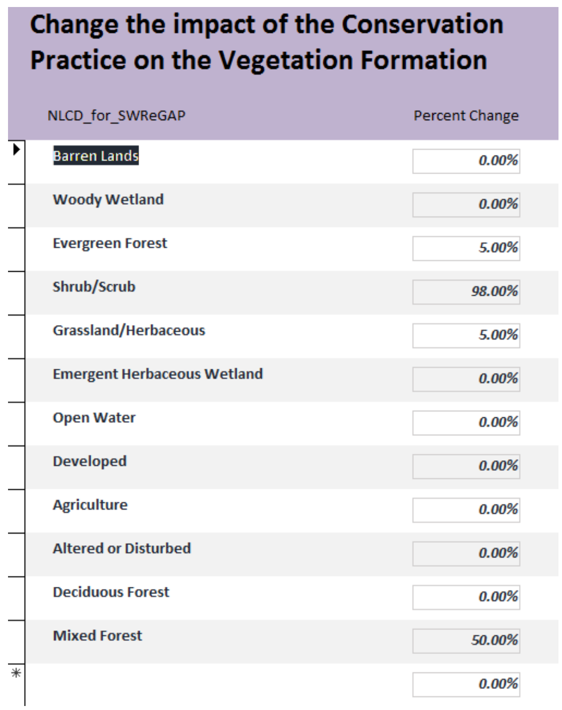


Figure 1. CEAP Biodiversity Database Introduction Form.

Step 1. Modify the conservation impact of the action by land cover formation.

This form allows the user to change the effect of a conservation practice on the vegetation formation. For simplicity, we used the formation and a crosswalk from formation to ecological system. The values of the effect are carried through the calculation. After final analysis tables are generated, the user can make adjustments for specific ecological system types.



Change the impact of the Conservation Practice on the Vegetation Formation

NLCD_for_SWReGAP	Percent Change
Barren Lands	0.00%
Woody Wetland	0.00%
Evergreen Forest	5.00%
Shrub/Scrub	98.00%
Grassland/Herbaceous	5.00%
Emergent Herbaceous Wetland	0.00%
Open Water	0.00%
Developed	0.00%
Agriculture	0.00%
Altered or Disturbed	0.00%
Deciduous Forest	0.00%
Mixed Forest	50.00%
	0.00%

Figure 2. Database form to change Conservation Practice effect.

Steps 2 through 5 are completed in ArcView. This Database must be closed to complete these steps.

IMPORTANT: Close CEAP.mdb Database. Failure to do so, will cause an error in the ArcGIS Models.

The next step is to open the CEAP_Biodiversity.mxd ArcGIS Project. The toolbox CEAP_Biodiversity contains 3 models. Both models start the same process of identifying the polygon (HUCs) and then running calculations and merging tables (see specifics below).

- CEAP Species (Final) - identifies the polygon, land cover within the polygon, and species associated with that land cover.
- CEAP Biodiversity Metrics – identifies the land cover and species richness statistics for a given biodiversity metric within the polygon.

Step 2 - CEAP Species (Final)

The model selects polygons using the lasso tool. This tool highlights any polygon included within the selected area. The model will then dissolve the polygons to identify on single Polygon (A) and use the 12-digit HUC number from the lowest numerical polygon. The model will then add a field for area and creates a value of 1 (area/area). This provides a method to standardize all polygon tabulate areas.

The area of each land cover type within the polygon (A) is then calculated using tabulate area. The resultant table identifies the area of each ecological system modeled within the polygon in square meters.

The land cover table with area is then joined to the table TBL_EcologicalSystems_list_short_long. This table identifies the dominant land cover type that 3 conservation practices may change over the course of 5 years and 10 years. This table is then joined to a table that identifies the potential impact of the conservation practice on the land cover crosswalked to the formation level (TBL_ConservationPracticeImpactbyFormations).

This table is then converted to a .dbf file for further model use and to a table within the database for database use. Fields are then added to the dbf file for current area in hectares (Area_HA), future area in hectares (Future_A), and difference between current area and future area (Area_Delta). Area_HA is calculated by dividing area in square meters by 10,000. Future_A is calculated by multiplyin the Area_HA by (1-% effect) from table TBL_ConservationPracticeImpactbyFormations). Area_Delta is calculated by subtracting Future_A from Area_HA. This table is then exported to an Excel file in the /output directory (TBL_LC_Calc.xls) and imported into database as (tmp_LandCover_Species_Analysis_1).

This table is then joined to the table of land cover associations for each species modeled in the SWReGAP project. An excel file is exported in the /output directory (TBL_Species_x_association.xls). The table is also exported to the database.

The table is then filtered to remove those habitat types that are not present within the area. The table is then converted to a dbf and then to an Excel file in the /output directory (TBL_Species_Landcover_Effect.xls).

Step 3 - CEAP Biodiversity Metrics Model

The model selects polygons using the lasso tool. This tool highlights any polygon included within the selected area. The model will then dissolve the polygons to identify on single Polygon (A) and use the 12-digit HUC number from the lowest numerical polygon. The model will then add a field for area and creates a value of 1 (area/area). This provides a method to standardize all polygon tabulate areas.

The area of each land cover type within the polygon (A) is then calculated using tabulate area. The resultant table identifies the area of each ecological system modeled within the polygon in square meters.

The land cover dataset is then extracted by the mask of Polygon A. This extracted spatial dataset is then used to calculate zonal statistics by land cover type and bird species richness (depending on the bird metric selected). Statistics calculated include the mean, standard deviation, and median of species richness for each land cover type. Additionally a zonal statistic grid is created. The zonal statistics table is then joined to the land cover area table. An excel file is created of this data for further use (TBL_landover_poly_bio_metrics.xls) in the /output directory.

The land cover table with area and richness zonal statistics are then joined to the table TBL_EcologicalSystems_list_short_long. This table identifies the dominant land cover type that 3 conservation practices may change over the course of 5 years and 10 years. This table is then joined to a table that identifies the potential impact of the conservation practice on the land cover crosswalked to the formation level (TBL_ConservationPracticeImpactbyFormations).

This table is then converted to a .dbf file for further model use and to a table within the database for database use. Fields are then added to the dbf file for current area in hectares (Area_HA), future area in hectares (Future_A), and difference between current area and future area (Area_Delta). Area_HA is calculated by dividing area in square meters by 10,000. Future_A is calculated by multiplying the Area_HA by (1-% effect) from table TBL_ConservationPracticeImpactbyFormations). Area_Delta is calculated by subtracting Future_A from Area_HA.

This table is then exported to the /output directory as an Excel file (TBL_biometrics_impacts.xls) and imported into database as (TBL_Biodiversity_metrics).

Step 4 Combined with Step 2

Step 5 Combined with Step 3

Step 6. List of species within the selected HUCs. (Open Database)

The list of species in Step 2 identifies species associated with ecological systems, but can include species that are associated with those ecological systems but with ranges not included in the study area. This dataset identifies those species that have a range within the polygon selected.

QRY_Species_List_in_Selected_Polgons

FirstOfITIScode	SWReGAPCName	SWReGAPSName	AttributeCat	WHRCatID	HUC	ShortTitle	Description
3	ARIZONA MYOTIS	Myotis occultus	13030201	18	13030201	k13	Known or probable occurrence, breeding, summering
173429	COUCH'S SPADEFOOT	Scaphiopus couchii	13030201	29	13030201	k34	Known or probable occurrence, breeding and non-breeding
173441	BULLFROG	Rana catesbeiana	13030201	29	13030201	k34	Known or probable occurrence, breeding and non-breeding
173451	CHIRICAHUA LEOPARD FROG	Rana chiricahuensis	13030201	29	13030201	k34	Known or probable occurrence, breeding and non-breeding
173462	YAVAPAI LEOPARD FROG	Rana yavapaiensis	13030201	49	13030201	p34	Potential occurrence, breeding and non-breeding, winter a
173468	GREAT PLAINS NARROWMOUTH TOAD	Gastrophryne olivacea	13030201	29	13030201	k34	Known or probable occurrence, breeding and non-breeding
173476	WOODHOUSE'S TOAD	Bufo woodhousii	13030201	29	13030201	k34	Known or probable occurrence, breeding and non-breeding
173481	COLORADO RIVER TOAD	Bufo alvarius	13030201	49	13030201	p34	Potential occurrence, breeding and non-breeding, winter a
173484	GREAT PLAINS TOAD	Bufo cognatus	13030201	29	13030201	k34	Known or probable occurrence, breeding and non-breeding
173485	GREEN TOAD	Bufo debilis	13030201	29	13030201	k34	Known or probable occurrence, breeding and non-breeding
173491	RED-SPOTTED TOAD	Bufo punctatus	13030201	29	13030201	k34	Known or probable occurrence, breeding and non-breeding
173510	CANYON TREEFROG	Hyla arenicolor	13030201	29	13030201	k34	Known or probable occurrence, breeding and non-breeding
173592	TIGER SALAMANDER	Ambystoma tigrinum	13030201	29	13030201	k34	Known or probable occurrence, breeding and non-breeding
173766	YELLOW MUD TURTLE	Kinosternon flavescens	13030201	29	13030201	k34	Known or probable occurrence, breeding and non-breeding
173768	SONORAN MUD TURTLE	Kinosternon sonoriense	13030201	49	13030201	p34	Potential occurrence, breeding and non-breeding, winter a
173778	ORNATE BOX TURTLE	Terrapene ornata	13030201	29	13030201	k34	Known or probable occurrence, breeding and non-breeding
173865	EASTERN FENCE LIZARD	Sceloporus undulatus	13030201	29	13030201	k34	Known or probable occurrence, breeding and non-breeding
173868	CLARK'S SPINY LIZARD	Sceloporus clarkii	13030201	29	13030201	k34	Known or probable occurrence, breeding and non-breeding
173872	YARROW'S SPINY LIZARD	Sceloporus jarrovii	13030201	29	13030201	k34	Known or probable occurrence, breeding and non-breeding
173873	DESERT SPINY LIZARD	Sceloporus magister	13030201	29	13030201	k34	Known or probable occurrence, breeding and non-breeding
173878	CREVICE SPINY LIZARD	Sceloporus poinsettii	13030201	29	13030201	k34	Known or probable occurrence, breeding and non-breeding
173879	BUNCH GRASS LIZARD	Sceloporus scalaris	13030201	29	13030201	k34	Known or probable occurrence, breeding and non-breeding
173881	STRIPED PLATEAU LIZARD	Sceloporus virgatus	13030201	29	13030201	k34	Known or probable occurrence, breeding and non-breeding
173910	GREATER EARLESS LIZARD	Cophosaurus texanus	13030201	29	13030201	k34	Known or probable occurrence, breeding and non-breeding
173912	COLLARED LIZARD	Crotaphytus collaris	13030201	29	13030201	k34	Known or probable occurrence, breeding and non-breeding
173924	LONG-NOSED LEOPARD LIZARD	Gambelia wislizenii	13030201	29	13030201	k34	Known or probable occurrence, breeding and non-breeding
173927	LESSER EARLESS LIZARD	Holbrookia maculata	13030201	29	13030201	k34	Known or probable occurrence, breeding and non-breeding
173938	TEXAS HORNED LIZARD	Phrynosoma cornutum	13030201	29	13030201	k34	Known or probable occurrence, breeding and non-breeding

Figure 3. Table created in Step 6 of Database.

Step 7. List of species with impacts to ecological systems.

This table identifies the species that are associated with ecological systems and with ranges within the polygon selected (combined Step 2 and Step 6). The table provides the species, each ecological system the species is associated with, and the current amount of habitat available (Area_HA) and the predicted future amount of area (Future_A). Also included is the change from current to future area (Area_Delta). For this analysis habitat is not added to ecosystems that benefit from the conservation practice. Only those ecological systems that are impacted negatively from current to the future are provided.

Qry_Species_by_Land_cover_and_impacts

FirstOfITIScode	SWReGAPCName	SWReGAPSName	ShortTitle	EcoSysName	Area_HA	Future_A	Area_Delta	
178189	ACORN WOODPECKER	Melanerpes formicivorus	k34	Madrean Pine-Oak Forest and Woodland	5.67	5.386	-0.284	Known or probable occurrer
178189	ACORN WOODPECKER	Melanerpes formicivorus	k34	North American Warm Desert Lower Montane Riparian Wooc	22.5	22.5	0	Known or probable occurrer
180012	ALLEN'S BIG-EARED BAT	Idionycteris phyllotis	k34	Madrean Pinyon-Juniper Woodland	1063.53	1010.353	-53.177	Known or probable occurrer
180012	ALLEN'S BIG-EARED BAT	Idionycteris phyllotis	k34	North American Warm Desert Wash	1300.86	1300.86	0	Known or probable occurrer
180012	ALLEN'S BIG-EARED BAT	Idionycteris phyllotis	k34	Madrean Pine-Oak Forest and Woodland	5.67	5.386	-0.284	Known or probable occurrer
180012	ALLEN'S BIG-EARED BAT	Idionycteris phyllotis	k34	Madrean Encinal	4461.57	4238.491	-223.079	Known or probable occurrer
180012	ALLEN'S BIG-EARED BAT	Idionycteris phyllotis	k34	Apacherian-Chihuahuan Mesquite Upland Scrub	1645.38	32.908	-1612.472	Known or probable occurrer
180012	ALLEN'S BIG-EARED BAT	Idionycteris phyllotis	k34	Chihuahuan Mixed Desert and Thorn Scrub	36913.77	738.275	-36000	Known or probable occurrer
180012	ALLEN'S BIG-EARED BAT	Idionycteris phyllotis	k34	North American Warm Desert Lower Montane Riparian Wooc	22.5	22.5	0	Known or probable occurrer
180012	ALLEN'S BIG-EARED BAT	Idionycteris phyllotis	k34	Southern Rocky Mountain Pinyon-Juniper Woodland	1.17	1.111	-0.059	Known or probable occurrer
176721	AMERICAN AVOCET	Recurvirostra americana	k21	Chihuahuan Mixed Salt Desert Scrub	3442.32	68.846	-3373.474	Known or probable occurrer
176721	AMERICAN AVOCET	Recurvirostra americana	k21	Chihuahuan Mixed Salt Desert Scrub	3442.32	68.846	-3373.474	Known or probable occurrer
176721	AMERICAN AVOCET	Recurvirostra americana	k21	Chihuahuan Mixed Salt Desert Scrub	3442.32	68.846	-3373.474	Known or probable occurrer
176721	AMERICAN AVOCET	Recurvirostra americana	k21	Chihuahuan Mixed Salt Desert Scrub	3442.32	68.846	-3373.474	Known or probable occurrer
176721	AMERICAN AVOCET	Recurvirostra americana	k21	Open Water	24.93	24.93	0	Known or probable occurrer
176721	AMERICAN AVOCET	Recurvirostra americana	k21	Open Water	24.93	24.93	0	Known or probable occurrer
174856	AMERICAN BITTERN	Botaurus lentiginosus	k22	Open Water	24.93	24.93	0	Known or probable occurrer
174856	AMERICAN BITTERN	Botaurus lentiginosus	p13	Open Water	24.93	24.93	0	Potential occurrence, breec
174856	AMERICAN BITTERN	Botaurus lentiginosus	k22	Open Water	24.93	24.93	0	Known or probable occurrer
174856	AMERICAN BITTERN	Botaurus lentiginosus	p13	Open Water	24.93	24.93	0	Potential occurrence, breec
174856	AMERICAN BITTERN	Botaurus lentiginosus	k22	Open Water	24.93	24.93	0	Known or probable occurrer
174856	AMERICAN BITTERN	Botaurus lentiginosus	p13	Open Water	24.93	24.93	0	Potential occurrence, breec
174856	AMERICAN BITTERN	Botaurus lentiginosus	k22	Open Water	24.93	24.93	0	Known or probable occurrer
174856	AMERICAN BITTERN	Botaurus lentiginosus	p13	Open Water	24.93	24.93	0	Potential occurrence, breec
176292	AMERICAN COOT	Fulica americana	k22	North American Warm Desert Lower Montane Riparian Wooc	22.5	22.5	0	Known or probable occurrer
176292	AMERICAN COOT	Fulica americana	k22	North American Warm Desert Lower Montane Riparian Wooc	22.5	22.5	0	Known or probable occurrer
176292	AMERICAN COOT	Fulica americana	k22	Open Water	24.93	24.93	0	Known or probable occurrer
176292	AMERICAN COOT	Fulica americana	k22	Open Water	24.93	24.93	0	Known or probable occurrer
176292	AMERICAN COOT	Fulica americana	k22	Agriculture	2317.77	2317.77	0	Known or probable occurrer
176292	AMERICAN COOT	Fulica americana	k22	Agriculture	2317.77	2317.77	0	Known or probable occurrer
176292	AMERICAN COOT	Fulica americana	k22	North American Warm Desert Lower Montane Riparian Wooc	22.5	22.5	0	Known or probable occurrer
176292	AMERICAN COOT	Fulica americana	k22	North American Warm Desert Lower Montane Riparian Wooc	22.5	22.5	0	Known or probable occurrer
179236	AMERICAN GOLDFINCH	Carduelis tristis	k22	North American Warm Desert Wash	1300.86	1300.86	0	Known or probable occurrer

Figure 4. Table created in Step 7.

Step 8. Biodiversity Metrics - Potential effects of conservation practices on species richness metrics (Birds).

This is a filtered table similar to TBL_biometrics_impacts.xls. **This file will change each time you run the model is Step 3.** This table has the ecological system (code and name), NLCD formation crosswalk value, statistics for the biodiversity metrics analyzed (mean and standard deviation), effect of conservation practice on system (P-Change), the current area (Area_HA), the future area (Future_A) and the change in HA (Area_Delta).

QRY_Biodiversity_Metric_Effects

CODE	EcoSysName	NLCD_for_S	MEAN	STD	P_Change	Area_HA	Future_A	Area_Delta
S068	Chihuahuan Stabilized Coppice Dune and Sand Flat Scrub	Shrub/Scrub	17.2719656385	0.55673909194	0.98	3813.57	76.271	-3737.299
S057	Mogollon Chaparral	Shrub/Scrub	61.098786103	1.21275599149	0.98	860.04	17.201	-842.839
S058	Apacherian-Chihuahuan Mesquite Upland Scrub	Shrub/Scrub	89.5843999562	1.18098263771	0.98	1645.38	32.908	-1612.472
S061	Chihuahuan Succulent Desert Scrub	Shrub/Scrub	49.9746835443	0.69569272803	0.98	49.77	0.995	-48.775
S062	Chihuahuan Mixed Desert and Thorn Scrub	Shrub/Scrub	66.2065838846	1.04683876336	0.98	36913.77	738.275	-36000
S116	Chihuahuan Mixed Salt Desert Scrub	Shrub/Scrub	42.1241372098	1.09313946674	0.98	3442.32	68.846	-3373.474
S113	Chihuahuan Sandy Plains Semi-Desert Grassland	Grassland/Herbaceous	44.4507964865	0.74658552207	0.05	1209.06	1148.607	-60.453
S112	Madrean Pinyon-Juniper Woodland	Evergreen Forest	105.787594144	2.34357201823	0.05	1063.53	1010.353	-53.177
S035	Madrean Pine-Oak Forest and Woodland	Evergreen Forest	122.920634921	1.64559621368	0.05	5.67	5.386	-0.284
S115	Madrean Juniper Savanna	Grassland/Herbaceous	66.1402958315	1.1865614255	0.05	401.58	381.501	-20.079
S038	Southern Rocky Mountain Pinyon-Juniper Woodland	Evergreen Forest	97.3076923077	0.72160242459	0.05	1.17	1.111	-0.059
S077	Apacherian-Chihuahuan Semi-Desert Grassland and Steppe	Grassland/Herbaceous	88.6019843599	1.57590316925	0.05	89711.55	85225.973	-4485.577
S051	Madrean Encinal	Evergreen Forest	73.3945897969	1.53470617332	0.05	4461.57	4238.491	-223.079
N11	Open Water	Open Water	29.9855595668	5.17001289661	0	24.93	24.93	0
S019	North American Warm Desert Volcanic Rockland	Barren Lands	8.07976497819	0.29424138321	0	1010.97	1010.97	0
S020	North American Warm Desert Wash	Woody Wetland	57.4639546146	0.8866396199	0	1300.86	1300.86	0
S021	North American Warm Desert Pavement	Barren Lands	8.08782681758	0.64098367177	0	1820.97	1820.97	0
N21	Developed, Open Space - Low Intensity	Developed	68	0	0	2.61	2.61	0
S016	North American Warm Desert Bedrock Cliff and Outcrop	Barren Lands	30.6310107949	0.97729878416	0	183.42	183.42	0
N80	Agriculture	Agriculture	88.1475167942	0.78837965995	0	2317.77	2317.77	0
S094	North American Warm Desert Lower Montane Riparian Woodland and Shrubland	Woody Wetland	124.72	1.84434270134	0	22.5	22.5	0
S098	North American Warm Desert Riparian Mesquite Bosque	Woody Wetland	99.1842105263	0.45045375707	0	3.42	3.42	0
N22	Developed, Medium - High Intensity	Developed	40.290879017	0.84460479596	0	380.88	380.88	0

Figure 5. Table created in Step 8.

Appendix C. Ecological Context MS Download Link

Link to current Ecological Context Manuscript
http://case.nmsu.edu/case/Projects/CEAP/Documents/ Appendix_C.pdf

Appendix D. Fine Scaled Thesis and Manuscript Download Link

Link to current Fine Scaled Thesis
http://case.nmsu.edu/case/Projects/CEAP/Documents/ Appendix_D_ms.pdf
Link to current Fine Scaled Manuscript
http://case.nmsu.edu/case/Projects/CEAP/Documents/Appendix_D_thesis.pdf

Appendix E. Model and Data Files Download Link

Link to current project data
http://case.nmsu.edu/case/Projects/CEAP/Data/CEAP_Data.html