A CLIMATE CHANGE VULNERABILITY ASSESSMENT FOR BIODIVERSITY IN NEW MEXICO, PART I:

Implications of Recent Climate Change on Conservation Priorities in New Mexico

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THE NATURE CONSERVANCY IN NEW MEXICO

COVER PHOTOS COURTESY OF CRAIG ALLEN, USGS:

TOP: PINON PINE MORTALITY IN THE JEMEZ MOUNTAINS, 2002

BOTTOM: PINON PINE MORTALITY WITHOUT NEEDLES AT SAME SITE, 2004

EXECUTIVE SUMMARY

There is now strong scientific consensus that human-induced climate change is affecting the earth's species and ecological systems. However, there is little regional information on climate impacts and vulnerability of species and ecosystems to guide conservation practitioners and managers in planning for and adapting management practices to climate change. To address this need, the Nature Conservancy in New Mexico (TNC-NM) has initiated a state-wide climate change vulnerability assessment. This report addresses the implications of recent changes in climate on previously-identified conservation priorities in New Mexico. Key findings include:

- Over 95% of New Mexico has experienced mean temperature increases of varying magnitude; warming has been greatest in southwestern, central and northwestern parts of the state, especially in the Jemez Mountains. While no change or slight cooling has occurred in parts of several mountainous habitats surrounding the Gila River headwaters, the Zuni Mountains, and the Sangre de Cristo Mountains, other parts of these ranges have experienced increasing trends in either minimum or maximum temperatures from 1970-2006.

- Precipitation changes have been more variable than temperature with 54% of the state tending toward wetter conditions, 41% drier conditions, and 5% showing no discernable change in precipitation between 1991 and 2005 compared to a 30-year baseline (1961-1990). This also holds true for the recent drought (2000-2005) with 24% of the state experiencing wetter conditions, 71% drier conditions, and 5% of the state showing no change.

- Most of New Mexico's mid- to high-elevation forests and woodlands have experienced consistently warmer and drier conditions or greater variability in temperature and precipitation from 1991 to 2005. Should this continue, as future climate projections suggest, these habitats may be most susceptible or vulnerable to ongoing climate change.

- In contrast, most grasslands experienced warmer-wetter conditions between 1991 and 2005, especially Great Plains grasslands in eastern New Mexico. Even during the recent drought, a greater proportion of grasslands experienced wetter and less variable conditions compared to other habitat types. If these trends continue, grasslands may be less vulnerable to ongoing climate change.

- Eleven high-elevation conservation areas, as identified by TNC-NM and by the New Mexico Department of Game and Fish in their state wildlife action plan, may be potentially most vulnerable to climate change due to their large number of drought-sensitive species and *the magnitude of their recent climate exposure* (i.e., warmer-drier conditions or greater variability in temperature and precipitation). Three areas may be particularly vulnerable: the Sierra San Luis/Peloncillo Mountains, the Jemez Mountains, and the Southern Sangre de Cristo Mountains.

- In contrast, 10 lower-elevation conservation sites that are also rich in drought-sensitive species experienced lower climate exposure (i.e., smaller increases in temperature coupled with small decreases in precipitation, no change or increased precipitation). These include: Bottomless Lakes, Bitter Lake and Blue River/Eagle Creek—all riparian sites rich in native fish species. Other sites with fewer or no drought sensitive species experienced even lower climate impacts from 1991 to 2005. These include the Western Plains of San Augustin, Salt Basin/Northern Brokeoff Mountains, Middle Pecos River, Rio Agua Negra, Salado Creek, Grulla National Wildlife Refuge, and Pastura Grasslands—all riparian or grasslands sites and all but two located in eastern New Mexico. Should recent trends continue, these sites may be among the least vulnerable to climate change in the state.

- We compiled 48 cases of recently observed ecological changes that may be linked to climate change from across New Mexico and the southwestern U.S. Over half involved population declines, with shifts in species' geographical distribution accounting for nearly a quarter of the remaining examples. Changes in the timing of life history events, species adaptations, and increases in invasive species comprised the remainder. Most of these cases were from higher-elevation conservation sites, such as the Jemez and Sacramento Mountains, where recent climate exposure has been particularly extreme (i.e., warmer-drier conditions).

Using this Information:
Our state-wide assessment of recent climate change enables practitioners and managers to make better informed decisions and to take action in the near-term by identifying the potential vulnerability of habitat types, priority conservation sites and species to climate change. Our approach not only provides a new perspective and information for planning and management, it also diminishes the focus on issues of uncertainty that are implicit to projections of future climate.

Climate change is likely to exacerbate the effects of natural and altered disturbance regimes, including wildfire, insect outbreaks, flooding and erosion, across all New Mexico's habitat types and may prompt abrupt ecological changes. This is particularly true in ecosystems such as grasslands, riparian areas, and forests where the effects of past management and land use change are substantial. Increased research and monitoring of these conservation priorities will be critical to documenting ecological responses to climate change at regional scales so that conservation practitioners and resource managers can incorporate this information into their planning and management processes.

Two follow-up studies will build on our results by incorporating the effects of recent climate changes on New Mexico's watersheds and by adding future climate change predictions. In doing so, we will strengthen our current understanding of the vulnerability of native species and ecosystems to ongoing climate change. This work will also identify pragmatic adaptation strategies that can be implemented by natural resource managers throughout the region to enhance the resilience of New Mexico's biodiversity and ecosystem services.

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Introduction

STATEMENT OF THE PROBLEM

Conservation practitioners, planners, and land and water managers are just beginning to consider how to anticipate and respond to the complexity of climate change (Smit et al. 2000, U.S.GAO 2007). Recent progress has been made with the recognition that current and future protected areas will play a pivotal role to conservation under climate change (Hannah et al. 2007) and with the preliminary identification of adaptation approaches that could be implemented across natural resource management systems in the U.S. (Hansen & Biringer 2003, United States CCSP SAP 4.4). However, there is still a paucity of practical information and tools for incorporating climate change into on-the-ground conservation planning, management, and action at regional and local scales.

In this report, we begin to address this information need through an analysis of recent changes in New Mexico's climate. We do this from the perspective of conservation priorities identified in the New Mexico Department of Game and Fish's Comprehensive Wildlife Conservation Strategy and The Nature Conservancy's ecoregional assessments.

The Nature Conservancy (TNC) has conducted comprehensive ecological analyses based on Bailey's (1995) ecoregions. Ecoregions are large areas of land and water characterized by distinct plant and animal communities, similar landforms, and environmental conditions such as climate. On the order of tens of millions of acres, they are useful units for evaluating the conservation requirements of biological diversity because they capture large proportions, if not entire distributions, of major ecological systems and individual species (Marshall et al. 2006). The goal of these assessments is to identify a network, or "portfolio," of conservation areas that will maintain the ecoregion's biodiversity over the long-term (Groves 2003, The Nature Conservancy 2000). While TNC's ecoregional analyses integrate data on human activities that affect the viability of native species, most only superficially address the impact of climate change. Seven ecoregions overlap the state of New Mexico: the Colorado Plateau, Southern Rocky Mountains, Arizona-New Mexico Mountains, Chihuahuan Desert, Southern Shortgrass Prairie, Central Shortgrass Prairie, and Apache Highlands (Fig. 1).

The New Mexico Department of Game and Fish's (NMDGF) Comprehensive Wildlife Conservation Strategy (CWCS) is a conservation action-oriented state wildlife plan that uses TNC's ecoregional framework to organize and describe terrestrial conservation priorities or "key areas for conservation action" (NMDGF 2006). These areas were identified based on four criteria: presence of key habitats, presence of species of greatest conservation need (SGCN), influence of factors that may have negative effects on habitats, and lack of long-term management plans or legal protection status. The CWCS did not explicitly consider climate change in its identification of key areas but recognized the need to understand its impact on the state's biological resources.

The goals of this study are twofold: first, to begin to understand the impact of recent climate change on the state's biological resources including major habitat types, ecoregions, conservation priorities and species; and second, to demonstrate that this retrospective approach can facilitate conservation planning and management in the shorter-term while we begin to tackle the challenges of climate change in the longer-term. This approach diminishes the focus on issues of uncertainty that are implicit to modeled projections of future climate change. We specifically ask:

1. How has New Mexico's climate changed since the mid-20th century?

2. Which major habitat types, ecoregions, and conservation areas have experienced the most and least change?

3. Which climate (drought) sensitive conservation target species have been most and least exposed to these changes? and

4. Are there existing published studies, unpublished data and expert observations that link recent ecological changes in New Mexico and the southwestern U.S. to climate change?

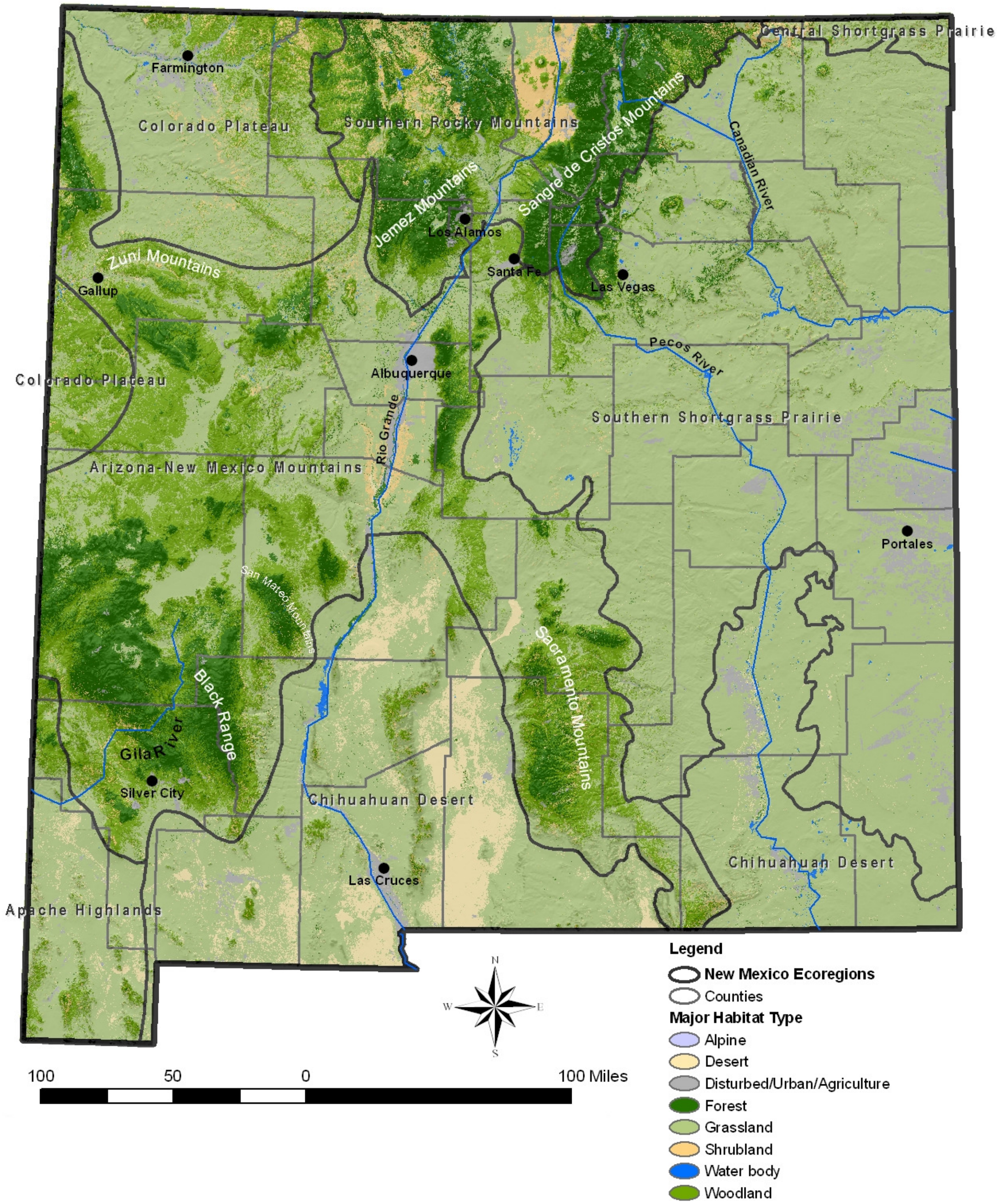

FIGURE 1. Thematic map of New Mexico, including the seven ecoregions that cross the state and major habitat types (SWreGAP 2004).

BACKGROUND

Recent Trends in Global and North American Climate

The earth's surface has warmed by an average of 0.74^{o}C (1.3^{o}F) during the 20th century, according to the world's foremost scientific authority on climate change, the Intergovernmental Panel on Climate Change (IPCC). Largely a consequence of anthropogenic carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions arising from a fossil fuel-based economy since the Industrial Revolution, current GHG concentrations in the earth's atmosphere have risen to a level (380 parts per million) that exceeds the natural variability of the past 650,000 years (180-300 parts per million) (Solomon 2007). Warming temperatures of the past century have been linked to the rapid melt of polar ice sheets and to sea level rise (Overpeck et al. 2006). Long-term trends in global precipitation have shown significant heterogeneity over the 20th century, but have tended toward more extreme events such as severe droughts and floods (Solomon 2007). Based on 20th century observations and improved predictive modeling capabilities, there is 90% confidence that fewer cold days and nights, more frequent heat waves, and heavy precipitation events will define the climate of the 21st century (Solomon 2007).

Across North America, mean annual temperatures have increased rapidly during the second half of the 20th and early part of 21st centuries, with the most dramatic warming in Alaska and northwestern Canada (Parry et al. 2007). The greatest changes in temperature have occurred during winter and spring, with daily minimum temperatures increasing more than daily maximum temperatures (Karl et al. 2005, Vincent & Mekis 2006). The length of North America's vegetation growing season has increased by an average of 2 days/decade since 1950, primarily as a function of earlier springtime warming (Bonsal et al. 2001, Easterling 2002). Annual precipitation increased across most of the continent during the 20th century, with the heaviest precipitation events occurring in the last decade of the century (Parry et al. 2007). Accordingly, net primary production has increased in the U.S., with most increases occurring in the central grasslands and croplands ((Boisvenue & Running 2006, Parry et al. 2007).

Recent Climate Trends in New Mexico and the Southwest

Mean annual temperatures have risen across New Mexico and the southwestern U.S. since the early 20th century (Shepperd et al. 2002). Warming trends in the southwestern U.S. have exceeded the global averages by nearly 50% since the 1970's (Gutzler & Garfin 2006). In New Mexico, mean annual temperatures increased 0.6^{o}F per decade, with a 1.8^{o}F overall change since 1976 when averaged across the state's eight climate divisions (Lenart & Crawford 2007). Mean winter temperatures are most responsible for this rise, yet springtime temperatures have also risen rapidly (Gutzler & Garfin 2006). Precipitation, on average, has increased slightly across the state since the mid-1970s. However, the long term tree-ring record shows severe droughts and multi-decadal megadroughts to be part of the natural climate variability of the southwestern U.S. (Grissimo-Meyer & Swetnam 2000, Cook et al. 2004, Woodhouse 2004). During the 20th

and early 21st centuries, shorter-term yet severe droughts occurred in the 1950's and in the early 2000's.

Ecological Effects of Climate Change

Temperature and precipitation strongly influence the abundance and distribution of the earth's biota (Brown & Gibson 1983, Woodward 1987, Stephenson 1990). Throughout the earth's history, organisms have had to respond to gradual or abrupt climate changes, leading to changes in community assemblages, local extirpations, extinctions, and speciation events (Davis 1986, Overpeck et al. 1991, Davis et al. 2005). The glacial-interglacial periods of the past 700,000 years define the range of natural climate variability associated with most modern biota (Overpeck et al. 2005). Growing scientific consensus, however, indicates that recent human-induced rapid climate change will continue to expose the globe's biodiversity to climate regimes outside this range (Jackson & Overpeck 2000, McCarty 2001, Scheffer et al. 2001, Overpeck et al. 2003, Hannah et al. 2005). This will compound existing threats to natural systems and accelerate the rate at which habitats are degraded and species are lost (Walther et al 2002, Hannah et al. 2002, McLaughlin et al. 2002, Thomas et al. 2004).

Recent studies have quantified the current effects of climate change on species, ecosystems, and ecosystem services globally (Parmesan & Yohe 2003, Millennium Ecosystem Assessment 2004). These effects include changes in the timing and synchronization of seasonal plant and animal life history events (Brown et al. 1999, Root et al. 2005, Parmesan 2006, Parmesan 2007); declines in species populations (Pounds et al. 2006, Martin 2007); shifts in species distributions (Root et al. 2003, Jetz et al. 2007, LaSorte & Thompson 2007, McCain 2007); appearance of new pests and pathogens (Brooks & Hoberg 2007); increased invasions by exotics (Walther et al. 2002, Geiger & McPherson 2005, Gitlin & Whitham 2007, Ward & Masters 2007); appearance of vegetation dieback (Breshears et al. 2005, van Mantgem & Stephenson 2007); and community-ecosystem reorganization (Brown et al. 1997, Gitlin et al. 2006, Morgan et al. 2007, Daufresne & Boet 2007). Because many species and ecosystems may not be able to adequately adapt to the rapid and stressful effects of climate change, recent studies suggest widespread extinctions by the mid 21st century (Pounds & Puschendorf 2004, Thomas et al. 2004). The risks are especially profound when coupled with the synergistic effects of land use change (Sala et al. 2000, Hansen et al. 2003, Root et al. 2003). Moreover, the capacity for species and ecosystems to provide critical ecosystem services for humans in current and future generations may also be seriously compromised (Millennium Ecosystem Assessment 2004).

Table 1 provides a summary of climate change effects by major taxonomic group.

Effects on Ecosystems in the Southwest

Drought-stressed forests and woodlands are particularly susceptible to climate change (Dale et al. 2001). Furthermore, wildfires in the western U.S. have become more frequent, intense, and large at least partially due to higher temperatures and reduced soil moisture (Grissino-Mayer et al. 2004, McKenzie et al. 2004, Westerling et al. 2006). Soils denuded of vegetation after severe fire increase the probability of erosion from wind and water, particularly along elevation gradients (Allen 2007). Evidence of this can be viewed in the Jemez Mountains of New Mexico following the catastrophic Cerro Grande wildfire of 2000 (Moody et al. 2007). Drought-stressed forests also are susceptible to large-scale insect outbreaks, such as the bark beetle infestations that contributed to the extensive dieback of southwestern forests during the 1950s and the 2000-2003 extreme drought event (Allen & Breshears 1998, Breshears et al. 2005, Shaw et al. 2005). The most recent dieback, affecting two million acres of ponderosa pine forests and three-and-a-half million acres of piñon-juniper woodlands (Allen pers. comm.), occurred under warmer but slightly wetter conditions than did the 1950's dieback event (Breshears et al. 2005). Short- and long-term effects of forest dieback may include changes in carbon storage and dynamics, runoff and erosion, genetic structure of dominant tree species, surface-atmospheric feedbacks, loss of food sources (e.g. piñon nuts) for many species including humans, forced migration and habitat fragmentation (Breshears et al. 2005, Mueller et al. 2005).

Impacts of climate change on grasslands may include the invasion of woody species as a function of increased CO_2 concentration and a change in seasonal precipitation patterns (Brown et al. 1997, Morgan et al. 2007). Both these factors favor the establishment of vegetation with the C_3 photosynthetic pathway (e.g. woody shrubs) at the expense of C_4 species (e.g. warm season perennial grasses) (Bazzaz and Carlson 1984, Patterson and Flint1990, Johnson et al. 1993). Increased nitrogen deposition in grasslands has also been identified as an effect of global change, typically with negative effects (Baez et al. 2007, Harpole et al.2007). Rising CO_2 levels may also reduce plant growth when combined with other climate change effects (Shaw et al. 2002). While increased woody shrubs, reduced perennial grass cover, changes in net primary productivity, and soil erosion have been observed in semi-arid grasslands of southern New Mexico, few studies implicate climate change as a primary driver due to complex, non-linear interactions associated with grazing, seasonal precipitation, soils, and human development (Peters et al. 2004, Gibbens et al. 2005, Peters et al 2006, Muldavin et al. 2007).

TABLE 1. Overview of climate change effects on major taxonomic groups.

Taxonomic Group	Climate Change Effects	Selected References
Amphibians	Recognized as one of the most vulnerable groups to climate change because of high sensitivity to changes in wetland pond depth, temperature, and pond duration; may exacerbate the spread of chytrid fungus.	Thomas et al. 2004, Pounds et al. 2006, Parmesan 2007
Birds	Range shifts in migratory species by shifting abundances in relation to weather patterns; a recent study shows that over 200 North American species are shifting their winter ranges poleward; non-migratory species may not be able to adapt in-situ; additional effects include earlier breeding, changes in timing of migration & arrivals, changes in breeding performance (egg size, nesting success), and changes in population sizes.	Brown et al. 1995, Inouye et al. 2000, Parmesan et al. 2000, Root et al. 2003, LaSorte & Thompson 2007
Fish & other aquatic species	Considered highly vulnerable to climate change, especially cold water species, with lower stream flows, increased pressure from non-native species, and elevated water temperatures, also linked to lowered oxygen levels, shown to increase fish mortality rates during reproduction and reduce invertebrate abundance and diversity; increased frequency of floods may scour fish nests ("redds"); in species-rich streams the abundance of invertebrates in the spring-time could decline by one-fifth for every degree of temperature rise.	Poff et al.2002, Daufresne & Boet 2007, Sharma et al. 2007, Durance & Ormerod 2007
Insects	Northward and upward shifting distributions of many butterfly species have been documented, with the Edith's checkerspot of California as one of the most recognized examples of this response; pollinators out of synchrony with plant hosts; increases in insect pests in mountainous areas (e.g. pine beetles) and low elevations near urban areas (e.g. mosquitoes).	Parmesan et al. 2000, Brooks & Hoberg 2007
Mammals	Latitudinal & altitudinal range shifts; changes in community composition and biomass as a function of moisture availability and thermal tolerances; hibernators may emerge earlier; small montane mammal species may be indicators of climate change as they tend to be have geographically and genetically isolated populations, especially in the mountains of the southwestern U.S.	McDonald & Brown 1992, Brown et al. 1997, Smith et al. 1998, Inouye et al. 2000, Brown & Ernest 2001, Beever et al. 2003, Ditto & Frey 2007, McCain 2007
Plants	Population declines due to moisture loss, asynchrony in timing of phenological events (e.g. plant-pollinator, changes in hydrologic cycle for riparian tree species), and increased susceptibility of reproductive parts (e.g. buds) to late season frost with earlier springtime emergence; increased competition from invasive plant species that may increase risk of wildfire (e.g. cheat grass invasion).	Parmesan 2006, Bradley et al. 2006, Lambrecht et al. 2007, Memmott et al. 2007
Reptiles	Those with small ranges and limited dispersal abilities are vulnerable; in freshwater turtles, elevated temperature effects may include enhanced juvenile growth rates, earlier age of maturity, and shifts in sex ratios.	Frazer et al. 1993, Janzen 1994, Gibbons et al. 2000

Methods

HISTORICAL CLIMATE & BIODIVERSITY OF THE NEW MEXICO STUDY AREA

Climate variability has always played a role in shaping the vegetation of New Mexico and the southwestern U.S. In fact, the region has experienced a gradual drying trend over the last 70 million years, with tropical savannas of the Upper Cretaceous epoch giving way to dry tropical forest, then to short tree forests, and finally to the woodlands, thorn forests, grasslands and deserts that began to develop during the Miocene epoch, 18 to 20 million years ago (Axelrod 1983). The Pleistocene epoch, however, brought slightly cooler and moister interludes to the region, characterized by vast low elevation coniferous forests some 22,000 years ago. With the beginning of the Holocene epoch 12,000 years ago, the drying trend was once again set into motion giving rise to today's more xeric habitats (Sivinski et al. 1996).

For most of the 20th century mean annual temperatures in New Mexico ranged from 64^{o}F in the extreme southeast to almost 40^{o}F in the high mountains and valleys of the north, with mean maximums ranging from 70 ^{o}F to 90^{o}F and mean minimums ranging from 35^{o}F to 55^{o}F (NOAA 1985). Mean annual precipitation during this time ranged between less than 10 inches in semi-arid regions to more than 20 inches at higher elevations. July and August have tended to be the wettest months, with brief yet intense convective thunderstorms, or "monsoons," bringing at least 30-40% of the year's moisture, with up to an additional 20% falling in the spring and fall. Wintertime frontal activity generated over the Pacific Ocean typically makes up the remaining half of the state's total precipitation. This produces the bimodal distribution characterizing inter-annual precipitation patterns in the southwestern U.S. and northern Mexico. Winter precipitation typically falls as snow (75% or more) in mountainous areas and rain or snow in lower elevations (Shepperd et al. 2002). The El Nino Southern Oscillation (ENSO) strongly influences the periodicity of corresponding wintertime wet-dry cycles in New Mexico and the region, with profound implications for snowpack and stream flow in these semi-arid systems (Molles & Dahm 1990, Dahm & Molles 1992). The Pacific Decadal Oscillation (PDO) and Atlantic Multi-year Oscillation (AMO), two major oceanic fluctuations operating on multi-decadal scales, also influence the regions climate, including enhancement or dampening of the ENSO cycle (Shepperd et al. 2002, Lenart 2007).

As a function of these regional climate patterns, complex topography, geology, and its relatively large size (121, 666 miles^2), New Mexico is rich in biodiversity, containing portions of seven physiographic ecoregional provinces (Bailey 1995). Ranked as having the 4th highest native species richness in the U.S., New Mexico contains at least 3,614 vascular plants, 107 fishes, 26 amphibians, 103 reptiles, 368 birds, and 178 mammals; the number of invertebrate species is unknown, with new species still being identified (Frazier 2007).

DATA ANALYSES

Climate Data

Trends in New Mexico's climate typically are derived from compiling data from the entire state or across the state's eight climate divisions. Because of the region's topographic heterogeneity, this approach does not provide a complete view of the state's recent trends in temperature and precipitation. To address this need, we considered a number of recently available spatially-explicit climate data sets. These data are generated using varying methods of statistically interpolating temperature and precipitation data from a network of historical meteorological stations to points on a grid-based digital map. Most methods do not adequately explain the extreme, complex variations in temperature that occur in mountainous regions (Daly 2006). The PRISM model (Parameter-elevation Regressions on Independent Slopes Model), however, uses point data and a digital elevation model to generate grid-based estimates of monthly and annual temperature, precipitation, and other climatic parameters at a spatial resolution of four kilometers (PRISM Group 2007). An expert-based conceptual framework is then applied to address the spatial scale and pattern of orographic-induced temperature and precipitation to further facilitate the model's performance in capturing climate patterns in areas with mountainous terrain (Daly 2006). Point data estimates of monthly temperature and precipitation used in PRISM originate from the following meteorological station data sources: National Weather Service Cooperative (COOP stations), Natural Resources Conservation Service (SNOTEL sites), and local networks. Finally, to develop more complete station data sets, statistically in-filled missing monthly data were generated by the National Center for Atmospheric Research (PRISM Group 2007). Maps of the spatial locations of the meteorological stations used in producing the interpolated datasets are available at the PRISM website (*cf.* reference section). All spatial analyses described in the present study are based on these temperature and precipitation data sets.

Generation of Climate Change Maps

To analyze recent changes in New Mexico's climate we first selected a baseline, or reference, climate period of 1961-1990. The use of a baseline from the first half of the century may have provided a more comprehensive view of recent climate departures because it would include a broader spectrum of patterns associated with the region's natural climate variability. However, we selected this 30-year climatology because: (1) the meteorological data that the PRISM data are based on are less complete and spatially distributed for the first half of the 20^{th} century, (2) NOAA and the IPCC often use this baseline for presenting 20^{th} century climate anomalies and for generating future projections, and (3) the 1961-1990 baseline captures the time just prior to, as well as at the beginning of, a notable temperature trend that is attributed to human-caused global warming (Mann et al. 1998, Cook et al. 2004, Weiss & Overpeck 2005). We generated baseline climatology maps for New Mexico by averaging across annualized PRISM grids for each year in the 30-year time period for mean annual temperature (T*mean*) and mean annual precipitation (PPT*mean*) using the geographical information systems software, ArcGIS (ESRI 2006). Minimum temperature is recognized as playing a key role in the distribution of species, particularly the northern extent of the range (Woodward 1987).

We also calculated the trend in New Mexico's mean minimum and maximum temperature (T*min,* T*max*) for the time period between 1970-2006.

Many researchers have demonstrated that an understanding of extreme events, in addition to trends, is important to fully understand the potential impacts of climate change on biodiversity and ecosystem function (Easterling et al. 2000, Parmesan et al. 2000, Jentsch et al. 2007). To at least partially address this observation, we generated maps of T*mean* and PPT*mean* departures, or anomalies, for two time periods: (1) a fifteen year period (1991-2005) representing late-century trends in climatic changes, and (2) a six-year period (2000-2005) highlighting an extreme drought event that some researchers characterized as "global change-like" with its anomalously high temperatures (Breshears et al. 2005). Climate departure maps were generated by either subtracting (for T*mean*) or dividing (for PPT*mean*) the departure time period values from values for the baseline time period.

For each departure period, we report recent changes in New Mexico's climate by temperature and precipitation and by aggregating the two variables. This resulted in five composite climate change classes: warmer-drier, warmer-wetter, cooler-wetter, cooler-drier, and no change in one or both variables. To visualize composite changes in temperature and precipitation, we devised a mapping classification scheme that captures direction and relative magnitude of change. This approach highlights gradients of bivariate changes (e.g. simultaneous temperature and precipitation departures showing relative magnitude of change), with one class representing no change in one or both variables.

Assessment of New Mexico's Conservation Priorities

We assessed the magnitude of recent climatic changes on conservation priorities identified in The Nature Conservancy's ecoregional assessments for New Mexico and in the NMDGF's Comprehensive Wildlife Conservation Strategy (CWCS 2006) by conducting a series of GIS-based analyses. We evaluated priorities in terms of their level of *exposure* to recent climate departures. In the context of risk assessment, exposure has been defined as the general degree, duration, and/or extent in which a system is in contact with a perturbation (Adger 2006, Gallopin 2006). Magnitude of exposure is often considered a component of vulnerability, as is the sensitivity and adaptive capacity of a species or system (Turner et al. 2003, Schroter et al. 2005). Similarly, the IPCC defines vulnerability as the magnitude of impact or exposure minus the capacity for adaptation (Parry et al. 2007). While we do not specifically address adaptive capacity in this study, we nevertheless presume all units of native biodiversity are likely to be vulnerable to rapid and abrupt climate change on some level, despite adaptive ability (e.g. Sala et al. 2000). This may be especially true for species, ecosystems, or places that have formalized conservation status, given that they were identified at least in part because of specific attributes (e.g. rarity, endemism, etc.) that may render them susceptible to human-induced threats. Here, we describe the level of exposure based on the direction, magnitude, and variation (in standard deviation units) in mean temperature and mean precipitation departures. Variation in mean temperature and precipitation may be critical in determining environmental conditions and, ultimately, in regulating ecological processes (Breshears 2006, Jentsch et al. 2007, Sabo & Post 2008)

Major Habitat Types

We first associated climate departures with spatially explicit landcover data produced by the USGS Southwest Regional GAP Analysis Project (SWReGAP 2004). We then cross-walked landcover classes with a classification of major habitat types that include forest, woodland, grassland, shrubland, riparian, wetland-cienega, and desert (*cf.* Schussman et al. 2006).

Key Conservation Areas by Ecoregion

In a second analysis, we associated recent climate departures with TNC-identified conservation areas and coincident NMDGF's key areas identified in the CWCS (Fig. 2), hereafter referred to as *key conservation areas*. There is agreement between the two systems of conservation priorities, with the exception of an area southeast of the Sacramento Mountains. For each coincident key conservation area we calculated mean values for a series of variables: mean temperature (^{o}C) and precipitation (%) departures and corresponding variation in mean departures (in standard deviation units) for both 1991-2005 and 2000-2005 departure periods, in addition to trend coefficients and corresponding probability values for T_{min} and T_{max} between 1970-2006. It should be noted that several of the smallest key conservation areas occupy geographical areas less than or roughly equal to the resolution of a single PRISM data cell (4 km^2, or 3954 acres).

Generation of Climate Exposure Scores

To summarize each key conservation area's suite of climate variables, we generated a *climate exposure score* based on mean temperature departures, mean precipitation departures, and standard deviations from each departure period. To calculate this score, we first normalized each variable by dividing all values by the maximum value so that the resulting values ranged between 0 and 1. While extreme precipitation events have the potential to induce ecological change as do extreme drought events (Easterling et al. 2000), we nonetheless assumed that species and ecosystems in the western U.S. are more sensitive to moisture stress as a potential pathway to increased insect attack and/or drought-induced mortality (Allen & Breshears 1998, Breshears et al. 2005, 2008). We thus reversed the signs associated with precipitation changes so that declines had positive values and increases had negative values. To generate exposure scores, we summed across the normalized variables from both departure periods and ranked key conservation areas by their overall score. This disproportionally weights variables in the 2000-2005 departure period due to the overlap with the 1991-2005 period. However, we believe this is justified based on the important role extreme climate events can play in shaping ecosystem properties, as did the impact of the 2000-2005 severe drought (Breshears et al. 2005, Jentsch et al. 2007). We assumed that the higher the climate exposure score, the more negative the potential ecological impact or physiological stress on species and ecosystems. We emphasize that this is not intended to be a definitive ranking of vulnerability to climate change. Nonetheless, we suggest that recent exposure to deviations in climate may indicate future susceptibility to climate change, particularly for conservation areas affected by other stressors.

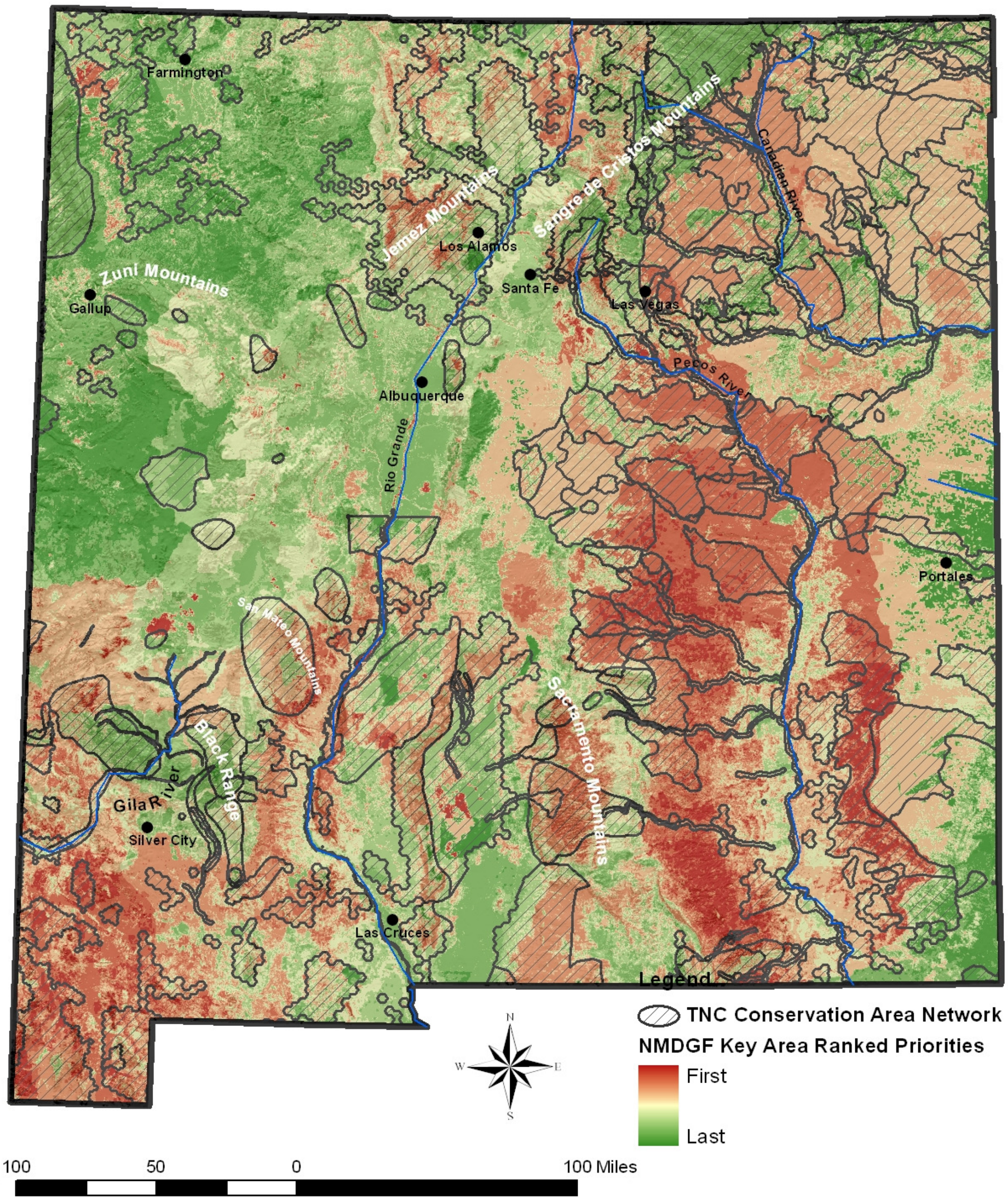

FIGURE 2. Map of *key conservation areas* (hatched) identified in The Nature Conservancy's ecoregional assessment process and coincident key area priorities ranked in the NMDGF's Comprehensive Wildlife Conservation Strategy.

Species Conservation Targets

A third analysis examined the relationship between the climate departure maps and species of conservation importance, or *conservation targets*. Conservation targets can be species, native plant communities, and ecological systems (Marshall et al. 2006). They are the basic unit of analysis that drive TNC's ecoregional assessment process (Groves 2003). We selected a collection of native species from across seven taxonomic groups (amphibian, bird, invertebrate, mammal, plant, reptile, and fish) that meet the following criteria: (1) identified as species of greatest conservation need (SGCNs) in NMDGF's CWCS, (2) identified as conservation targets in TNC's ecoregional analyses for New Mexico, and (3) appeared on a NMDGF-compiled list of species that may be sensitive to drought (Ward et al. 2006). Because these species exhibit drought sensitivity in at least one phase of their life cycle, we presumed that they may be more susceptible to the effects of climate change (Table 1). We acquired geographical point locations ("species element occurrences") for the group of conservation targets from the New Mexico Natural Heritage Program, located at the University of New Mexico (http://nhnm.unm.edu/). Although we cannot be certain that they still represent extant species occurrences, we nevertheless presumed that the point locations represent a potential species population within its typical range. We did not acquire point locations for fish species, but instead used the number of fish targets identified for each conservation area in the original ecoregional assessments. We summarized all location data across key conservation areas by (1) drought-sensitive target diversity (e.g. species richness and taxonomic richness) and (2) exposure of drought-sensitive species occurrences to climate departures aggregated by four *terrestrial* taxonomic groups: birds, mammals, amphibians, and plants.

Climate-Linked Ecological Change in the Southwest

Many researchers have identified the types of ecological change that could be attributed as an effect of climate change. These include species population declines (e.g. drought-induced mortality), changes in phenology, shifts in distribution in either elevation or latitude, and increases in invasive species (native and non-native) (Parmesan & Yohe 2003, Root et al. 2003). We gathered ecological studies from around the southwestern U.S. that documented such changes and, to the extent possible, related changes to the conservation priorities examined in this study. Additionally, we conducted a series of expert interviews to identify unpublished observational cases of the types of ecological changes that show potential for being linked to climate change. In doing so, we highlight where further monitoring or research may be needed in order to obtain more robust climate change attribution.

TABLE 2. List of drought-sensitive conservation target species examined by geographical location.

Taxonomic Group	Common Name	Scientific Name
Amphibian	CHIRICAHUA LEOPARD FROG	RANA CHIRICAHUENSIS
	JEMEZ MOUNTAINS SALAMANDER	PLETHODON NEOMEXICANUS
	LOWLAND LEOPARD FROG	RANA YAVAPAIENSIS
	SACRAMENTO MOUNTAIN SALAMANDER	ANEIDES HARDII
Bird	ABERT'S TOWHEE	PIPILO ABERTI
	AMERICAN PEREGRINE FALCON	FALCO PEREGRINUS ANATUM
	BAIRD'S SPARROW	AMMODRAMUS BAIRDII
	BELL'S VIREO	VIREO BELLII
	BLACK SWIFT	CYPSELOIDES NIGER
	BOREAL OWL	AEGOLIUS FUNEREUS
	BOTTERI'S SPARROW	AIMOPHILA BOTTERII
	BROAD-BILLED HUMMINGBIRD	CYNANTHUS LATIROSTRIS
	COMMON BLACK-HAWK	BUTEOGALLUS ANTHRACINUS
	COMMON GROUND-DOVE	COLUMBINA PASSERINA
	COSTA'S HUMMINGBIRD	CALYPTE COSTAE
	GILA WOODPECKER	MELANERPES UROPYGIALIS
	GOULD'S WILD TURKEY	MELEAGRIS GALLOPAVO MEXICANA
	GRAY VIREO	VIREO VICINIOR
	INTERIOR LEAST TERN	STERNA ANTILLARUM ATHALASSOS
	LESSER PRAIRIE-CHICKEN	TYMPANUCHUS PALLIDICINCTUS
	MEXICAN SPOTTED OWL	STRIX OCCIDENTALIS LUCIDA
	SOUTHWESTERN WILLOW FLYCATCHER	EMPIDONAX TRAILLII EXTIMUS
	VARIED BUNTING	PASSERINA VERSICOLOR
	WESTERN SNOWY PLOVER	CHARADRIUS ALEXANDRINUS NIVOSUS
	WHITE-TAILED PTARMIGAN	LAGOPUS LEUCURUS
	WILSON'S PHALAROPE	PHALAROPUS TRICOLOR
Invertebrate	ANIMAS MOUNTAINS GASTROCOPTA	GASTROCOPTA DALLIANA DALLIANA
	BIG HATCHET MOUNTAINS ASHMUNELLA	ASHMUNELLA HEBARDI
	COOKE'S PEAK WOODLANDSNAIL	ASHMUNELLA MACROMPHALA
	LILLJEBORG'S PEA-CLAM	PISIDIUM LILLJEBORGI
	OVATE VERTIGO	VERTIGO OVATA
	PECOS ASSIMINEA SNAIL	ASSIMINEA PECOS
	SANGRE DE CRISTO PEA-CLAM	PISIDIUM SANGUINICHRISTI
	SAY'S POND SNAIL	LYMNAEA CAPERATA
Mammal	ALLEN'S BIG-EARED BAT	IDIONYCTERIS PHYLLOTIS
	COATI	NASUA NARICA
	DESERT BIGHORN SHEEP	OVIS CANADENSIS MEXICANA
	FULVOUS HARVEST MOUSE	REITHRODONTOMYS FULVESCENS
	GOAT PEAK PIKA	OCHOTONA PRINCEPS NIGRESCENS
	LEAST SHREW	CRYPTOTIS PARVA
	LONG-TONGUED BAT	CHOERONYCTERIS MEXICANA
	MASKED SHREW	SOREX CINEREUS
	MERRIAM'S SHREW	SOREX MERRIAMI
	NEW MEXICAN JUMPING MOUSE	ZAPUS HUDSONIUS LUTEUS
	NORTHERN PYGMY MOUSE	BAIOMYS TAYLORI
	PINE MARTEN	MARTES AMERICANA
	SOUTHERN LONG-NOSED BAT	LEPTONYCTERIS CURASOAE
	SWIFT FOX	VULPES VELOX
	WHITE-SIDED JACK RABBIT	LEPUS CALLOTIS
	YELLOW-NOSED COTTON RAT	SIGMODON OCHROGNATHUS
Plant		AGASTACHE PRINGLEI VAR VERTICILLATA
		SPIRANTHES ROMANZOFFIANA
	CHAPLINE'S COLUMBINE	AQUILEGIA CHRYSANTHA VAR CHAPLINEI
	CRESTED CORALROOT	HEXALECTRIS SPICATA
	DAVIDSON'S CLIFF CARROT	PTERYXIA DAVIDSONII
	FIVE-FLOWER ROCKDAISY	PERITYLE QUINQUEFLORA
	GILA GROUNDSEL	SENECIO QUAERENS

Taxonomic Group	Common Name	Scientific Name
	GUADALUPE VALERIAN	VALERIANA TEXANA
	KERR'S MILKVETCH	ASTRAGALUS KERRII
	KUENZLER HEDGEHOG CACTUS	ECHINOCEREUS FENDLERI VAR KUENZLERI
	MCKITTRICK PENNYROYAL	HEDEOMA APICULATUM
	MIMBRES FIGWORT	SCROPHULARIA MACRANTHA
	MOGOLLON CLOVER	TRIFOLIUM LONGIPES VAR NEUROPHYLLUM
	ORGAN EVENING-PRIMROSE	OENOTHERA ORGANENSIS
	PARISH'S ALKALI GRASS	PUCCINELLIA PARISHII
	PUZZLE SUNFLOWER	HELIANTHUS PARADOXUS
	SACRAMENTO MOUNTAINS THISTLE	CIRSIUM VINACEUM
	SHOWY LEASTDAISY	CHAETOPAPPA ELEGANS
	SMOOTH FIGWORT	SCROPHULARIA LAEVIS
	STEYERMARK'S MILKWORT	POLYGALA RIMULICOLA
	TALL PRAIRIE-GENTIAN	EUSTOMA EXALTATUM
	TODSEN'S PENNYROYAL	HEDEOMA TODSENII
	VILLARD'S PINCUSHION CACTUS	ESCOBARIA VILLARDII
	WOOTON'S HAWTHORN	CRATAEGUS WOOTONIANA
Reptile	GRAY-CHECKERED WHIPTAIL	CNEMIDOPHORUS DIXONI
	NEW MEXICO RIDGENOSE RATTLESNAKE	CROTALUS WILLARDI OBSCURUS
Fish	ZUNI BLUEHEAD SUCKER	CATOSTOMUS DISCOBOLUS YARROWI
	PECOS PUPFISH	CYPRINODON PECOSENSIS
	WHITE SANDS PUPFISH	CYPRINODON TULAROSA
	GREENTHROAT DARTER	ETHEOSTOMA LEPIDUM
	PECOS GAMBUSIA	GAMBUSIA NOBILIS
	CHIHUAHUA CHUB	GILA NIGRESCENS
	ROUNDTAIL CHUB	GILA ROBUSTA
	SPIKEDACE	MEDA FULGIDA
	GILA TROUT	ONCORHYNCHUS GILAE
	SOUTHERN REDBELLY DACE	PHOXINUS ERYTHROGASTER
	COLORADO SQUAWFISH	PTYCHOCHEILUS LUCIUS
	LOACH MINNOW	RHINICHTHYS COBITIS
	RAZORBACK SUCKER	XYRAUCHEN TEXANUS
	RIO GRANDE CUTTHROAT TROUT	ONCORHYNCHUS CLARKI VIRGINALIS
	BONYTAIL CHUB	GILA ELEGANS

Results

Recent Changes in New Mexico's Climate

Relative to the 1961-1990 baseline, both the 1991-2005 and 2000-2005 periods show temperature increases in over 95% of the geographical area of New Mexico (Fig. 3-1). The magnitude of warming was variable spatially, however, with warming greatest in northwestern (the Jemez Mountains, in particular), central, and southwestern New Mexico. While no change or slight cooling occurred in parts of the Southern Sangre de Cristo Mountains, the Zuni Mountains, the vicinity of the Gila River headwaters, and a small region in the Lower Pecos-Roswell River basin, other parts of these regions have experienced increasing trends in either minimum or maximum temperatures from 1970-2006. In contrast, precipitation departures showed substantial spatial heterogeneity in both direction and magnitude, with 54% of the state tending toward wetter conditions, 41% drier conditions, and 5%, showing no change during the 1991-2005 departure period (Fig. 3-2). The 2000-2005 drought event was not spatially uniform, with 24% of the state experiencing wetter conditions, 71% drier conditions, and 5% of the state showing no change. Composite temperature and precipitation departure maps further emphasize this spatial heterogeneity, with 59% of the state showing warmer-wetter conditions and 35% showing warmer-drier conditions in the 1991-2005 departure period (Fig. 3A-3). In contrast, 23% of the state was warmer-wetter and 71% was warmer-drier during the 2000-2005 drought event (Fig. 3B-3).

Assessment of Conservation Priorities in New Mexico

Major Habitat Types

Grasslands comprise over half of (65%) of New Mexico's landcover, with the remaining area comprised of woodland (17%), forest (10%), desert (4%), shrubland (3%), and riparian/wetlands (1%) (Fig. 1). Although most of New Mexico's major habitat types (MHTs) experienced warmer-wetter conditions during the 1991-2005 departure period, differential patterns were primarily related to precipitation variability (Fig. 4a). For example, warmer-drier conditions were experienced in over half of deserts (57%) and woodlands (51%), while over a quarter of forested areas (38%), shrubland areas (34%), grassland areas (30%), and riparian areas (30%) also experienced these conditions. In contrast, less than a quarter of wetlands (22%) were warmer-drier. Spatial variability in precipitation patterns were less apparent across MHTs during the 2000-2005 drought event (Fig. 4b), with most land cover types experiencing predominately warmer-drier conditions. Yet, while nearly 65% of grasslands experienced warmer-drier conditions, over a third (35%) experienced warmer-wetter conditions. A closer analysis of 2000-2005 departures revealed that most semi-desert grassland and montane grasslands experienced warmer-drier conditions, whereas a majority of Great Plains grasslands experienced warmer-wetter conditions. Taking both departure periods into account, woodlands and deserts appear to have experienced the most consistent warmer-drier patterns relative to the other habitat types. Great Plains grasslands, on the other hand, have experienced the most consistent warmer-wetter conditions.

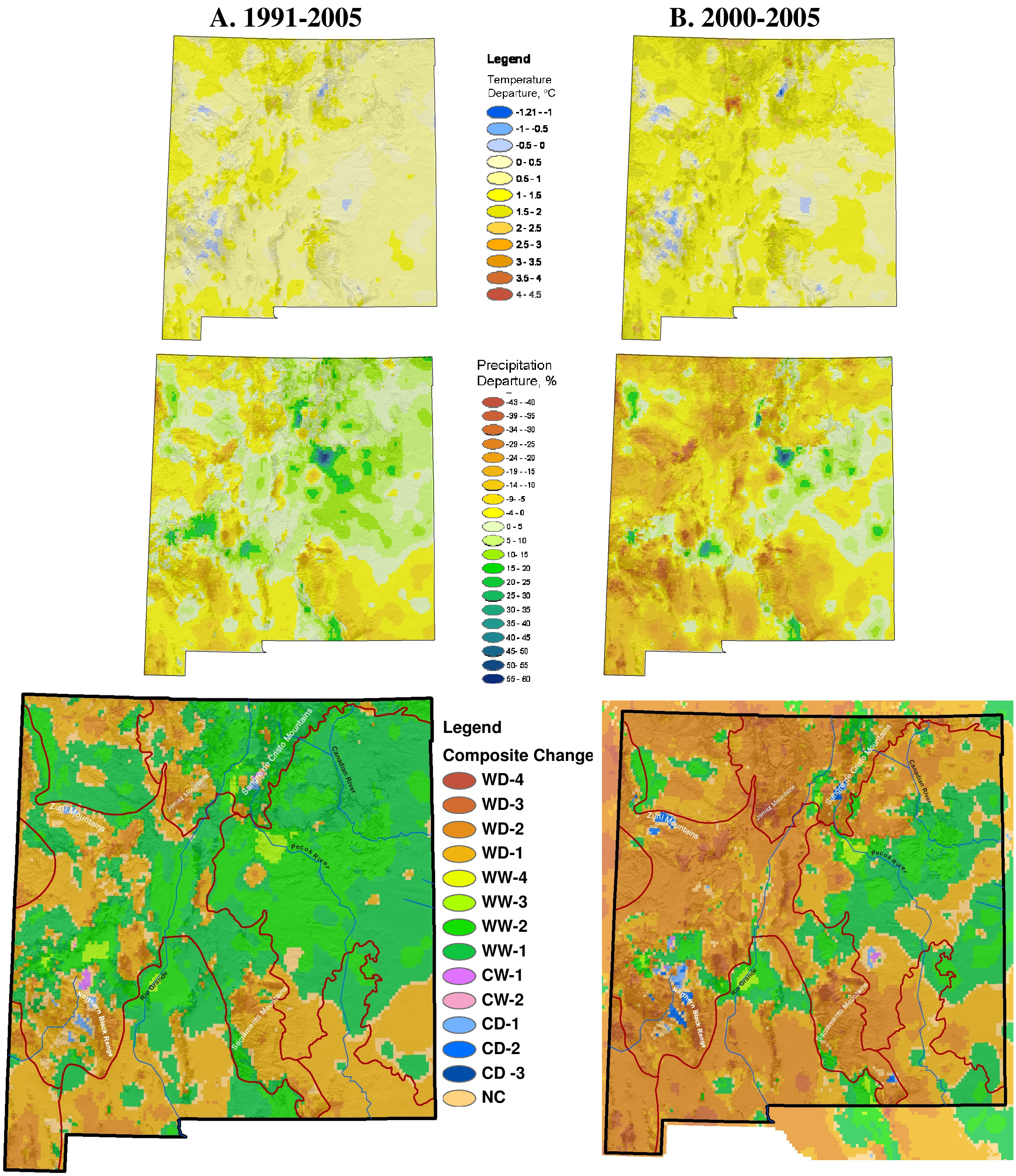

FIGURE 3. Column (A) graphics associated with the 1991-2005 departure period, column (B) graphics associated with the 2000-2005 departure period; both are relative to the mean 1961-1990 climatology. Row 1 shows mean temperature departures, Row 2 shows mean precipitation departures, and Row 3 represents a composite of the two. WD=warmer-drier, WW=warmer-wetter, CW=cooler-wetter, CD=cooler-drier, NC=no change in temperature and/or precipitation. Numbers in the composite change legend reflect magnitude (i.e. WD-4 is the most extreme warmer-drier category). Red lines are ecoregional boundaries (see Fig. 1 for key).

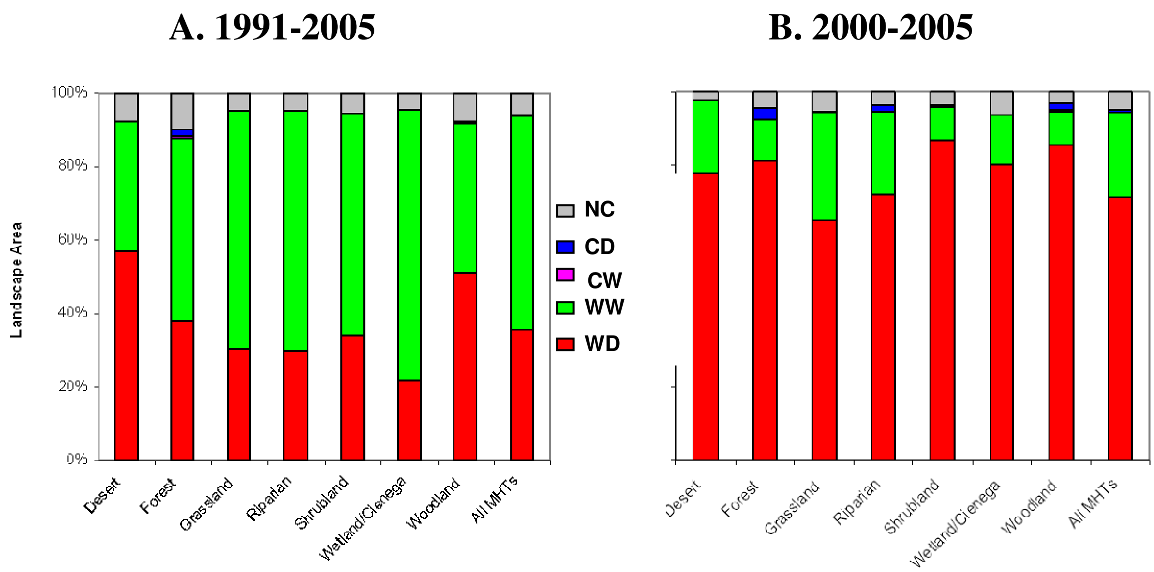

FIGURE 4. Percent area of major habitat types exposed to anomalous climate conditions relative to 1961-1990. (A) 1991-2005 departure period, (B) 2000-2005 departure period. WD=warmer-drier, WW=warmer-wetter, CW=cooler-wetter, CD=cooler-drier, NC=no change in temperature and/or precipitation.

Key Conservation Areas by Ecoregion

Climate exposure scores for New Mexico's state-wide network of key conservation areas were divided into percentiles for easier interpretation. The Jemez Mountains (site #131) in the Southern Rocky Mountain ecoregion ranked at the top (100th percentile) with the highest climate exposure score, while the Northern Brokeoff Mountains (site #21) in the Chihuahuan Desert ecoregion ranked in the lowest percentile (Appendix 1). The Turkey Mountains Grasslands (site #180) in the Southern Shortgrass Prairie ecoregion ranked at the 50th percentile.

We generated a map of the entire key conservation area network colorized by the range, or gradient, of climate exposure scores (Fig. 5). We assumed that the higher the climate exposure score, the more negative the potential ecological impact or physiological stress on the species and ecosystems in the conservation area. By ecoregion, we highlight conservation areas with the highest (most exposure) and lowest (least exposure) scores, in addition to long-term trends in T*min* and T*max*. Scatter diagrams of mean temperature and precipitation departures are provided to facilitate comparison between conservation areas within an ecoregion. We also report the mean climate exposure score percentile ranking for each ecoregion relative to the state-wide network.

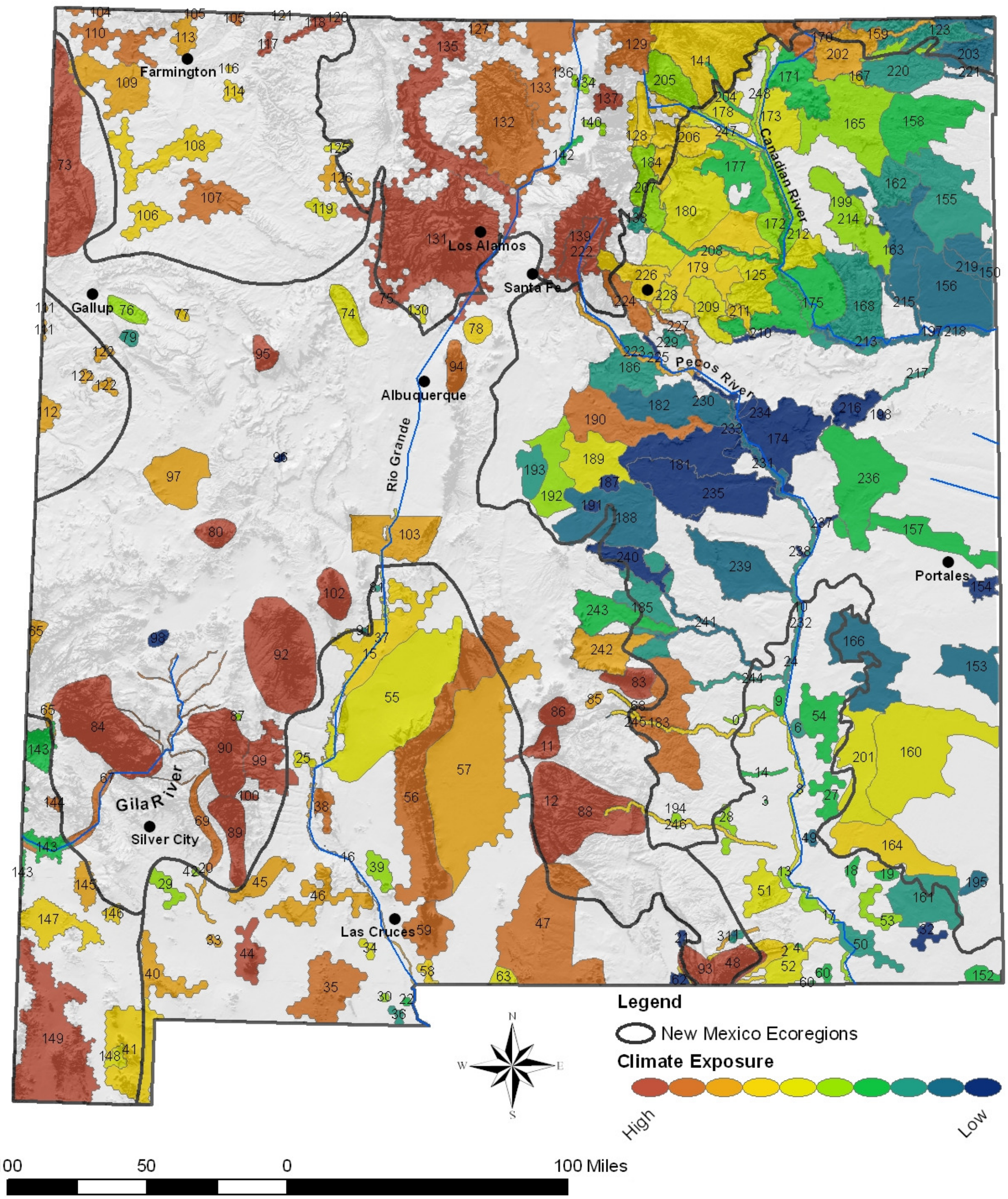

FIGURE 5. Map of New Mexico's key conservation areas ranked by climate exposure percentiles (*cf.* Appendix 1). Percentiles ranging between 50-100% are indicated by a gradient of yellow to red; percentiles ranging between 49.9 and <1.0% are indicated by a gradient of green to blue. Labels inside conservation areas are ID numbers that correspond with conservation area names listed in Appendices 1 & 2.

Chihuahuan Desert

The northern portion of this semi-desert grassland and desert shrubland-dominated ecoregion reaches into central New Mexico with the remainder extending into Mexico and Texas. New Mexico has 60 conservation sites within its portion of the Chihuahuan Desert. Relative to this group, the Florida Mountains (#44) ranked highest in climate exposure (92.1^{th} percentile), with consistent warmer-drier conditions across the two departure periods (Fig. 6) and significant positive trends in T_{min} and T_{max} between 1970-2006 (Appendix 1). In contrast, the Northern Brokeoff Mountains (#21), ranked lowest (0.0^{th} percentile) not only in the ecoregion but in the overall network, with consistent wetter conditions across the two departure periods but non-significant long-term positive (increasing) trends for both temperature variables. The mean and median climate exposure score for the ecoregion was in the 48^{th} percentile.

Arizona-New Mexico Mountains

Host to more species of birds and mammals than any other ecoregion in the southwestern U.S., this ecoregion encompasses Arizona's Mogollon Rim in its western portion, extending through the mountain ranges of western New Mexico to the central and southern mountain ranges, down to the Guadalupe Mountains in Texas (Bell et al. 1999). Of the ecoregion's 34 conservation areas located in New Mexico, the Mount Taylor site (#95) ranked highest in climate exposure (99.5^{th} percentile), with consistent warmer-drier conditions across the two departure periods (Fig. 6) and significant long-term positive trends in T_{min} and T_{max} between 1970-2006 (Appendix 1). In contrast, the Western Plains of Saint Augustin site (#98) ranked lowest (0.4^{th} percentile) in the ecoregion (and second lowest in overall conservation area network), with consistently wetter average conditions, non-significant negative trend in T_{min}, and a non-significant positive trend in T_{max}. The mean climate exposure score for the ecoregion was in the 79^{th} percentile; the median score was in the 86^{th} percentile.

Colorado Plateau

Encompassing the far northwestern portion of New Mexico, with the remaining portion extending into the Four Corner states of Arizona, Utah, and Colorado, the ecoregion is considered ecologically important as a result of its complex geological formations and its more than 300 endemic plant species (Tuhy et al. 2002). Of the 18 conservation areas in the New Mexico portion of the ecoregion, the Carracas Mesa/Navajo Reservoir site (#118) ranked highest in climate exposure (91.7^{th} percentile) not only as a result of consistent warmer-drier conditions (Fig. 6), but because of the variation experienced in temperature across the two departure periods (Appendix 1). Moreover, the site had significant positive trends in both T_{min} and T_{max} between 1970-2006. The Ceja Pelon Mesa (#119) site ranked lowest in exposure (52.6^{th} percentile) with moderate departures and variation in temperature and precipitation relative to other sites in the ecoregion and significant positive trends in both T_{min} and T_{max}. The mean and median climate exposure score for the ecoregion was in the 78^{th} percentile.

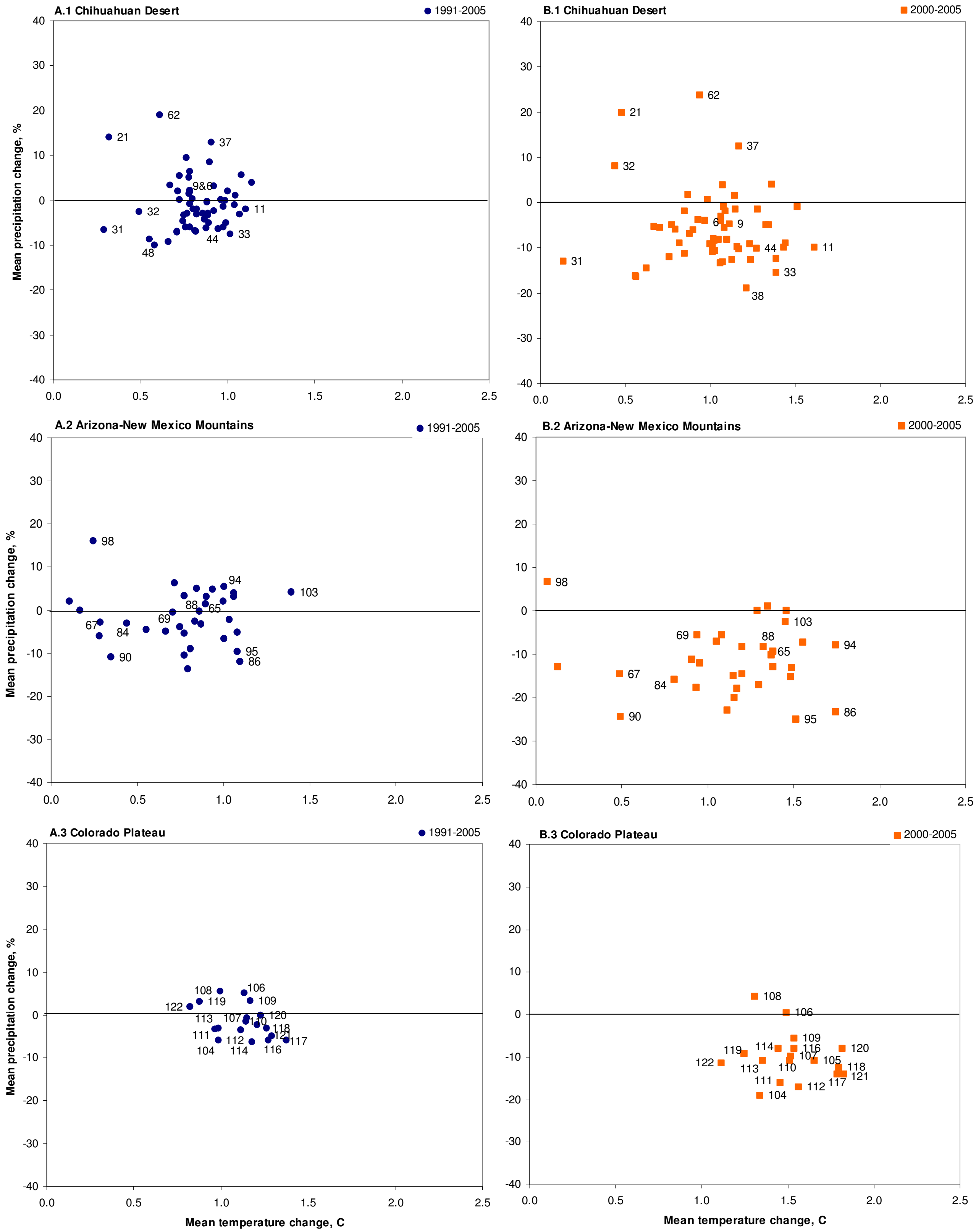

FIGURE 6. Averaged annual temperature departures and annual precipitation departures for key conservation areas located in three of New Mexico's ecoregions. ID numbers are provided for conservation areas mentioned in the text (*cf.* Appendix 1 for names). Column (A) shows the 1991-2005 departure period and column (B) shows the 2000-2005 departure period relative to 1961-1990 "normal" period. Points below line=warmer-drier, points above line=warmer-wetter.

Southern Rocky Mountains

The southernmost extent of the ecoregion reaches into northern New Mexico, while the remainder encompasses the high-elevation mountainous areas of Colorado. During the 1991-2005 departure period, all but one of the 18 conservation areas in the New Mexico portion of the ecoregion showed increases in temperature and precipitation. The single exception was the Jemez Mountains (#131) site, which experienced warmer and slightly drier conditions in this departure period. However, in the 2000-2005 departure period, 15 out of 18 sites experienced drier conditions and 17 sites experienced average temperature departures over 1^{o}C; 11 of these showed mean temperature departures of at least 1.5^{o}C (Fig. 7). The Jemez Mountains site ranked highest in climate exposure (100th percentile) not only as a result of consistent warmer-drier conditions, but because of the variation (or standard deviation) experienced in temperatures across the two departure periods (Appendix 1). The Southern Sangre de Cristo Mountains (site #139) is also noteworthy, given its moderate mean temperature departures (less than 1^{o}C) and mean precipitation departures of +3% (1991-2005) and -10% (2000-2005). However, the substantial variation in mean temperature across both departure periods increased the site's exposure score to the second highest in the ecoregion (98.2th percentile). The Sapello/Mora Valley (site #138) ranked lowest (29.1th percentile) in the ecoregion with consistent increases in precipitation and relatively low variation in temperatures in both departure periods. All sites had significant positive trends in both T_{min} and T_{max}, except Coyote Creek (#128, 60.0th percentile) and Agua Caliente (#142, 33.9th percentile) which showed significant positive trends only in T_{min} between 1970-2006. The mean and median climate exposure score for the ecoregion was in the 79th percentile.

Apache Highlands

Also referred to as the Madrean Archipelago, the ecoregion is recognized for its isolated mountain ranges and semi-desert grasslands that occupy valley basins (Brown & Lowe 1979). With the convergence of sub-tropical and temperate mountain influences, the basin and range physiography has given rise to an unusually rich flora and fauna (Marshall et al. 2004). While a majority of the ecoregion occurs in Arizona, the eastern-most portion occurs in southwestern New Mexico's "bootheel," with the southern portion extending into northern Mexico. Seven conservation areas occur within New Mexico's state lines, three of which share borders with Arizona and Mexico. The Sierra San Luis/Peloncillo Mountains (site #149) ranked highest in climate exposure score (96.5th percentile) as a result of consistent warmer-drier conditions (Fig. 7) and the degree of variation in temperatures across the two departure periods (Appendix 1). The Blue River/Eagle Creek (site #143) had the lowest exposure score (35.6th percentile), with no or moderate departures overall relative to other sites in the ecoregion and a non-significant long-term positive trend in T_{max}. All sites had significant positive trends in T_{min}. The mean and median climate exposure score for the ecoregion was in the 73rd percentile.

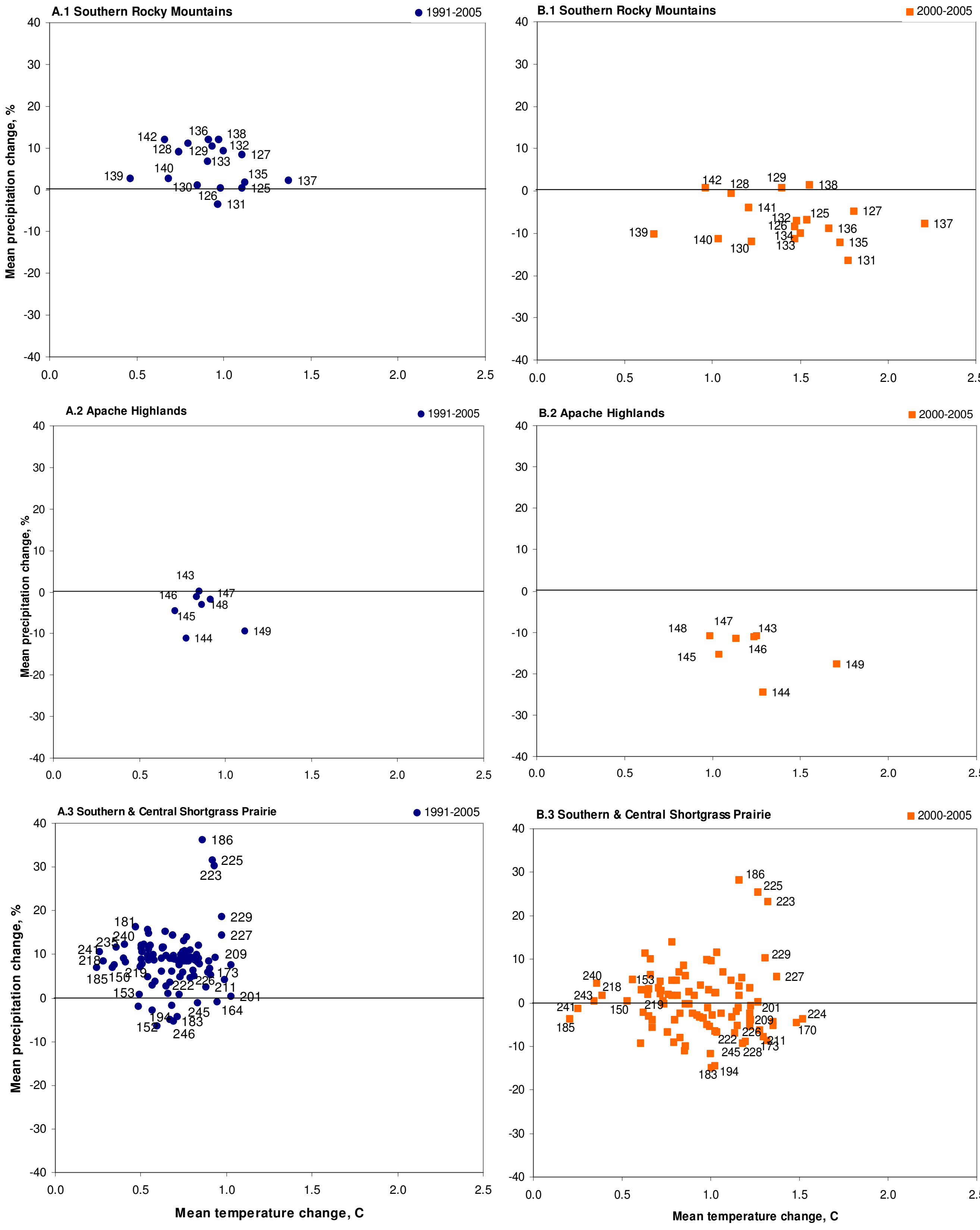

FIGURE 7. Averaged annual temperature departures and annual precipitation departures for key conservation areas located in three of New Mexico's ecoregions. ID numbers are provided for conservation areas mentioned in the text (*cf.* Appendix 1 for names). Column (A) shows the 1991-2005 departure period and column (B) shows the 2000-2005 departure period relative to 1961-1990 "normal" period. Points below line=warmer-drier, points above line=warmer-wetter.

Southern and Central Shortgrass Prairie

Characterized by high plains plateaus and fragmented by escarpments, the southern tip of the Central Shortgrass Prairie and the westernmost portion of the Southern Shortgrass Prairie ecoregions extend into New Mexico (The Nature Conservancy 2004). In total, 97 shortgrass prairie conservation areas occur within the state (only one in the Central Shortgrass Prairie ecoregion). The Pecos River Headwaters site (#222) had the highest climate exposure score (94.3th percentile) primarily as a result of the substantial variation in temperatures during the two departure periods, in addition to significant positive trends in both T*min* and T*max* between 1970-2006 (Appendix 1). While the Rio Agua Negra (#233) and the Charco Creek Mesas (#198) sites had the lowest scores (1.3th and 2.1th percentiles respectively) in the ecoregions, both sites are less than 7,000 acres. The Grulla National Wildlife Refuge site (#154), with the next lowest score (2.6th percentile), experienced consistent yet moderate warmer-wetter conditions across the two departure periods, in addition to significant positive trends in T*max* and T*min* (Fig. 7). Overall, the mean and median climate exposure score for the ecoregion was in the 30th percentile.

Drought-Sensitive Species by Conservation Area

Drought-sensitive(D-S) conservation target species occur in 103 of the 231 key conservation areas (46%) identified in New Mexico. To identify those areas with the greatest D-S species richness, sites were sorted by the highest number of D-S taxonomic groups (out of seven) and then by the greatest number of D-S species. We then related this ranking scheme to recent climate changes using climate exposure scores (Appendix 2). Overall, we identified 21 drought-sensitive species-rich key conservation areas with the highest (eleven sites over 85th percentile rank) and the lowest (ten sites under 50th percentile rank) exposure scores (Table 3).

Of the eleven D-S species-rich key conservation areas with the highest climate exposure scores, the Jemez Mountains conservation area ranked at the top. The site with the highest D-S species richness, the Sierra San Luis/ Peloncillos Mountains, ranked sixth in terms of climate exposure. All sites experienced significant increasing trends in T*min* (or nighttime temperatures in winter) between 1970-2006. Four sites located in the vicinity of the Gila River headwaters (Northern Black Range, Mogollon Divide, Mimbres River, and Gila River) experienced no change in T*max* (or daytime temperatures in summer), whereas the remaining had significant increasing trends. Six of the eleven sites are located in the Arizona-New Mexico Mountains ecoregion, four sites are in the Southern Rocky Mountains ecoregion, and one site the Apache Highlands ecoregion.

Of the ten D-S species-rich key conservation areas with the lowest climate exposure scores, the Bottomless Lakes site ranked as the lowest. The site with the highest D-S richness in this group, Bitter Lake, ranked fourth in terms of climate exposure. All sites experienced significant increasing trends in T*min* between 1970-2006. With the exception of the Blue River/ Eagle Creek site (Apache Highlands ecoregion), all sites also experienced significant long-term increasing trends in T*max*. Nine of the ten sites are located in the Chihuahuan Desert ecoregion.

TABLE 3. Key conservation areas with the highest drought-sensitive (D-S) species richness sorted by highest (white) and lowest (shaded) climate exposure percentile ranks. Significantly increasing trends (1970-2006) are indicated by an asterisk (*) for minimum temperature (T*min*) and maximum temperature (T*max*).

ID	Key Conservation Area	Ecoregion	# D-S Taxa	Total # D-S Species	Percent Rank	T*min*	T*max*
131	Jemez Mountains	Southern Rocky Mountains	5	12	100.0%	*	*
137	Rio Hondo	Southern Rocky Mountains	5	6	99.1%	*	*
86	Sierra Blanca	Arizona - New Mexico Mountains	5	9	98.6%	*	*
139	Southern Sangre de Cristo Mountains	Southern Rocky Mountains	5	12	98.2%	*	*
135	Rio Chama	Southern Rocky Mountains	4	8	96.9%	*	*
149	Sierra San Luis/ Peloncillos Mountains	Apache Highlands	5	27	96.5%	*	*
90	Northern Black Range	Arizona - New Mexico Mountains	5	8	96.0%	*	
88	Sacramento Mountains	Arizona - New Mexico Mountains	5	10	95.2%	*	*
84	Mogollon Divide	Arizona - New Mexico Mountains	5	14	89.5%	*	
69	Mimbres River	Arizona - New Mexico Mountains	5	6	88.6%	*	
67	Gila River	Arizona - New Mexico Mountains	4	12	87.8%	*	
6	Bottomless Lakes	Chihuahuan Desert	3	5	20.4%	*	*
12	Lost River	Chihuahuan Desert	3	3	23.4%	*	*
10	Pecos River High Plains	Chihuahuan Desert	1	6	26.9%	*	*
9	Bitter Lake	Chihuahuan Desert	5	10	30.0%	*	*
143	Blue River/Eagle Creek	Apache Highlands	3	15	35.6%	*	
14	Rio Felix	Chihuahuan Desert	1	6	37.3%	*	*
0	Lower Hondo	Chihuahuan Desert	1	8	42.6%	*	*
17	Pecos River Delaware	Chihuahuan Desert	1	12	45.6%	*	*
13	Pecos River Carlsbad	Chihuahuan Desert	1	14	46.0%	*	*
8	Pecos River Roswell	Chihuahuan Desert	4	18	49.5%	*	*

Drought-Sensitive Species by Taxonomic Group

We assessed recent climate change patterns for known locations of drought-sensitive (D-S) target species listed in Table 1. For simplicity, we summarized these patterns by four terrestrial taxonomic groups: birds, mammals, amphibians, and plants. Key conservation areas containing the highest numbers of D-S species within each taxonomic group also are identified; climate exposure percentile ranks are also provided. Most sites identified for taxonomic richness also appear in the highest climate exposure score portion of Table 3.

Birds

We assessed 22 D-S bird species targets. During the 1991-2005 departure period, half of the 707 occurrences (e.g. point locations) were exposed to warmer-wetter conditions on average, whereas 38% were exposed to warmer-drier conditions. Nearly 10% of D-S bird occurrences experienced an increase in just temperature, while less than 2% experienced small increases and decreases in precipitation only. The 2000-2005 departure period showed that more than half (63%) of D-S bird occurrences were exposed to warmer-drier conditions and nearly a third (32%) warmer-wetter, with the remaining 5% experiencing no change in one or both variables. The Southern Sangre de Cristo site (#139; 98^{th} percentile) has the highest D-S bird diversity (7 species), while the Gila River (#67, 87^{th} percentile) and the Sierra San Luis/Peloncillos (#149; 96^{th} percentile) sites has the 2^{nd} greatest number of D-S bird species, each with six (Appendix 2).

Mammals

Sixteen D-S mammal species targets were examined. Analysis of the 1991-2005 departure period indicated that over half (53%) of the 118 occurrences of these targets were potentially exposed to warmer-drier conditions, with 36% warmer-wetter and the remaining 11% with no change in one or both variables. Analysis of the 2000-2005 departure period showed that most (92%) of D-S mammals experienced warmer-drier conditions and 4% experienced warmer-wetter conditions. Only 1% experienced cooler-drier conditions (the Mimbres River site #69, 88^{th} percentile), while the remaining 3% experienced warmer conditions. The Sierra San Luis/Peloncillos site (#149; 96^{th} percentile) contains the greatest number of D-S mammals (seven species); four sites have the second highest number (two species): Southern Sangre de Cristo Mountains (#139; 98^{th} percentile), Jemez Mountains (#131, 100^{th} percentile), Rio Hondo (#137, 99^{th} percentile), Ojo Caliente (#132, 82^{nd} percentile) (Appendix 2).

Amphibians

Given the their life history and physiological requirements, we recognize that all amphibians are drought-sensitive; we examine four species here. Analysis of the 1991-2005 departure period showed that nearly half (49%) of the 151 occurrences of these species were exposed to warmer-wetter conditions and almost the other half (47%) warmer-drier. Only 1% experienced cooler-drier conditions (primarily in the Northern

Black Range), with the remaining 3% exposed to drier or warmer conditions. In contrast, over three quarters (83%) of occurrences experienced warmer-drier conditions during the 2000-2005 departure period, with <1% experiencing warmer-wetter conditions and <1% experienced cooler-drier conditions. Nearly 15% experienced warmer conditions and only <1% experienced drier. The Sierra San Luis/Peloncillos Mountains site (#149; 96th percentile) and the Blue River/San Francisco River site each contain three amphibian species (the Chiricahua leopard frog, Lowland leopard frog, and Southwestern/Arizona toad). Two conservation areas contain endemic mountain salamander species, the Jemez Mountains and the Sacramento Mountains (Appendix 2).

Plants

Twenty-five plant species were identified as D-S targets. Analysis of the 1991-2005 departure period showed that over half (62%) of 423 occurrences of these plants experienced warmer-drier conditions, whereas nearly one third (30%) experienced warmer-wetter conditions. One percent experienced cooler-drier conditions, 6% faced warmer conditions and the remaining 1% experienced no changes. Analysis of the 2000-2005 departure period showed that a majority (87%) of occurrences were exposed to warmer-drier conditions, with 1% warmer-wetter, and the remaining 12% warmer. Overall, the Sacramento Mountains site contained the greatest number of drought-sensitive plants (7 species), with the Sierra Blanca (#86; 98th percentile), Guadalupe Mountains Escarpment (#93; 93rd percentile), and Guadalupe Mountains (#48; 66th percentile) conservation areas each containing five species, or the second highest number of D-S plants (Appendix 2).

CLIMATE-LINKED ECOLOGICAL CHANGE IN THE SOUTHWEST

Several studies have described rigorous statistical methods for attributing climate change as a driver of recent ecological changes (Root et al. 2003, Parmesan 2006, Parmesan 2007). In our search for such examples, we found few from the southwestern U.S. We therefore adopted a more flexible approach and identified 48 examples where researchers link five categories of recently observed ecological changes to climate change (Appendix 3). Over half of these changes involved population declines, with changes in distribution of species' ranges accounting for nearly a quarter of the examples. Changes in phenology, species evolution, and increases in invasive species comprised the remainder. To provide a relative measure of credibility, we noted four sources of evidence ranging from highest to lowest: peer-reviewed literature, published report, unpublished data cited by an expert, and unpublished observation by an expert. We considered an expert to be a researcher or professional with at least a decade of natural resources-related experience in the southwestern U.S.

Peer-reviewed literature

While only 11 cases of ecological change linked to climate change were found in the peer-reviewed scientific literature, they provide the strongest evidence to-date of climate change-type effects. This evidence spans the five categories of ecological change. Five published studies are focused on population declines in three ecosystems: (1) population size reductions in seven bird and three tree species over a 20 year period at a high-elevation riparian study site in the Arizona-New Mexico Mountains ecoregion (Martin 2007); (2) documentation of massive piñon pine forest dieback primarily in the Southern Rockies and Colorado Plateau ecoregions (Breshears et al. 2005, Mueller et al. 2005, Shaw et al. 2005); (3) and mortality gradients identified within cottonwood-dominated riparian areas across the Southwest (Gitlin et al. 2006). Two peer-reviewed studies attribute climate change as a factor in distribution shifts documented in (1) a riparian bird along the Rio Grande (Taylor 2003) and (2) a desert rodent community in a semi-desert grassland site (Brown et al. 1997). We found only one published peer-reviewed example of phenological change, a change in timing of egg hatching in Mexican jays (Brown et al. 1999), a common inhabitant of sky island mountain ranges in Arizona, New Mexico, and Mexico (Apache Highlands ecoregion). However, a new study in the peer-review process analyzes 20 years of data documenting the temperature-induced shift in the timing of blooming in various plant species distributed along an elevation gradient in another sky island mountain range of the Apache Highlands (Mau-Crimmins et al. *in review*). Smith et al. (1998) document a climate-induced evolutionary shift in the body size of the White-throated woodrat, a species inhabiting a key conservation area in central New Mexico, the Sevilleta National Wildlife Refuge (Arizona-New Mexico Mountains ecoregion), a site well-recognized as a major ecotone. Increased species invasion is demonstrated by Gitlin & Whitham's (2007) study of salt cedar (*Tamarisk spp.*), an exotic drought tolerant species that out-competes water-stressed cottonwoods in riparian areas throughout the Southwest. The authors speculate that salt cedar is likely to displace broad-leaved cottonwood trees with increasingly severe droughts. Finally, two other examples of climate-induced species invasions were identified: (1) invasion of a montane grassland in the Valles Caldera of the Jemez Mountains by a native tree species may be at least partially explained by years of rising minimum summer temperatures (Coop and Givnish 2007) and (2) the invasion of semi-desert grasslands in the Apache Highlands ecoregion by the exotic Lehman's lovegrass (*Eragrostis lehmanniana*), an African perennial grass introduced in rangelands during the 1930s (Geiger & McPherson 2005).

Published Reports

We found 11 cases of population change linked to climate change in published reports. In particular, NMDGF's CWCS (2006) identifies three amphibian species (including the endemic Jemez Mountains and Sacramento Mountain salamanders), one mammal (the Goat Peak pika), and four insects in this category. Two riparian birds have experienced apparent climate-induced population decline in the vicinity of the San Pedro River in southeastern Arizona (the Apache Highlands ecoregion): the Southwestern willow flycatcher and the Yellow-billed cuckoo (Price et al. 2005). A recent Audubon Society study (Butcher & Niven 2007) suggests that Arizona grasshopper sparrows are experiencing dramatic declines because, in addition to habitat fragmentation, increased CO_2 is exacerbating the woody encroachment and subsequent conversion of grasslands to shrublands.

Unpublished Expert-Provided Evidence

Recent ecological changes linked to climate change include 27 cases based on unpublished data and expert observations. Of these, 15 cases involve population decline, including eight birds (each based on expert observations) and seven plants (each based on analyzed data). Ten cases involve species distribution shifts, with five bird species moving north from Mexico into New Mexico, four bat species shifting to higher elevations throughout the state's mountain ranges, and one mammal species (Bailey's pocket mouse) moving from Mexico to desert grassland sites in southeastern Arizona. Two expert-identified examples of increased exotic species invasions include (1) the drought-induced salt cedar and Russian olive invasion in the wetlands of the Blue Hole Cienega (Southern shortgrass prairie ecoregion) at the expense of drought-stressed native plants, including the Pecos sunflower, and (2) buffel grass invasion of Sonoran Desert sites (exacerbated by warming temperatures), increasing the risk of fire into this non-fire adapted ecoregion. While these examples may lack the rigor of the peer-reviewed evaluation process, they nonetheless suggest emerging ecological trends that may be linked to climate change. Furthermore, these observations highlight species and systems that may require additional attention by the conservation and research communities via continued monitoring, experimentation, and data analysis to better elucidate the possible effects of climate change.

Twenty-two documented and/or observed cases of climate-linked ecological change have direct implications for conservation priorities in New Mexico (*cf.* Appendix 3). These include impacts on three major habitat types: dieback in piñon pine forest and woodland, reorganization of a semi-desert grassland rodent and plant community, and exotic species invasion of riparian/wetland areas. Additionally, climate-linked population declines have been identified in one mammal (Goat Peak pika), three amphibians (Jemez Mountains Salamander, Sacramento Mountains Salamander, and Chiricahua leopard frog), four drought-sensitive bird species (White-tailed ptarmigan, Boreal owl, Southwestern willow flycatcher, and Bell's vireo), and five drought-sensitive plant species (the Sacramento Mountain's thistle, and Parish's alkali grass, and three rare cactus species *Sclerocactus mesae-verdae, Sclerocactus cloveriae ssp. Brackii, and Pediocactus knowltonii*). A shift in the distribution of Allen's big-eared bat along elevation gradients also has been observed in mountainous areas of New Mexico. We identified the key conservation areas that contain these 14 identified species and ranked them by climate exposure score (Appendix 4). Twenty-seven sites contained between one and four species. The Gila River site contains four species but ranked 13th in exposure, while the Jemez Mountains site contains three species and ranked first in climate exposure.

Discussion

Over 95% of New Mexico has warmed by varying magnitudes since the 1961-1990 "normal" period examined in our study. This is consistent with previous work that has shown the second half of the 20^{th} century in the Southwest to be warmer than any other 50-year period in the last 400-500 years (Sheppard et al. 2002, IPCC 2007). Our analysis showed mean annual temperature increases of at least $1^{o}C$ (~1.8 ^{o}F) in nearly a quarter of the state between 1991-2005, with less than 1% of the state showing increases of over 2 ^{o}C (~3.6 ^{o}F). Between 2000-2005, over half of the state (60%) experienced mean annual temperature increases of over $1^{o}C$ and 4% of the state had increases of $2^{o}C$ or more. In contrast, precipitation changes have been more variable geographically and temporally. For example, over half the area of New Mexico experienced precipitation increases from 1991-2005, although most of the increases (82%) were relatively small (less than 10%). Between 2000-2005, however, three quarters of the state experienced drier conditions. Nearly half (49%) of these precipitation decreases were 10% or greater than the average during 1961-1990.

Although our study would benefit from an examination of seasonal precipitation changes, we believe the annual patterns in temperature and precipitation identified here give an overall perspective of recent climate change that can be used to guide conservation planning and land management. Increasingly high temperatures produce greater evaporative demands on soils, plants, streams, rivers, and reservoirs in every season. Budyko (1982) suggested that for every $1^{o}C$ (~1.8 ^{o}F) increase in temperature, evapo-transpiration would increase by 3-4%, while Nash and Gleick (1991, 1993) concluded that precipitation increases of at least 20% would be required to offset the effects of a $7^{o}F$ (~3.9 ^{o}C) temperature rise in the Colorado River Basin. Furthermore, in projections of future climate change, rapidly increasing mean annual temperatures are a more certain effect than is the timing, direction, or magnitude of precipitation changes (Solomon et al. 2007). Future projections estimate mean annual temperature rises of at least $5^{o}F$ (~$2.8^{o}C$) by the late 21^{st} century in New Mexico (Gutzler & Garfin 2006). Additionally, numerous future climate projections for the Southwest predict both warming *and* drying trends not unlike the 2000-2005 period of severe drought, further amplifying the evaporative effect of increasing temperatures (Diffenbaugh et al. 2005, Seager et al. 2007, Hoerling & Eischeid 2007).

CONSERVATION IMPLICATIONS OF RECENT CLIMATE CHANGE

Major Habitat Types

Comprising over a quarter of New Mexico's land cover, the state's mid- to high-elevation forests and woodlands have experienced the highest levels of climate exposure since the late 20^{th} century, particularly in terms of mean temperature increases. While no change or slight cooling has occurred in parts of several mountainous habitats surrounding the Gila River headwaters, the Zuni Mountains, and the Sangre de Cristo Mountains, other areas in these ranges have experienced increasing trends in either minimum or maximum temperatures from 1970-2006. Furthermore, the high-elevation habitats of the Sangre de

Cristo Mountains have experienced particularly strong annual variability in temperature and precipitation patterns which can produce highly stressful environmental conditions (Breshears 2008, Sabo & Post 2008). The forests and woodlands of the northwestern part of the state, however, have been subjected to consistently warmer-drier conditions, especially in the Jemez Mountains. Elevated moisture stress in southwestern forests and woodlands has been shown to amplify the effects of ecological disturbance regimes such as insect outbreaks and fire, in addition to increasing the risk of large-scale forest dieback events (Breshears et al. 2005, Westerling et al. 2006, Rich et al. 2008). These disturbances are expected to increase under the warmer-drier conditions that most climate models predict for 21st century climate in the region (Hoerling & Eisheid 2007, Seager et al. 2007, Nitschke & Innes 2008). Moreover, the IPCC recently stated that "mountainous ecosystems are virtually certain to experience the most severe ecological impacts from climate change, including species extinctions and major biome shifts" (Parry et al. 2007).

Most of New Mexico's lower-elevation habitats have experienced a lower magnitude of recent climate change exposure when compared to high-elevation habitats. Our study identified consistent warmer-wetter conditions in shrublands, riparian areas, wetlands, and grasslands, especially in the Great Plains grasslands of eastern and northeastern New Mexico. Desert habitats, which comprise less than 5% of the state's land cover, and the semi-desert grasslands of New Mexico's bootheel were the exceptions, both experiencing consistently warmer-drier conditions during the two time periods analyzed, 1991-2005 and 2000-2005. Some suggest that desert and semi-desert regions may be best adapted for these conditions, especially if climate continues to change along this trajectory (Price et al. 2007). However, lower-elevation grasslands and riparian-wetland areas may be less resilient to ongoing climate change than our results suggests. For example, grasslands are affected by two known climate change effects, changes in the timing of precipitation (from summer- to winter-dominated rainfall) and increased CO_2 concentrations (Brown et al. 1997, Morgan et al. 2007). Not only do these factors favor the encroachment of woody shrubs and loss of perennial grass cover, but they may act synergistically with human-linked land-use changes in grasslands and elsewhere (Hansen et al. 2002, Peters et al. 2004, Burkett et al. 2005, Jetz et al. 2007, Enquist & Gori *in press*). For riparian areas and grasslands, added stressors include surface water diversions, groundwater pumping, intensive grazing regimes, fire suppression, non-native species invasions, atmospheric feedbacks (e.g. nitrogen deposition from urban areas), and habitat fragmentation associated with residential, commercial, and energy development. Clearly, the abatement or substantial reduction of multiple stressors will be critical to conservation of lower-elevation habitats, especially with the over-arching impact of climate change.

Key Conservation Areas & Drought-Sensitive Species

Our analysis of New Mexico's ecoregions and corresponding network of key conservation areas found that climate exposure was greater for higher-elevation ecoregions and smaller for lower-elevation ecoregions. Ranked from highest to lowest exposure, these ecoregions are: the Southern Rocky Mountains, the Arizona-New Mexico Mountains, Colorado Plateau, Apache Highlands, Chihuahuan Desert, and Southern/Central Shortgrass Prairie ecoregions. Accordingly, a site located in the Southern Rocky Mountains ecoregion, the Jemez Mountains, ranked highest in climate exposure, while the Northern Brokeoff Mountains in the Chihuahuan Desert ecoregion ranked lowest.

When drought-sensitive species richness was added to our analysis of climate exposure, we found that the Jemez Mountains site again ranked highest out of a group of eleven higher-exposure sites, followed by three other sites in the Southern Rocky Mountains ecoregion (*cf.* Table 3) including the Southern Sangre de Cristo Mountains, a site with the highest D-S bird species richness in the network of key conservation areas. Six sites in the Arizona-New Mexico Mountains also were among those with the highest D-S species richness and highest climate exposure, with four of these located in the vicinity of the Gila River headwaters (the Northern Black Range, Mogollon Divide, Mimbres River, and Gila River sites). While the Sierra San Luis/ Peloncillos Mountains site in the Apache Highlands ranked highest in D-S species overall, including the highest in D-S mammal and amphibian species richness, it ranked sixth highest when factoring in climate exposure. The Sacramento Mountains of the Arizona-New Mexico Mountains, highest in D-S plant species richness, ranked eighth when taking into account overall D-S species richness and climate exposure. From the perspective of conservation planning and management prioritization, these higher-elevation sites may require urgent attention, especially when considering the interactive effects of altered disturbance regimes that already are affecting these areas (Allen 2007).

We also identified ten D-S species-rich conservation areas with lowest climate exposure. The Chihuahuan Desert's Bottomless Lakes site ranked at the top of this group with the lowest climate exposure while Bitter Lake, the site with the highest D-S species richness in the group, ranked fourth based on exposure. All but one of these 10 areas are lower-elevation freshwater sites (riparian, wetland, or aquatic) located in the Chihuahuan Desert ecoregion (Table 3). Of these, three of the Pecos River sites (Delaware, Carlsbad, and Roswell) contain between 12 and 15 native fish species. The group's exception is Blue River/ Eagle Creek, a higher-elevation riparian and grassland site in the Apache Highlands ecoregion that contains nine native fish species, four amphibian species, and two D-S bird species. Should future climate changes resemble recent changes, our results suggest that these D-S species-rich sites may be somewhat less susceptible than most higher-elevation sites to ongoing climate change.

Other sites with fewer or no drought sensitive species experienced even lower climate impacts from 1991 to 2005. These include the Western Plains of San Augustin, Salt Basin/Northern Brokeoff Mountains, Middle Pecos River, Rio Agua Negra, Salado

Creek, Grulla National Wildlife Refuge, and Pastura Grasslands—all riparian or grasslands sites and all but two located in eastern New Mexico. However, low-elevation areas are likely to be strongly affected by other human impacts related to land use changes, such that the relative resilience of these sites to climate change may be offset or compromised. Thus, we suggest that the assemblage of lower-elevation sites identified in our study be considered as higher-level priorities for attention by regional planners and land managers.

Ecological Changes Linked to Climate Change

We identified 48 cases of recent ecological change in New Mexico and the Southwest that may be linked to climate change and persistent drought. While less than a quarter of these were vetted in the peer-reviewed literature, they are suggestive of emerging ecological trends that warrant additional attention by the conservation and research communities to elucidate the effects of climate change. Furthermore, 22 cases have direct implications for New Mexico's conservation priorities, including cases of widespread forest dieback, declines in endemic species, and exotic species invasions.

A majority of the identified cases of ecological change are from higher-elevation sites, such as the Sierra San Luis/Peloncillo Mountains, Jemez Mountains, Mogollon Divide, Sangre de Cristo Mountains, and the Sacramento Mountains. Of these, two may be especially important: the Jemez Mountains and Sacramento Mountains. Both contain D-S endemic species that already have reported population declines, the Jemez Mountains Salamander and the Sacramento Mountains Salamander. In addition, the Sacramento Mountains have the highest D-S plant species richness, many of which are rare or endemic while the Jemez Mountains are home to the Goat Peak pika, an endemic sub-species of the American pika. These mammals have experienced recent population declines that have been linked to rising temperatures associated with climate change (Beever et al. 2003, NMDGF 2006). High-elevation endemic species, in general, are likely to be at greater risk from climate change given their limited habitat options (Parry et al. 2007). Moreover, the Jemez Mountains was the site of the catastrophic Cerro Grande wildfire of 2000 and they have been described as the epicenter of recent widespread piñon pine forest dieback in the Southwest (C. Allen, *pers. comm.*).

Notably, nine of the eleven key conservation areas identified for high D-S species richness and high climate exposure scores contain D-S species that may already be experiencing the effects of climate change (Table 3, Appendix 3). All nine sites are high-elevation and include not only the Jemez Mountains, but also the Rio Hondo, Southern Sangre de Cristo Mountains, Sierra San Luis/ Peloncillos Mountains, the Northern Black Range, Sacramento Mountains, Mogollon Divide, the Mimbres River, and the Gila River (*cf.* Fig. 5). In contrast to mountain sites, climate change impacts on lower-elevation grassland and riparian sites are less well represented in the observational and published evidence, with most studies pointing to increased invasions by both native (e.g. woody shrub encroachment) and non-native (e.g. exotic grasses in grasslands and salt cedar in riparian areas) species. Overall, the identified cases of climate change-linked ecological change in New Mexico and the greater southwestern U.S. validate many of the results reported in this study.

CONCLUSION

Our study provides perspective on the recent climate change exposure of conservation priorities in New Mexico. We recognize that, to complete a comprehensive vulnerability assessment, this type of retrospective analysis should be followed by a prospective analysis that incorporates an evaluation of adaptive capacity (Schroter et al. 2005). However, future predictions of ecosystem and species' responses to climate change are challenging since they are likely to be non-linear and highly variable, especially when interacting with natural disturbance regimes such as fire, insects, and erosion which are also expected to continue changing with climate (Allen & Breshears 1998, Breshears et al. 2005, Easterling et al. 2000, Brown et al. 2004, Peters et al. 2004, Burkett et al. 2005, Allen 2007, Falk et al. 2007). Moreover, altered disturbance regimes are likely to exacerbate the gradual and sometimes extreme effects of climate change across all New Mexico's major habitat types and may prompt abrupt ecological changes as critical thresholds are crossed (Allen 2007). This may be especially true in landscapes where the ramifications of past forest management (e.g. increased stand density due to fire suppression in forests and woodlands) and land use change (e.g. desertification and fragmentation of grassland habitats) are substantial (Burkett et al. 2005).

Nonetheless, this study shows that a majority of New Mexico's ecoregions and key conservation areas already have experienced average departures of approximately $1^{o}C$ from the baseline period of 1961-1990. Previous work suggests that species may respond to as little as $0.6^{o}C$ of warming and, for each 1 ^{o}C increase in temperature, ecological zones can shift an average of 160 km (Parmesan 2006, Thuiller 2007). As our analysis of recent climate-linked ecological changes illustrates, many species and ecological systems in New Mexico and the southwestern U.S. may already be experiencing the effects of climate change.

Understanding the ramifications of climate change on species and ecological systems has been described as a "grand challenge" in ecology and land management (Thuiller 2007, USFWS 2008). The urgency associated with this challenge is especially acute when considering the synergistic effects of climate change with other major human-related threats (Dale et al. 2001, Hansen et al. 2002, Burkett et al. 2005, Jetz et al. 2007). As a result of these interactions, a number of studies predict increased rates of species extirpation and extinction, rapid loss of habitat, and the reduced capacity of ecosystems to provide critical services with ongoing climate change (Millenium Ecosystem Assessment, Thomas et al. 2004, Mayhew et al. 2007, Williams & Jackson 2007). Furthermore, the emergence of novel future climate regimes, ecological communities, and species interactions further confound conservation planning and natural resources management (Saxon et al. 2005, Williams et al. 2007). Despite these formidable challenges, managers need immediate access to information on climate change impacts and adaptation strategies to better prioritize, manage, and conserve natural resources (U.S. GAO 2007). While numerous reports are becoming available, there is still a paucity of practical climate change information that addresses regional conservation planning and natural resource management priorities (SRAG 2000, Zimmerman et al. 2006, Glick 2006, New Mexico Agency Working Group 2005, Lenart 2007, Gutzler & Garfin 2006, Nelson et al. 2007, Saunders & Easley 2007, Saunders et al. 2008). This study represents one of the first attempts to bridge this gap with its focus on the southwestern United States.

This study specifically assessed the implications of recent climate change on major habitat types and on conservation priorities identified by The Nature Conservancy in New Mexico and the New Mexico Department of Game and Fish using a spatially-explicit framework. While our results are specific to these priorities, the approach can be readily applied to other geographies and management jurisdictions (e.g. the U.S. Forest Service, National Park Service, Bureau of Land Management, or other special designation sites). Furthermore, the relatively simple assessment framework provides a basis for future research and development. Although it does not eliminate the need for future climate scenarios and an evaluation of adaptation capacity, the approach described here diminishes the focus on issues of uncertainty that are implicit to modeled projections of climate change. In sum, our retrospective approach enables natural resource managers to take conservation and management action in the near-term by facilitating critical prioritization and decision-making processes.

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APPENDIX 1. Long-term trend coefficients and probability values for minimum (Tmin) and maximum (Tmax) temperature, mean departures and variation (standard deviation, STD) in temperature (T) and precipitation (P), climate exposure scores, and associated percentile ranks for key conservation areas sorted by ID number and listed by ecoregion (Central and Southern Shortgrass ecoregions are combined). For each ecoregion, conservation areas with the **highest** climate exposure scores are in **bold**; areas with the *lowest* scores are in *italics*.

Chihuahuan Desert			Long-term trend (1970-2006)				1991-2005 Departures				2000-2005 Departures					
Id	Key Conservation Area	Acres	Tmin coef.	Tmin Pvalue	Tmax coef.	Tmax Pvalue	Tmean (C)	Tvar (STD)	Pmean (%)	Pvar (STD)	Tmean (C)	Tvar (STD)	Pmean (%)	Pvar (STD)	Climate Exposure Score	Percent Rank
0	Lower Hondo	32,383	0.04	0.00	0.03	0.00	0.8	2.28	0	0.83	1.0	4.64	-11	1.92	1.660	42.6%
1	Sitting Bull Falls	13,753	0.04	0.00	0.01	0.58	0.6	12.96	-9	1.25	0.6	23.34	-16	3.09	2.192	70.4%
2	Black River	42,051	0.04	0.00	0.02	0.02	0.8	25.90	-3	1.49	0.7	28.98	-6	3.30	2.185	69.1%
3	Cottonwood Springs	914	0.05	0.00	0.03	0.01	0.9	0.00	-3	0.00	1.0	0.00	-8	0.00	1.445	32.1%
4	Blue Spring	5,816	0.04	0.00	0.03	0.00	0.8	0.00	-7	0.00	0.8	0.00	-12	0.00	1.552	38.6%
6	Bottomless Lakes	20,313	0.03	0.00	0.04	0.00	0.8	0.87	2	0.43	1.1	2.18	-4	0.71	1.243	20.4%
8	Pecos River Roswell	48,725	0.05	0.00	0.03	0.01	0.9	9.72	-1	1.69	1.1	17.98	-3	1.64	1.799	49.5%
9	Bitter Lake	24,444	0.04	0.00	0.04	0.00	0.8	4.32	2	0.50	1.1	4.56	-5	0.83	1.392	30.0%
10	Pecos River High Plains	59,610	0.04	0.00	0.03	0.00	0.8	3.68	6	3.09	1.1	4.97	-1	2.16	1.346	26.9%
11	Tularosa Creek	75,328	0.06	0.00	0.03	0.00	1.1	9.63	-3	3.66	1.6	20.42	-10	5.15	2.842	90.8%
12	Lost River	54,799	0.05	0.00	0.02	0.01	0.7	5.50	2	0.00	1.0	8.00	-4	1.00	1.275	23.4%
13	Pecos River Carlsbad	21,361	0.04	0.00	0.04	0.00	0.9	6.34	-2	2.05	1.0	10.40	1	4.19	1.731	46.0%
14	Rio Felix	15,698	0.05	0.00	0.02	0.03	0.8	0.50	-2	0.00	1.0	2.50	-11	0.00	1.532	37.3%
15	Rio Grande Elephant Butte	100,442	0.03	0.00	0.05	0.00	0.9	12.62	8	3.77	1.1	11.88	2	7.38	1.865	53.9%
16	Rio Grande Caballo	37,032	0.04	0.00	0.02	0.01	0.8	14.58	-1	4.32	1.0	17.39	-10	4.31	2.348	75.6%
17	Pecos River Delaware	56,897	0.04	0.00	0.03	0.00	0.9	4.08	-5	1.04	0.9	6.07	-6	1.93	1.711	45.6%
18	Clayton Basin Lakes	18,511	0.04	0.00	0.03	0.00	0.8	2.96	-6	0.71	0.8	3.77	-6	0.71	1.477	33.4%
19	Laguna Plata	20,321	0.05	0.00	0.03	0.00	0.9	0.83	-4	0.83	0.9	1.30	-4	0.43	1.398	30.4%
20	Mimbres River	40,564	0.05	0.00	0.03	0.00	1.0	3.07	0	3.41	1.4	3.61	-12	1.85	2.187	70.0%
21	*Northern Brokeoff Mountains*	*9,884*	*0.01*	*0.15*	*0.01*	*0.18*	*0.3*	*0.00*	*14*	*0.00*	*0.5*	*0.00*	*20*	*0.00*	*-0.650*	0.0%
22	Caballo Lake	4,942	0.05	0.00	0.02	0.03	1.1	0.00	4	0.00	1.5	0.00	-1	0.00	1.426	31.3%
24	Crawford Ranch	4,942	0.04	0.00	0.04	0.00	0.8	0.00	5	0.00	1.1	0.00	-2	0.00	0.986	15.2%
25	TorC West	19,769	0.04	0.00	0.03	0.01	0.9	3.12	0	0.75	1.2	6.57	-13	2.65	1.963	59.1%
27	Crow Flats/Ishee Lakes	74,132	0.05	0.00	0.03	0.00	1.0	1.80	0	1.02	1.2	4.10	-1	1.26	1.476	33.0%
28	Hope	39,538	0.04	0.00	0.02	0.04	0.7	2.06	-7	0.60	0.9	2.78	-11	0.99	1.646	42.1%
29	San Vicente Wash/Walnut Creek	49,422	0.06	0.00	0.01	0.21	0.7	10.32	6	1.26	1.2	8.87	-10	1.86	1.700	44.3%
30	Lanark	4,942	0.05	0.00	0.02	0.02	1.0	0.00	-1	0.00	1.3	0.00	-5	0.00	1.558	39.5%
31	Sitting Bull Falls	9,884	0.03	0.00	0.01	0.71	0.3	10.00	-7	0.50	0.1	15.50	-13	1.00	1.338	26.0%
32	Antelope Ridge	39,538	0.03	0.00	0.01	0.15	0.5	4.42	-3	0.50	0.4	6.51	8	2.05	0.629	6.5%
33	Red Mountain	9,884	0.06	0.00	0.03	0.00	1.0	3.50	-8	0.50	1.4	2.50	-16	0.50	2.260	73.0%
34	Kenzin	14,827	0.06	0.00	0.02	0.03	1.0	2.05	-6	0.82	1.2	2.45	-10	0.94	1.929	56.9%
35	Potrillo Mountains	247,930	0.06	0.00	0.02	0.02	1.0	7.92	-5	2.90	1.2	11.16	-9	4.99	2.449	80.0%

Chihuahuan Desert			Long-term trend (1970-2006)				1991-2005 Departures				2000-2005 Departures					
Id	Key Conservation Area	Acres	Tmin coef.	Tmin Pvalue	Tmax coef.	Tmax Pvalue	Tmean (C)	Tvar (STD)	Pmean (%)	Pvar (STD)	Tmean (C)	Tvar (STD)	Pmean (%)	Pvar (STD)	Climate Exposure Score	Percent Rank
36	Strauss Sinks	14,276	0.05	0.00	0.02	0.02	1.1	2.45	6	0.47	1.4	2.83	4	0.82	1.240	20.0%
37	Bosque Wilderness Area	327,350	0.03	0.00	0.05	0.00	0.9	9.68	13	8.94	1.2	11.71	12	14.41	2.038	62.6%
38	Caballo Mountains/ Southern Jornada	45,783	0.03	0.00	0.04	0.00	0.9	8.74	-6	3.38	1.2	15.70	-19	4.12	2.779	87.3%
39	Dona Ana Mountains	54,389	0.04	0.00	0.03	0.00	0.8	6.79	0	0.75	1.0	8.98	-8	0.98	1.660	43.0%
40	Cedar Mountains	128,683	0.07	0.00	0.03	0.00	1.1	6.04	-2	1.62	1.4	9.01	-10	2.94	2.310	73.4%
41	Hatchet & Alamo Hueco Mountains	350,457	0.05	0.00	0.03	0.00	1.0	7.49	-1	1.69	1.1	12.20	-8	2.57	2.043	63.0%
42	Mimbres Hot Spring	5,209	0.05	0.00	0.03	0.01	1.0	0.00	2	0.00	1.4	0.00	-9	0.00	1.633	41.7%
44	**Florida Mountains**	**99,052**	**0.05**	**0.00**	**0.03**	**0.00**	**0.9**	**14.72**	**-6**	**4.17**	**1.3**	**22.54**	**-10**	**6.56**	**2.915**	**92.1%**
45	Nutt Grasslands	96,249	0.04	0.00	0.02	0.01	0.8	7.88	-6	2.14	1.1	12.97	-13	2.46	2.214	70.8%
46	Robledo & Las Uvas Mountains	174,577	0.05	0.00	0.02	0.01	0.8	8.33	-3	3.95	1.0	14.10	-8	6.71	2.315	74.3%
47	Otero Mesa	692,701	0.03	0.00	0.03	0.00	0.7	27.41	3	4.81	0.9	49.38	-7	8.32	2.798	89.1%
48	Guadalupe Mountains	230,562	0.04	0.00	0.02	0.05	0.6	6.30	-10	2.10	0.6	11.81	-16	3.40	2.088	66.5%
49	Chalk Bluffs	13,031	0.04	0.00	0.03	0.01	0.8	3.30	-2	0.00	0.9	4.08	-2	0.00	1.189	18.2%
50	Remuda / Big SInks	95,859	0.04	0.00	0.03	0.00	0.8	6.58	-3	1.24	0.9	7.19	2	1.58	1.369	28.6%
51	Seven Rivers	119,334	0.03	0.00	0.03	0.00	0.7	11.90	-5	1.50	0.8	16.96	-5	3.33	1.856	53.4%
52	Black River Basin	95,210	0.03	0.00	0.03	0.02	0.7	6.84	-9	0.83	0.6	7.46	-15	1.19	1.845	52.1%
53	Livingstone Ridge	60,957	0.04	0.00	0.03	0.01	0.7	6.83	-7	1.38	0.7	15.36	-5	3.05	1.736	46.9%
54	Hagerman	159,979	0.05	0.00	0.04	0.00	0.9	5.94	3	1.30	1.3	6.70	-2	1.13	1.528	36.9%
55	Northern Jornada Basin	871,356	0.03	0.00	0.04	0.00	0.8	11.48	9	5.31	1.1	17.09	4	9.75	1.893	55.6%
56	San Andres - Oscura Mountains	775,371	0.05	0.00	0.02	0.01	0.7	20.71	0	4.43	1.0	31.18	-9	7.12	2.673	85.2%
57	Tularosa Basin Desert	1,073,621	0.05	0.00	0.02	0.02	0.8	14.95	2	4.28	1.1	19.57	-6	6.97	2.314	73.9%
58	Franklin Mountains	21,755	0.04	0.00	0.02	0.07	0.9	7.23	-3	0.88	1.1	11.53	-13	1.67	2.086	65.6%
59	Organ Mountains	145,604	0.06	0.00	0.03	0.00	1.0	20.55	1	2.70	1.3	33.67	-5	4.32	2.626	83.4%
60	Yeso Hills	19,410	0.04	0.00	0.03	0.00	0.8	0.83	-7	0.43	0.8	0.83	-9	0.71	1.549	38.2%
62	*Salt Basin*	*17,010*	*0.04*	*0.00*	*0.02*	*0.07*	*0.6*	*13.60*	*19*	*1.41*	*0.9*	*20.98*	*24*	*2.62*	*0.196*	*0.8%*
63	Hueco Mountains	33,126	0.04	0.00	0.03	0.00	0.9	1.80	-3	0.58	1.1	6.63	-13	1.21	1.878	54.7%

Arizona-New Mexico Mountains			**Long-term trend (1970-2006)**				**1991-2005 Departures**				**2000-2005 Departures**					
Id	**Key Conservation Area**	**Acres**	**T-MIN coef**	**T-MIN P-val**	**T-MAX coef**	**T-MAX P-val**	**T-MEAN (C)**	**T-STD**	**P-MEAN (%)**	**P-STD**	**T-MEAN (C)**	**T-STD**	**P-MEAN (%)**	**P-STD**	**Climate Exposure Score**	**Portfolio Rank**
65	Blue River/San Francisco River	65,827	0.05	0.00	0.03	0.00	0.9	10.25	1	2.53	1.4	18.43	-9	4.65	2.359	76.5%
67	Gila River	172,839	0.03	0.00	0.01	0.37	0.3	28.78	-3	5.37	0.5	50.81	-15	6.63	2.784	87.8%
68	Rio Hondo	10,941	0.05	0.00	0.02	0.02	0.9	0.00	3	0.00	1.4	0.00	1	0.00	1.138	17.8%
69	Mimbres River	83,682	0.03	0.00	0.01	0.26	0.7	33.28	0	3.32	0.9	47.59	-6	6.31	2.797	88.6%
72	Sitting Bull Falls	3,063	0.01	0.14	0.01	0.54	0.3	0.00	-6	0.00	0.1	0.00	-13	0.00	0.887	12.6%
73	Chuska Mountains	576,249	0.03	0.00	0.02	0.02	0.7	31.08	-5	8.30	0.9	49.94	-11	9.16	3.542	97.8%
74	Mesa Prieta	94,967	0.03	0.00	0.03	0.00	0.8	7.79	5	2.03	1.2	12.44	-8	2.96	1.865	54.3%
75	White Mesa - Todilito Gypsum	41,295	0.03	0.00	0.03	0.00	0.8	18.54	-3	2.49	1.3	36.73	-17	2.77	2.894	91.3%
76	Zuni Mountains	53,603	-0.02	0.10	0.03	0.00	0.2	12.80	0	3.03	0.0	26.21	-15	5.17	1.622	40.8%
77	Prewitt/Thoreau	10,877	-0.02	0.11	0.05	0.00	0.6	9.74	-5	1.89	0.9	12.50	-18	1.25	2.071	64.3%
78	San Felipe - Todilito Limestone	50,521	0.03	0.00	0.04	0.00	0.9	4.02	5	2.51	1.4	10.21	-10	2.23	1.987	60.8%
79	Rio Nutria	19,897	0.01	0.35	0.05	0.00	0.7	4.17	6	1.17	1.1	8.45	-7	0.63	1.342	26.5%
80	Sawtooth/Datils	70,275	0.05	0.00	0.02	0.04	1.0	11.50	2	7.24	1.4	16.89	-13	6.23	2.934	92.6%
81	Sedillo Spring	3,081	0.05	0.00	0.05	0.00	1.1	0.00	3	0.00	1.3	0.00	0	0.00	1.261	21.7%
83	Capitan Mountains	107,044	0.05	0.00	0.02	0.03	0.8	19.33	-10	4.28	1.2	34.30	-20	5.87	3.373	95.6%
84	Mogollon Divide	496,221	0.04	0.00	0.01	0.49	0.4	27.02	-3	4.03	0.8	40.57	-16	5.57	2.802	89.5%
85	Fort Stanton/Rio Bonito Area	14,842	0.08	0.00	0.03	0.00	1.0	2.05	-2	3.09	1.6	4.50	-7	5.25	2.341	75.2%
86	Sierra Blanca	65,710	0.07	0.00	0.03	0.00	1.1	15.91	-12	2.38	1.7	32.67	-23	3.02	3.681	98.6%
87	Mineral Creek	3,087	0.05	0.00	0.00	0.89	0.8	0.00	-4	0.00	1.2	0.00	-15	0.00	1.701	44.7%
88	Sacramento Mountains	581,395	0.03	0.00	0.03	0.00	0.9	25.72	0	6.47	1.3	44.02	-8	7.93	3.293	95.2%
89	Southern Black Range/Cook's Peak	151,387	0.05	0.00	0.03	0.01	0.8	25.86	-9	4.59	1.2	37.46	-18	6.46	3.497	97.3%
90	Northern Black Range	269,855	0.03	0.00	-0.01	0.41	0.3	37.57	-11	3.04	0.5	56.53	-24	5.33	3.393	96.0%
91	Willow Spring, Cienega Ranch	3,081	0.01	0.12	0.07	0.00	1.1	0.00	4	0.00	1.5	0.00	0	0.00	1.311	24.7%
92	San Mateo Mountains Complex	545,131	0.03	0.00	0.03	0.01	0.8	19.35	3	9.55	1.1	30.24	-6	13.22	3.155	93.4%
93	Guadalupe Mountains Escarpment	200,171	0.04	0.00	0.02	0.06	0.8	19.24	-5	6.41	1.0	28.63	-12	9.94	3.165	93.9%
94	Sandia Wilderness	71,795	0.04	0.00	0.04	0.00	1.0	21.07	5	2.64	1.7	31.02	-8	2.93	2.675	85.6%
95	**Mount Taylor**	**52,683**	**0.04**	**0.00**	**0.04**	**0.00**	**1.1**	**14.92**	**-10**	**5.68**	**1.5**	**26.46**	**-25**	**9.22**	**4.023**	**99.5%**
96	Blue Water Creek Canyon	5,642	0.00	0.64	0.02	0.04	0.1	0.00	2	0.00	0.0	0.00	-7	0.00	0.267	1.7%
97	North Plains	224,710	0.04	0.00	0.03	0.01	0.9	7.39	-3	1.83	1.2	9.82	-15	1.94	2.239	71.7%
98	*Western Plains of San Augustin*	*21,218*	*-0.01*	*0.24*	*0.02*	*0.07*	*0.2*	*7.71*	*16*	*2.61*	*0.1*	*11.74*	*7*	*2.24*	*0.081*	*0.4%*
99	Ladder Ranch	184,162	0.05	0.00	0.03	0.01	1.0	15.39	-7	2.59	1.5	23.04	-15	3.31	2.985	93.0%
100	Hillsboro West	10,135	0.04	0.00	0.03	0.00	0.8	14.38	-14	0.47	1.1	22.95	-23	0.82	2.840	90.4%

102	Magdalena Mountains	107,182	0.03	0.00	0.05	0.00	1.1	15.35	-5	3.29	1.5	28.66	-13	6.81	3.218	94.7%
103	Sevilleta NWR	269,339	0.05	0.00	0.06	0.00	1.4	17.90	4	1.94	1.5	11.13	-3	3.15	2.364	76.9%

Colorado Plateau

			Long-term trend (1970-2006)				1991-2005 Departures				2000-2005 Departures					
Id	**Key Conservation Area**	**Acres**	**T-MIN coef**	**T-MIN P-val**	**T-MAX coef**	**T-MAX P-val**	**T-MEAN (C)**	**T-STD**	**P-MEAN (%)**	**P-STD**	**T-MEAN (C)**	**T-STD**	**P-MEAN (%)**	**P-STD**	**Climate Exposure Score**	**Portfolio Rank**
104	Canyon of the Ancients	17,805	0.05	0.00	0.04	0.00	1.0	7.70	-6	1.96	1.3	10.68	-19	2.56	2.665	84.7%
105	Lower Animas River	18,767	0.06	0.00	0.05	0.00	1.2	13.24	-2	1.60	1.7	12.09	-11	1.77	2.625	83.0%
106	Standing Rock	81,629	0.03	0.00	0.04	0.00	1.1	15.54	5	1.28	1.5	25.84	1	2.69	2.109	67.3%
107	Chaco Canyon	166,805	0.04	0.00	0.04	0.00	1.1	11.05	-1	1.36	1.5	16.71	-10	2.23	2.474	80.8%
108	Bisti / De-Na-Zin	211,442	0.05	0.00	0.03	0.00	1.0	10.23	6	5.01	1.3	14.88	4	6.97	2.045	63.4%
109	Table Mesa	233,887	0.07	0.00	0.03	0.01	1.2	7.33	3	4.90	1.5	9.22	-6	4.45	2.423	79.1%
110	San Juan River (Shiprock)	155,921	0.06	0.00	0.04	0.00	1.1	14.77	-1	2.73	1.5	14.15	-11	3.56	2.697	86.5%
111	Puerco River	8,595	0.03	0.00	0.04	0.00	1.0	3.70	-3	1.30	1.5	5.54	-16	3.39	2.403	78.6%
112	Zuni River	47,523	0.03	0.00	0.06	0.00	1.1	2.71	-4	0.66	1.6	3.86	-17	0.74	2.379	77.8%
113	Lower La Plata	59,340	0.05	0.00	0.04	0.00	1.0	6.49	-3	1.73	1.4	12.07	-11	1.74	2.239	72.1%
114	Angel Peak	25,941	0.07	0.00	0.03	0.01	1.2	2.77	-6	0.43	1.4	3.91	-8	0.00	2.074	65.2%
116	Potter Canyon	3,706	0.07	0.00	0.04	0.00	1.3	0.00	-6	0.00	1.5	0.00	-8	0.00	2.058	63.9%
117	Simon Canyon	14,816	0.07	0.00	0.05	0.00	1.4	3.83	-6	1.73	1.8	7.43	-14	1.73	2.811	90.0%
118	**Carracas Mesa / Navajo Reservoir**	**43,142**	**0.06**	**0.00**	**0.04**	**0.00**	**1.3**	**13.87**	**-3**	**1.51**	**1.8**	**15.29**	**-12**	**2.87**	**2.908**	**91.7%**
119	*Ceja Pelon Mesa*	*33,302*	*0.03*	*0.00*	*0.03*	*0.00*	*0.9*	*5.27*	*3*	*1.73*	*1.2*	*10.70*	*-9*	*1.75*	*1.850*	*52.6%*
120	San Juan River (Carracas)	3,563	0.07	0.00	0.04	0.00	1.2	17.00	0	1.00	1.8	22.00	-8	1.00	2.644	83.9%
121	Los Pinos River	1,514	0.08	0.00	0.04	0.00	1.3	0.00	-5	0.00	1.8	0.00	-14	0.00	2.389	78.2%
122	Zuni	48,266	0.01	0.45	0.05	0.00	0.8	8.17	2	4.19	1.1	12.44	-11	5.90	2.317	74.7%

Southern Rocky Mountains

			Long-term trend (1970-2006)				1991-2005 Departures				2000-2005 Departures					
Id	**Key Conservation Area**	**Acres**	**T-MIN coef**	**T-MIN P-val**	**T-MAX coef**	**T-MAX P-val**	**T-MEAN (C)**	**T-STD**	**P-MEAN (%)**	**P-STD**	**T-MEAN (C)**	**T-STD**	**P-MEAN (%)**	**P-STD**	**Climate Exposure Score**	**Portfolio Rank**
125	Canyon Largo	14,826	0.06	0.00	0.04	0.00	1.1	3.27	0	0.43	1.5	5.43	-7	0.71	1.929	56.5%
126	Chacon Canyon	62,272	0.04	0.00	0.04	0.00	1.0	6.33	0	1.89	1.5	14.31	-9	2.73	2.218	71.3%
127	Conejos River	28,839	0.06	0.00	0.03	0.01	1.1	19.94	8	1.58	1.8	33.04	-5	2.80	2.509	81.7%
128	Coyote Creek	121,576	0.05	0.00	0.01	0.32	0.7	17.60	9	3.51	1.1	27.79	-1	6.18	1.979	60.0%
129	Culebra Range	167,272	0.05	0.00	0.02	0.01	0.9	18.76	10	5.30	1.4	30.86	1	8.28	2.443	79.5%
130	Jemez Canyon Reservoir	17,790	0.03	0.00	0.04	0.00	0.9	3.74	1	0.82	1.2	6.02	-12	1.41	1.821	50.4%
131	**Jemez Mountains**	**1,002,246**	**0.04**	**0.00**	**0.05**	**0.00**	**1.0**	**49.32**	**-3**	**4.13**	**1.8**	**84.74**	**-17**	**4.64**	**4.471**	**100.0%**
132	Ojo Caliente	542,659	0.04	0.00	0.04	0.00	1.0	18.94	9	4.45	1.5	26.36	-7	6.06	2.611	82.1%
133	Punche Valley	317,792	0.04	0.00	0.04	0.00	0.9	20.50	7	3.81	1.5	23.81	-11	5.35	2.688	86.0%
134	Questa	14,826	0.04	0.00	0.05	0.00	0.8	4.19	11	1.41	1.5	9.27	-10	2.16	1.680	43.9%
135	Rio Chama	513,854	0.05	0.00	0.05	0.00	1.1	25.93	2	5.04	1.7	38.78	-12	4.44	3.416	96.9%
136	Rio Grande Gorge	5,931	0.03	0.00	0.05	0.00	0.9	7.50	12	0.00	1.7	14.50	-9	1.00	1.738	47.3%
137	Rio Hondo	44,479	0.07	0.00	0.04	0.00	1.4	32.02	2	5.04	2.2	53.80	-8	5.29	3.957	99.1%
138	*Sapello/Mora Valleys*	*44,479*	*0.03*	*0.00*	*0.03*	*0.00*	*1.0*	*2.68*	*12*	*1.79*	*1.6*	*4.63*	*1*	*2.80*	*1.382*	*29.1%*

139	Southern Sangre de Cristo Mountains	385,474	0.04	0.00	0.02	0.02	0.5	56.59	3	5.02	0.7	93.90	-10	7.13	3.639	98.2%
140	Taos Pueblo	14,827	0.04	0.00	0.03	0.00	0.7	11.56	3	0.47	1.0	17.52	-11	0.47	1.734	46.5%
141	Vermejo Park/Upper Purgatoire	841,581	0.04	0.00	0.02	0.02	0.7	20.77	9	2.42	1.2	35.15	-4	4.22	2.100	66.9%
142	Agua Caliente	17,792	0.05	0.00	0.02	0.08	0.7	5.50	12	4.90	1.0	8.57	1	6.76	1.477	33.9%
Apache Highlands			**Long-term trend (1970-2006)**				**1991-2005 Departures**				**2000-2005 Departures**					
Id	**Key Conservation Area**	**Acres**	**T-MIN coef**	**T-MIN P-val**	**T-MAX coef**	**T-MAX P-val**	**T-MEAN (C)**	**T-STD**	**P-MEAN (%)**	**P-STD**	**T-MEAN (C)**	**T-STD**	**P-MEAN (%)**	**P-STD**	**Climate Exposure Score**	**Portfolio Rank**
143	*Blue River/Eagle Creek*	*176,461*	*0.06*	*0.00*	*0.01*	*0.13*	*0.8*	*10.73*	*0*	*2.38*	*1.3*	*18.97*	*-11*	*3.12*	*1.506*	*35.6%*
144	Blue Creek/Lemmons Canyon	12,383	0.08	0.00	-0.01	0.47	0.8	4.79	-11	1.94	1.3	8.45	-25	3.07	2.785	88.2%
145	Knight Canyon/Thompson Canyon	63,120	0.04	0.00	0.03	0.00	0.7	16.55	-5	1.39	1.0	12.00	-15	1.65	2.249	72.6%
146	Langford Mountains	21,030	0.04	0.00	0.03	0.01	0.8	11.50	-1	1.17	1.2	5.04	-11	1.17	1.982	60.4%
147	Lordsburg Playa	164,925	0.04	0.00	0.04	0.00	0.9	13.02	-2	0.79	1.1	18.31	-12	1.06	2.160	68.6%
148	Big Hatchet Mountains	25,975	0.05	0.00	0.03	0.00	0.9	7.85	-3	1.07	1.0	13.40	-11	1.07	1.949	57.8%
149	**Sierra San Luis/Peloncillos Mountains**	**668,441**	**0.06**	**0.00**	**0.04**	**0.00**	**1.1**	**13.61**	**-9**	**2.74**	**1.7**	**28.55**	**-18**	**4.34**	**3.415**	**96.5%**
Southern Shortgrass Prairie			**Long-term trend (1970-2006)**				**1991-2005 Departures**				**2000-2005 Departures**					
Id	**Key Conservation Area**	**Acres**	**T-MIN coef**	**T-MIN P-val**	**T-MAX coef**	**T-MAX P-val**	**T-MEAN (C)**	**T-STD**	**P-MEAN (%)**	**P-STD**	**T-MEAN (C)**	**T-STD**	**P-MEAN (%)**	**P-STD**	**Climate Exposure Score**	**Portfolio Rank**
123	Mesa de Maya **(Central Shortgrass Prairie)**	270,121	0.01	0.15	0.03	0.00	0.5	8.64	15	2.59	0.7	18.40	5	3.60	0.847	11.7%
150	Canadian River - Punta de Agua	51,871	0.02	0.03	0.00	0.83	0.3	11.46	7	1.92	0.5	13.02	0	2.66	0.900	13.4%
152	Winkler Sandhills	44,009	0.04	0.00	0.03	0.00	0.6	4.83	-7	1.07	0.8	7.36	-3	2.01	1.416	30.8%
153	Milnesand	177,942	0.03	0.00	0.01	0.37	0.5	6.90	1	2.43	0.7	5.53	3	2.42	0.984	14.7%
154	*Grulla NWR*	*46,135*	*0.02*	*0.00*	*0.02*	*0.05*	*0.6*	*4.56*	*10*	*0.57*	*0.7*	*9.15*	*10*	*0.87*	*0.340*	*2.6%*
155	Tramperos Creek Shortgrass	393,111	0.02	0.00	0.02	0.11	0.6	10.45	9	3.09	0.8	9.35	2	5.22	1.256	21.3%
156	Sand Springs	476,829	0.02	0.00	0.01	0.53	0.4	14.67	8	1.91	0.6	22.31	2	2.70	1.069	16.9%
157	Blackwater Draw	241,941	0.04	0.00	0.02	0.01	0.8	12.59	5	2.21	1.0	15.60	2	3.28	1.535	37.8%
158	Mt. Dora Shortgrass	342,678	0.03	0.00	0.02	0.02	0.7	5.76	6	2.13	1.0	6.74	-5	2.88	1.464	32.6%
159	Lower Dry Cimarron Mesas	312,568	0.01	0.06	0.03	0.00	0.5	8.75	9	3.62	0.6	15.65	-2	4.19	1.263	22.1%
160	MescaleroCaprock	676,469	0.04	0.00	0.01	0.31	0.6	25.00	-3	2.20	0.7	28.12	-3	2.08	1.885	55.2%

Southern Shortgrass Prairie			Long-term trend (1970-2006)				1991-2005 Departures				2000-2005 Departures					
Id	Key Conservation Area	Acres	T-MIN coef	T-MIN P-val	T-MAX coef	T-MAX P-val	T-MEAN (C)	T-STD	P-MEAN (%)	P-STD	T-MEAN (C)	T-STD	P-MEAN (%)	P-STD	Climate Exposure Score	Portfolio Rank
161	Antelope Ridge	260,908	0.04	0.00	0.02	0.05	0.7	8.59	-2	1.91	0.7	10.45	3	3.20	1.332	25.6%
162	Ute - Tramperos Canyons	143,240	0.02	0.00	0.01	0.25	0.5	9.59	5	1.04	0.7	16.45	-4	2.61	1.253	20.8%
163	Bueyeros Grasslands	380,504	0.02	0.00	0.02	0.10	0.5	10.74	8	1.42	0.7	20.63	3	2.44	0.988	15.6%
164	Querecho Plains	289,390	0.05	0.00	0.03	0.01	0.9	13.56	-1	2.10	1.0	12.40	-3	4.02	1.993	61.3%
165	Pasamonte Shortgrass	630,846	0.02	0.00	0.03	0.01	0.7	8.77	5	2.15	1.0	15.74	-7	2.58	1.703	45.2%
166	Lone Wolf Sandhills	378,216	0.04	0.00	0.03	0.01	0.8	5.93	8	2.21	1.1	7.76	5	1.38	1.097	17.3%
167	Sierra Grande	29,189	0.01	0.17	0.04	0.00	0.7	5.24	1	2.35	1.0	9.78	-12	3.11	1.833	50.8%
168	Carpenter Mesa	369,999	0.03	0.00	0.03	0.01	0.7	10.61	10	3.49	1.1	19.80	7	3.13	1.274	23.0%
170	Upper Dry Cimarron Mesas	239,691	0.02	0.00	0.03	0.01	0.8	20.93	9	4.81	1.5	46.51	-5	5.33	2.657	84.3%
171	Raton Mesa and Volcanoes	210,450	0.03	0.00	0.03	0.01	0.8	6.93	11	3.40	1.2	11.40	-1	4.18	1.499	34.7%
172	Canadian River Gorge	222,501	0.04	0.00	0.02	0.08	0.8	11.08	8	1.19	1.2	21.59	-1	2.47	1.602	40.0%
173	Chico Creek Grasslands	205,893	0.04	0.00	0.03	0.02	0.9	7.63	6	1.95	1.3	13.29	-9	2.63	1.927	56.0%
174	San Juan de Dios	465,131	0.02	0.00	0.03	0.01	0.5	6.53	12	2.28	0.8	10.47	7	4.20	0.764	9.1%
175	Bell Ranch Grasslands	460,924	0.03	0.00	0.03	0.00	0.8	9.96	8	2.08	1.2	18.36	4	3.22	1.389	29.5%
176	Canyon Largo	368,463	0.03	0.00	0.03	0.00	0.8	10.01	6	3.31	1.1	19.09	-2	4.58	1.836	51.3%
177	Ocate Creek Grasslands	219,545	0.04	0.00	0.03	0.01	0.8	5.56	9	1.98	1.2	8.90	-4	2.80	1.511	36.0%
178	Miami	182,052	0.04	0.00	0.03	0.01	0.7	20.50	9	1.77	1.0	37.00	-6	3.31	1.950	58.2%
179	Mora River Grasslands	491,152	0.03	0.00	0.04	0.00	0.9	11.05	9	4.12	1.4	19.62	-4	3.92	2.072	64.7%
180	Turkey Mountains Grasslands	564,595	0.03	0.00	0.03	0.00	0.8	13.17	9	2.86	1.2	21.10	-5	2.76	1.800	50.0%
181	Pastura Grasslands	523,615	0.01	0.12	0.02	0.03	0.5	6.89	16	3.68	0.6	6.31	11	4.47	0.441	3.9%
182	Milagro Springs	307,336	0.01	0.10	0.04	0.00	0.6	10.36	15	4.30	0.9	11.27	6	4.18	1.021	16.0%
183	Capitan / Sacremento Mountain Foothills	445,035	0.04	0.00	0.02	0.04	0.7	19.09	-4	2.07	1.0	34.64	-15	3.05	2.617	82.6%
184	Mora River Valley	238,866	0.05	0.00	0.01	0.18	0.8	18.99	8	2.65	1.1	28.86	-3	4.19	1.973	59.5%
185	Big Juan (Juan Largo)	371,927	0.02	0.02	-0.01	0.46	0.2	10.12	7	6.11	0.2	16.56	-4	7.27	1.353	27.3%
186	Pecos Canyon and Mesas	244,939	0.03	0.00	0.05	0.00	0.9	12.50	36	13.12	1.2	20.57	28	15.65	1.277	23.9%
187	Encino Lake	24,042	0.02	0.01	0.04	0.00	0.8	5.90	13	2.00	1.0	9.20	10	1.72	0.698	8.2%
188	Duran Grasslands	418,514	0.01	0.04	0.03	0.02	0.5	13.92	11	2.14	0.7	20.67	6	2.48	0.893	13.0%
189	Encino Grasslands	224,449	0.02	0.01	0.04	0.00	0.7	8.11	10	6.45	0.9	13.37	2	9.94	1.853	53.0%
190	Pintada Arroyo	307,311	0.02	0.01	0.04	0.00	0.7	10.39	4	9.35	0.8	13.63	-9	13.22	2.710	86.9%
191	Duran Lakes	12,870	0.02	0.00	0.04	0.00	0.8	3.56	14	0.82	1.0	5.56	10	0.47	0.478	4.7%

Southern Shortgrass Prairie			**Long-term trend (1970-2006)**				**1991-2005 Departures**				**2000-2005 Departures**					
Id	**Key Conservation Area**	**Acres**	**T-MIN coef**	**T-MIN P-val**	**T-MAX coef**	**T-MAX P-val**	**T-MEAN (C)**	**T-STD**	**P-MEAN (%)**	**P-STD**	**T-MEAN (C)**	**T-STD**	**P-MEAN (%)**	**P-STD**	**Climate Exposure Score**	**Portfolio Rank**
192	Estancia Grasslands	193,907	0.02	0.01	0.04	0.00	0.8	8.90	9	2.83	0.9	13.47	-3	5.04	1.605	40.4%
193	Estancia Basin Wetlands	92,105	0.01	0.23	0.04	0.00	0.5	12.89	10	1.78	0.7	19.31	-6	1.56	1.263	22.6%
194	Dunken	11,442	0.03	0.00	0.02	0.01	0.7	0.82	-5	0.94	1.0	2.49	-15	0.82	1.775	48.2%
195	Monument Draw	30,825	0.05	0.00	0.02	0.03	0.7	3.77	1	0.47	0.9	6.36	3	0.96	1.027	16.5%
197	Logan	4,583	0.04	0.00	0.01	0.43	0.7	0.00	9	0.00	1.0	0.00	3	0.00	0.581	5.2%
198	*Charco Creek Mesas*	*6,407*	*0.02*	*0.00*	*0.02*	*0.06*	*0.6*	*0.50*	*12*	*0.50*	*0.9*	*1.00*	*9*	*0.50*	*0.292*	*2.1%*
199	Yates Carbonate Glades	44,679	0.02	0.00	0.01	0.20	0.7	3.74	6	0.82	0.9	6.24	0	1.25	0.974	14.3%
201	Mescalero Sands	285,009	0.05	0.00	0.03	0.00	1.0	5.73	0	1.83	1.2	8.70	-2	2.71	1.844	51.7%
202	Dry Cimarron River	210,970	0.01	0.11	0.03	0.00	0.6	11.89	3	4.67	0.9	25.85	-10	6.08	2.186	69.5%
203	Carrizozo Creek	123,925	0.02	0.00	0.03	0.01	0.6	2.61	11	0.93	0.9	6.73	0	1.27	0.793	10.0%
204	Vermejo River	26,593	0.03	0.00	0.02	0.04	0.5	10.51	9	2.49	0.8	17.08	-7	4.34	1.502	35.2%
205	Ponil Creek	148,688	0.04	0.00	0.02	0.03	0.6	20.10	12	3.25	1.0	29.00	2	5.06	1.665	43.4%
206	Rayado Creek	133,327	0.05	0.00	0.02	0.07	0.8	18.81	9	2.22	1.2	31.22	-4	3.27	1.999	61.7%
207	Coyote Creek	149,847	0.04	0.00	0.01	0.13	0.7	18.89	9	1.62	1.1	31.22	-3	3.18	1.756	47.8%
208	Mora River	49,197	0.03	0.00	0.04	0.00	0.8	10.49	12	2.83	1.3	18.44	0	2.68	1.556	39.1%
209	Conchas River	137,876	0.03	0.00	0.05	0.00	0.9	7.43	7	3.01	1.2	15.40	-6	4.53	1.947	57.3%
210	Conchas River	23,546	0.03	0.00	0.03	0.00	0.7	4.27	14	2.17	1.0	6.10	12	2.96	0.599	5.6%
211	Conchas River	28,589	0.04	0.00	0.04	0.00	0.9	5.85	2	3.14	1.3	8.30	-8	6.05	2.154	67.8%
212	Middle Canadian River	88,748	0.04	0.00	0.02	0.03	0.8	10.84	8	1.28	1.2	17.49	2	4.09	1.478	34.3%
213	Middle Canadian River	59,643	0.03	0.00	0.03	0.02	0.8	11.00	11	1.56	1.2	15.12	6	2.88	1.202	19.1%
214	Ute Creek	272,368	0.02	0.00	0.02	0.11	0.6	16.08	6	3.06	0.8	26.16	2	5.29	1.624	41.3%
215	Ute Creek	29,466	0.03	0.00	0.02	0.07	0.7	4.78	10	1.40	0.9	10.31	4	2.67	0.916	13.9%
216	Charo Creek	96,405	0.02	0.01	0.02	0.07	0.5	8.75	16	2.62	0.8	12.27	14	3.30	0.453	4.3%
217	Revuelto Creek	32,429	0.04	0.00	0.03	0.02	0.8	7.16	10	0.94	1.2	14.82	3	1.95	1.206	19.5%
218	Lower Canadian River	27,631	0.03	0.00	0.00	0.88	0.3	20.76	8	0.47	0.4	27.80	2	0.94	0.834	11.3%
219	Lower Canadian River Tributaries	57,916	0.02	0.00	0.01	0.39	0.5	6.79	7	0.94	0.7	11.01	0	1.53	0.880	12.1%
220	Beaver River	204,737	0.02	0.01	0.03	0.00	0.7	6.43	8	2.22	1.0	6.94	-4	3.05	1.368	28.2%
221	Beaver River	22,222	0.02	0.00	0.03	0.01	0.7	1.10	9	0.00	0.9	3.66	-3	0.00	0.814	10.8%
222	**Pecos River Headwaters**	**144,717**	**0.05**	**0.00**	**0.03**	**0.01**	**0.8**	**40.73**	**5**	**4.18**	**1.1**	**65.58**	**-7**	**5.77**	**3.202**	**94.3%**
223	Upper Pecos River	60,224	0.03	0.00	0.06	0.00	0.9	20.20	30	15.44	1.3	36.66	23	18.51	2.356	76.0%
224	Tecolote Creek	107,335	0.03	0.00	0.06	0.00	1.0	18.53	8	3.84	1.5	29.81	-4	4.85	2.506	81.3%
225	Tecolote Creek	10,327	0.03	0.00	0.06	0.00	0.9	20.27	32	3.64	1.3	33.44	25	3.77	0.620	6.0%
226	Gallinas River	138,921	0.03	0.00	0.05	0.00	0.9	8.82	5	2.96	1.3	18.35	-6	4.24	2.086	66.0%
227	Gallinas River	38,206	0.02	0.00	0.06	0.00	1.0	23.69	14	6.61	1.4	38.91	6	8.74	2.450	80.4%
228	Gallinas River	30,846	0.03	0.00	0.06	0.00	1.0	8.49	4	0.69	1.2	20.69	-9	1.53	1.954	58.6%
229	Gallinas River	27,362	0.03	0.00	0.06	0.00	1.0	8.17	19	4.37	1.3	11.05	10	5.87	1.280	24.3%

Southern Shortgrass Prairie			**Long-term trend (1970-2006)**				**1991-2005 Departures**				**2000-2005 Departures**					
Id	**Key Conservation Area**	**Acres**	**T-MIN coef**	**T-MIN P-val**	**T-MAX coef**	**T-MAX P-val**	**T-MEAN (C)**	**T-STD**	**P-MEAN (%)**	**P-STD**	**T-MEAN (C)**	**T-STD**	**P-MEAN (%)**	**P-STD**	**Climate Exposure Score**	**Portfolio Rank**
230	Middle Pecos River	21,766	0.01	0.27	0.04	0.00	0.6	2.00	12	0.00	0.8	0.00	5	1.00	0.348	3.0%
231	Middle Pecos River	60,989	0.02	0.00	0.03	0.01	0.5	7.17	11	1.20	0.8	10.83	2	2.23	0.768	9.5%
232	Middle Pecos River	73,063	0.04	0.00	0.03	0.01	0.7	10.26	10	2.06	1.0	12.20	-1	3.00	1.325	25.2%
233	*Rio Agua Negra*	*6,995*	*0.00*	*0.82*	*0.04*	*0.00*	*0.4*	*0.00*	*9*	*0.00*	*0.6*	*0.00*	*3*	*0.00*	*0.208*	*1.3%*
234	El Rito Creek	15,715	0.00	0.56	0.04	0.00	0.5	6.96	11	1.12	0.8	11.28	5	1.58	0.654	7.8%
235	Salado Creek	447,716	0.01	0.03	0.02	0.08	0.4	5.16	12	2.84	0.6	8.72	5	4.50	0.635	6.9%
236	Taiban Creek	436,895	0.03	0.00	0.02	0.03	0.6	13.75	4	2.70	0.7	18.19	0	3.02	1.433	31.7%
237	Taiban Creek	10,286	0.04	0.00	0.02	0.04	0.6	0.00	9	0.00	0.9	0.00	-3	0.50	0.719	8.6%
238	Yeso Creek	4,625	0.03	0.00	0.02	0.02	0.5	0.00	9	0.00	0.8	0.00	-4	0.00	0.642	7.3%
239	Arroyo de la Mora	298,665	0.03	0.00	0.01	0.20	0.5	9.25	12	1.66	0.7	13.39	2	2.05	0.810	10.4%
240	Arroyo del Macho	122,308	0.02	0.01	0.01	0.62	0.4	7.16	12	0.48	0.4	8.37	5	4.39	0.419	3.4%
241	Arroyo del Macho	69,958	0.02	0.00	0.00	0.69	0.3	25.07	10	2.60	0.3	38.43	-1	2.03	1.195	18.6%
242	Arroyo del Macho	192,377	0.04	0.00	0.01	0.34	0.5	21.92	-2	3.88	0.6	37.33	-9	5.81	2.365	77.3%
243	Arroyo del Macho	178,045	0.02	0.01	-0.01	0.44	0.3	23.77	7	2.83	0.3	38.69	0	5.28	1.515	36.5%
244	Salt Creek (Pecos)	34,910	0.03	0.00	0.03	0.01	0.7	6.02	3	0.68	0.8	8.48	-8	0.99	1.353	27.8%
245	Rio Hondo	73,690	0.04	0.00	0.03	0.01	0.8	4.15	-1	1.85	1.2	8.20	-9	4.20	2.008	62.1%
246	Rio Penasco	62,075	0.03	0.00	0.03	0.01	0.7	11.16	-5	2.79	0.9	11.63	-11	4.70	2.157	68.2%
247	Cimarron River	25,588	0.04	0.00	0.03	0.01	0.9	9.60	8	1.60	1.4	18.22	-5	1.97	1.790	49.1%
248	Upper Canadian River	40,365	0.04	0.00	0.03	0.02	0.7	12.86	9	1.87	1.0	23.33	-7	4.01	1.785	48.6%

APPENDIX 2. Key conservation areas ranked by drought-sensitive (D-S) species richness and climate exposure. Areas were sorted first by number of D-S taxonomic groups, second by number of D-S species, and third by the descending percent rank of it's climate exposure score. Significant increasing trends (1970-2006) in minimum (T*min*) and maximum (T*max*) temperatures are indicated by *.

Rank	**Id**	**Key Conservation Area**	**Ecoregion**	**# D-S Birds**	**# D-S Mammals**	**# D-S Plants**	**# D-S Reptiles**	**# D-S Inverte-brates**	**# Amph-ibians**	**# Fish**	**# D-S Taxa**	**Total # D-S Species**	**Percent Rank**	**T*min***	**T*max***
1	149	Sierra San Luis/Peloncillos Mountains	Apache Highlands	6	7	0	2	0	3	9	5	27	96.5%	*	*
2	84	Mogollon Divide	Arizona - New Mexico Mountains	2	1	4	0	0	1	6	5	14	89.5%	*	
3	131	Jemez Mountains	Southern Rocky Mountains	5	2	0	0	1	1	3	5	12	100.0%	*	*
4	139	Southern Sangre de Cristo Mountains	Southern Rocky Mountains	7	2	1	0	1	0	1	5	12	98.2%	*	*
5	88	Sacramento Mountains	Arizona - New Mexico Mountains	1	1	7	0	0	1	1	5	10	95.2%	*	*
6	9	Bitter Lake	Chihuahuan Desert	2	1	1	0	1	0	5	5	10	30.0%	*	*
7	86	Sierra Blanca	Arizona - New Mexico Mountains	2	0	5	0	0	1	1	5	9	98.6%	*	*
8	90	Northern Black Range	Arizona - New Mexico Mountains	1	1	2	0	0	1	3	5	8	96.0%	*	
9	137	Rio Hondo	Southern Rocky Mountains	1	2	1	0	1	0	1	5	6	99.1%	*	*
10	69	Mimbres River	Arizona - New Mexico Mountains	1	1	1	0	0	1	2	5	6	88.6%	*	
11	8	Pecos River Roswell	Chihuahuan Desert	1	1	1	0	0	0	15	4	18	49.5%	*	*
12	67	Gila River	Arizona - New Mexico Mountains	6	1	0	0	0	1	4	4	12	87.8%	*	
13	65	Blue River/San Francisco River	Arizona - New Mexico Mountains	1	0	1	0	0	3	7	4	12	76.5%	*	*
14	135	Rio Chama	Southern Rocky Mountains	2	1	0	0	0	1	4	4	8	96.9%	*	*
15	92	San Mateo Mountains Complex	Arizona - New Mexico Mountains	1	1	0	0	0	2	1	4	5	93.4%	*	*
16	2	Black River	Chihuahuan Desert	1	0	4	0	0	0	10	3	15	69.1%	*	*
17	143	Blue River/Eagle Creek	Apache Highlands	2	0	0	0	0	4	9	3	15	35.6%	*	
18	15	Rio Grande Elephant Butte	Chihuahuan Desert	3	1	0	0	0	0	5	3	9	53.9%	*	*
19	59	Organ Mountains	Chihuahuan Desert	3	1	2	0	0	0	0	3	6	83.4%	*	*
20	132	Ojo Caliente	Southern Rocky Mountains	1	2	0	0	0	0	3	3	6	82.1%	*	*
21	6	Bottomless Lakes	Chihuahuan Desert	0	1	1	0	0	0	3	3	5	20.4%	*	*
22	89	Southern Black Range/Cook's Peak	Arizona - New Mexico Mountains	1	0	1	0	1	0	0	3	3	97.3%	*	*
23	12	Lost River	Chihuahuan Desert	1	0	0	0	0	1	1	3	3	23.4%	*	*
24	93	Guadalupe Mountains Escarpment	Arizona - New Mexico Mountains	2	0	5	0	0	0	0	2	7	93.9%	*	
25	48	Guadalupe Mountains	Chihuahuan Desert	2	0	5	0	0	0	0	2	7	66.5%	*	*

Rank	Id	Key Conservation Area	Ecoregion	# D-S Birds	# D-S Mammals	# D-S Plants	# D-S Reptiles	# D-S Inverte-brates	# Amph-ibians	# Fish	# D-S Taxa	Total # D-S Species	Percent Rank	T*min*	T*max*
26	16	Rio Grande Caballo	Chihuahuan Desert	0	0	0	0	1	0	5	2	6	75.6%	*	*
27	56	San Andres - Oscura Mountains	Chihuahuan Desert	4	1	0	0	0	0	0	2	5	85.2%	*	*
28	222	Pecos River Headwaters	Southern Shortgrass Prairie	3	0	0	0	0	0	1	2	4	94.3%	*	*
29	41	Hatchet & Alamo Hueco Mountains	Chihuahuan Desert	0	2	0	0	2	0	0	2	4	63.0%	*	*
30	37	Bosque Wilderness Area	Chihuahuan Desert	3	1	0	0	0	0	0	2	4	62.6%	*	*
31	52	Black River Basin	Chihuahuan Desert	3	0	1	0	0	0	0	2	4	52.1%	*	*
32	94	Sandia Wilderness	Arizona - New Mexico Mountains	2	1	0	0	0	0	0	2	3	85.6%	*	*
33	83	Capitan Mountains	Arizona - New Mexico Mountains	0	0	1	0	0	1	0	2	2	95.6%	*	*
34	99	Ladder Ranch	Arizona - New Mexico Mountains	0	0	0	0	0	1	1	2	2	93.0%	*	*
35	47	Otero Mesa	Chihuahuan Desert	0	1	1	0	0	0	0	2	2	89.1%	*	*
36	246	Rio Penasco	Southern Shortgrass Prairie	0	0	1	0	0	0	1	2	2	68.2%	*	*
37	226	Gallinas River	Southern Shortgrass Prairie	1	0	0	0	0	0	1	2	2	66.0%	*	*
38	166	Lone Wolf Sandhills	Southern Shortgrass Prairie	1	1	0	0	0	0	0	2	2	17.3%	*	*
39	123	Mesa de Maya	Central Shortgrass Prairie	0	0	0	0	0	1	1	2	2	11.7%		*
40	13	Pecos River Carlsbad	Chihuahuan Desert	0	0	0	0	0	0	14	1	14	46.0%	*	*
41	17	Pecos River Delaware	Chihuahuan Desert	0	0	0	0	0	0	12	1	12	45.6%	*	*
42	0	Lower Hondo	Chihuahuan Desert	0	0	0	0	0	0	8	1	8	42.6%	*	*
43	14	Rio Felix	Chihuahuan Desert	0	0	0	0	0	0	6	1	6	37.3%	*	*
44	10	Pecos River High Plains	Chihuahuan Desert	0	0	0	0	0	0	6	1	6	26.9%	*	*
45	4	Blue Spring	Chihuahuan Desert	0	0	0	0	0	0	5	1	5	38.6%	*	*
46	232	Middle Pecos River	Southern Shortgrass Prairie	0	0	0	0	0	0	5	1	5	25.2%	*	*
47	231	Middle Pecos River	Southern Shortgrass Prairie	0	0	0	0	0	0	5	1	5	9.5%	*	*
48	230	Middle Pecos River	Southern Shortgrass Prairie	0	0	0	0	0	0	5	1	5	3.0%		*
49	57	Tularosa Basin Desert	Chihuahuan Desert	4	0	0	0	0	0	0	1	4	73.9%	*	*
50	3	Cottonwood Springs	Chihuahuan Desert	0	0	0	0	0	0	4	1	4	32.1%	*	*
51	144	Blue Creek/Lemmons Canyon	Apache Highlands	0	0	0	0	0	0	3	1	3	88.2%	*	
52	133	Punche Valley	Southern Rocky Mountains	0	0	0	0	0	0	3	1	3	86.0%	*	*
53	104	Canyon of the Ancients	Colorado Plateau	0	0	0	0	0	0	3	1	3	84.7%	*	*

Rank	Id	Key Conservation Area	Ecoregion	# D-S Birds	# D-S Mammals	# D-S Plants	# D-S Reptiles	# D-S Inverte-brates	# Amph-ibians	# Fish	# D-S Taxa	Total # D-S Species	Percent Rank	T*min*	T*max*
54	129	Culebra Range	Southern Rocky Mountains	0	0	0	0	0	0	3	1	3	79.5%	*	*
55	1	Sitting Bull Falls	Chihuahuan Desert	0	0	0	0	0	0	3	1	3	70.4%	*	
56	20	Mimbres River	Chihuahuan Desert	0	0	0	0	0	0	3	1	3	70.0%	*	*
57	142	Agua Caliente	Southern Rocky Mountains	1	0	0	0	0	0	2	1	3	33.9%	*	
58	218	Lower Canadian River	Southern Shortgrass Prairie	0	0	0	0	0	0	2	1	2	11.3%	*	
59	95	Mount Taylor	Arizona - New Mexico Mountains	1	0	0	0	0	0	0	1	1	99.5%	*	*
60	73	Chuska Mountains	Arizona - New Mexico Mountains	0	0	0	0	0	0	1	1	1	97.8%	*	*
61	102	Magdalena Mountains	Arizona - New Mexico Mountains	1	0	0	0	0	0	0	1	1	94.7%	*	*
62	44	Florida Mountains	Chihuahuan Desert	1	0	0	0	0	0	0	1	1	92.1%	*	*
63	11	Tularosa Creek	Chihuahuan Desert	0	0	0	0	0	0	1	1	1	90.8%	*	*
64	100	Hillsboro West	Arizona - New Mexico Mountains	0	0	0	0	0	1	0	1	1	90.4%	*	*
65	117	Simon Canyon	Colorado Plateau	0	0	0	0	0	1	0	1	1	90.0%	*	*
66	110	San Juan River (Shiprock)	Colorado Plateau	0	0	0	0	0	0	1	1	1	86.5%	*	*
67	127	Conejos River	Southern Rocky Mountains	0	0	0	0	0	0	1	1	1	81.7%	*	*
68	224	Tecolote Creek	Southern Shortgrass Prairie	1	0	0	0	0	0	0	1	1	81.3%	*	*
69	227	Gallinas River	Southern Shortgrass Prairie	0	0	0	0	0	0	1	1	1	80.4%	*	*
70	242	Arroyo del Macho	Southern Shortgrass Prairie	0	0	0	0	0	1	0	1	1	77.3%	*	
71	223	Upper Pecos River	Southern Shortgrass Prairie	0	0	0	0	0	0	1	1	1	76.0%	*	*
72	85	Fort Stanton/Rio Bonito Area	Arizona - New Mexico Mountains	0	0	1	0	0	0	0	1	1	75.2%	*	*
73	202	Dry Cimarron River	Southern Shortgrass Prairie	0	1	0	0	0	0	0	1	1	69.5%		*
74	141	Vermejo Park/Upper Purgatoire	Southern Rocky Mountains	0	0	0	0	0	0	1	1	1	66.9%	*	*
75	116	Potter Canyon	Colorado Plateau	0	0	0	0	0	1	0	1	1	63.9%	*	*
76	245	Rio Hondo	Southern Shortgrass Prairie	0	0	0	0	0	0	1	1	1	62.1%	*	*
77	164	Querecho Plains	Southern Shortgrass Prairie	1	0	0	0	0	0	0	1	1	61.3%	*	*
78	128	Coyote Creek	Southern Rocky Mountains	1	0	0	0	0	0	0	1	1	60.0%	*	
79	228	Gallinas River	Southern Shortgrass Prairie	0	0	0	0	0	0	1	1	1	58.6%	*	*
80	148	Big Hatchet Mtns	Apache Highlands	0	0	0	0	1	0	0	1	1	57.8%	*	*

Rank	Id	Key Conservation Area	Ecoregion	# D-S Birds	# D-S Mammals	# D-S Plants	# D-S Reptiles	# D-S Inverte-brates	# Amph-ibians	# Fish	# D-S Taxa	Total # D-S Species	Percent Rank	T*min*	T*max*
81	74	Mesa Prieta	Arizona - New Mexico Mountains	0	0	1	0	0	0	0	1	1	54.3%	*	*
82	201	Mescalero Sands	Southern Shortgrass Prairie	1	0	0	0	0	0	0	1	1	51.7%	*	*
83	167	Sierra Grande	Southern Shortgrass Prairie	0	1	0	0	0	0	0	1	1	50.8%		*
84	180	Turkey Mountains Grasslands	Southern Shortgrass Prairie	1	0	0	0	0	0	0	1	1	50.0%	*	*
85	248	Upper Canadian River	Southern Shortgrass Prairie	0	0	0	0	0	0	1	1	1	48.6%	*	*
86	194	Dunken	Southern Shortgrass Prairie	0	0	1	0	0	0	0	1	1	48.2%	*	*
87	136	Rio Grande Gorge	Southern Rocky Mountains	1	0	0	0	0	0	0	1	1	47.3%	*	*
88	76	Zuni Mountains	Arizona - New Mexico Mountains	1	0	0	0	0	0	0	1	1	40.8%		*
89	157	Blackwater Draw	Southern Shortgrass Prairie	0	1	0	0	0	0	0	1	1	37.8%	*	*
90	212	Middle Canadian River	Southern Shortgrass Prairie	0	0	0	0	0	0	1	1	1	34.3%	*	*
91	244	Salt Creek (Pecos)	Southern Shortgrass Prairie	1	0	0	0	0	0	0	1	1	27.8%	*	*
92	79	Rio Nutria	Arizona - New Mexico Mountains	0	0	0	0	0	0	1	1	1	26.5%		*
93	31	Sitting Bull Falls	Chihuahuan Desert	0	0	1	0	0	0	0	1	1	26.0%	*	
94	161	Antelope Ridge	Southern Shortgrass Prairie	1	0	0	0	0	0	0	1	1	25.6%	*	*
95	229	Gallinas River	Southern Shortgrass Prairie	0	0	0	0	0	0	1	1	1	24.3%	*	*
96	213	Middle Canadian River	Southern Shortgrass Prairie	0	0	0	0	0	0	1	1	1	19.1%	*	*
97	68	Rio Hondo	Arizona - New Mexico Mountains	0	0	0	0	0	0	1	1	1	17.8%	*	*
98	195	Monument Draw	Southern Shortgrass Prairie	1	0	0	0	0	0	0	1	1	16.5%	*	*
99	153	Milnesand	Southern Shortgrass Prairie	1	0	0	0	0	0	0	1	1	14.7%	*	
100	72	Sitting Bull Falls	Arizona - New Mexico Mountains	0	0	0	0	0	0	1	1	1	12.6%		
101	234	El Rito Creek	Southern Shortgrass Prairie	0	0	0	0	0	0	1	1	1	7.8%		*
102	233	Rio Agua Negra	Southern Shortgrass Prairie	0	0	0	0	0	0	1	1	1	1.3%		*
103	105	Lower Animas River	Colorado Plateau	0	0	0	0	0	0	1	0	1	83.0%	*	*

APPENDIX 3. Recently observed ecological changes that have been linked to climate change in New Mexico and the Southwest. Five types of ecological change were identified: population declines, distribution shifts, phenological changes, evolutionary changes, and species invasions (native and non-native). The source of evidence is noted to provide level of relative credibility (peer-reviewed literature, published report, unpublished data, unpublished observation).

Ecological Change	Species or Ecosystem	Name	Conservation Target	Trend and Geography	Source of Evidence	Citations
Population decline	Forest	Piñon pine forests	Ecosystem	Climate-induced forest dieback (Southwest-wide, but especially severe in Jemez Mountains)	Peer-reviewed literature	Breshears et al. 2005, Mueller et al. 2005, Shaw et al. 2005
	Riparian	Cottonwood forests	Ecosystem	Drought-induced mortality (Southwest-wide)	Peer-reviewed literature	Gitlin & Whitham 2007, Gitlin et al. 2006
	Riparian	High-elevation riparian species (NM Locust, Rocky Mountain Maple, Aspen)	Ecosystem	Climate-induced population declines; decline in habitat linked to declines in 7 native bird species (AZ Mogollon Rim, AZ-NM Mountains ecoregion)	Peer-reviewed literature	Martin 2007
	Amphibian	Jemez Mountains salamander	Species (D-S)	Potentially drought-induced large population declines for nearly 20 years; drought is listed as a factor influencing this species; unpublished data is currently being prepared for publication (Jemez Mountains, Southern Rockies ecoregion)	Published report	NMDGF 2006
		Sacramento Mountains Salamander	Species (D-S)	Drought is listed as a factor influencing this species (Sacramento Mountains)	Published report	NMDGF 2006
		Chiricahua leopard frog	Species (D-S)	Potentially drought-induced population declines (Southwestern mountain ranges, Apache Highlands & AZ-NM Mountains ecoregions)	Published report	NMDGF 2006
	Bird	Brown-capped rosy-finch		Warming threatening high-elevation habitat via reduced soil moisture, stressed vegetation, altered disturbance regimes (Southern Rockies ecoregion)	Unpublished observation	USFWS biologist, pers. comm.
		White-tailed ptarmigan	Species (D-S)	Warming threatening high-elevation habitat via reduced soil moisture, stressed vegetation, altered disturbance regimes (Southern Rockies ecoregion)	Unpublished observation	USFWS & NMDGF biologists, pers. comm.
		Boreal owl	Species (D-S)	Warming threatening high-elevation habitat via reduced soil moisture, stressed vegetation, altered disturbance regimes (Southern Rockies ecoregion)	Unpublished observation	NMDGF biologist, pers. comm.
		Olive-sided flycatcher		Warming threatening high-elevation habitat via reduced soil moisture, stressed vegetation, altered disturbance regimes (Southern Rockies ecoregion)	Unpublished observation	NMDGF biologist, pers. comm.
		Swainson's thrush		Warming threatening high-elevation habitat via reduced soil moisture, stressed vegetation, altered disturbance regimes (Southern Rockies ecoregion)	Unpublished observation	NMDGF biologist, pers. comm.
		Pine grosbeak		Warming threatening high-elevation habitat via reduced soil moisture, stressed vegetation, altered disturbance regimes (Southern Rockies ecoregion)	Unpublished observation	NMDGF biologist, pers. comm.
		Gray jay		Warming threatening high-elevation habitat via reduced soil moisture, stressed vegetation, altered disturbance regimes (Southern Rockies ecoregion)	Unpublished observation	NMDGF biologist, pers. comm.

Ecological Change	Species or Ecosystem	Name	Conservation Target	Trend and Geography	Source of Evidence	Citations
Population decline (continued)		Southwestern willow flycatcher	Species (D-S)	Warming threatening riparian habitat via altered hydrological regimes, increased competition from invasive species (Southwest)	Published report	Price et al. 2005
		Bell's vireo	Species (D-S)	Warming threatening riparian habitat via altered hydrological regimes, increased competition from invasive species (Southwest)	Unpublished observation	NMDGF biologist, pers. comm.
		Yellow-billed cuckoo		Warming threatening riparian habitat via altered hydrological regimes, increased competition from invasive species (West-wide)	Published report	Price et al. 2005
		Arizona grasshopper sparrow	Species	Has experienced a 65% decline across range; warming, changing distribution of intra-annual precipitation, and increased CO2 may contribute to conversion to shrubland (semi-arid grasslands of New Mexico & Arizona)	Published report	Butcher & Niven 2007
	Plant	Sacramento Mtns thistle	Species (D-S)	Drought-induced decline in flowering stems 1995-2005 (Sacramento Mountains, AZ-NM Mountains ecoregion)	Unpublished data	USFWS biologist, pers. comm.
		Wright's marsh thistle	Species (D-S)	Drought-induced decline in numbers & habitat quality (Sacramento Mountains, AZ-NM Mountains ecoregion)	Unpublished data	USFWS biologist, pers. comm.
		Parish's alkali grass	Species (D-S)	Drought-induced decline in numbers & habitat quality (Sacramento Mountains, AZ-NM Mountains ecoregion)	Unpublished data	USFWS biologist, pers. comm.
		Sacramento prickly poppy	Species (D-S)	Drought-induced decline in numbers, but recently observed abundance in seedlings and some adults may be response to more recent precipitation (Sacramento Mountains, AZ-NM Mountains ecoregion)	Unpublished data	USFWS biologist, pers. comm.
		Sclerocactus mesae-verdae	Species (D-S)	2000-2003 very low population numbers coincided with severe drought but may be linked to insects; population beginning to recover (Mesa Verde, Colorado Plateau ecoregion)	Unpublished data	USFWS biologist, pers. comm.
		Sclerocactus cloveriae ssp. brackii		2000-2003 very low population numbers coincided with severe drought but may be linked to insects; population beginning to recover (Mesa Verde, Colorado Plateau ecoregion)	Unpublished data	USFWS biologist, pers. comm.
		Pediocactus knowltonii (Knowlton's cactus)	Species (D-S)	Drought-induced decline since 1995, yet few new seedlings found recently despite more recent precipitation (Colorado Plateau ecoregion)	Unpublished report	Sivinski 2006
	Mammal	Goat peak pika	Species (D-S)	Climate change is listed as a factor influencing this sub-species of the American pika, which has experienced recent population declines primarily in terms of thermal maxima (Beever et al. 2003) (Jemez Mountains)	Published report	NMDGF 2006
	Insect	Capulin Mountain Arctic		"Global warming" is listed as a factor influencing this species	Published report	NMDGF 2006, NMDGF biologists, pers. comm
		Buchholz's/Boisduval's Blue		"Global warming" is listed as a factor influencing this species	Published report	NMDGF 2006
		Mogollon Blue		"Global warming" is listed as a factor influencing this species	Published report	NMDGF 2006
		Mountain Checkered-Skipper		"Global warming" is listed as a factor influencing this species	Published report	NMDGF 2006
Distribution change	Bird	Ruddy ground-dove		Moving north from Mexico into New Mexico	Unpublished observation	USFWS biologist, pers. comm.

Ecological Change	Species or Ecosystem	Name	Conservation Target	Trend and Geography	Source of Evidence	Citations
Distribution change (continued)	Bird	Short-tailed hawk		Moving north from Mexico into New Mexico	Unpublished data	USFWS biologist, pers. comm.
		Black-capped gnatcatcher		Moving north from Mexico into New Mexico	Unpublished observation	USFWS biologist, pers. comm.
		Green kingfisher		Moving north from Mexico into New Mexico	Unpublished observation	USFWS biologist, pers. comm.
		White-winged dove		Moving further north into central New Mexico	Unpublished observation	TNC ornithologist, pers. comm.
		Bewick's wren		Recent rapid expansion of breeding populations into riparian forests along the Middle Rio Grande, New Mexico.	Peer-reviewed literature	Taylor 2003
	Mammal	Myotis volans		Relative frequency of capture of several bat species appears to be changing elevationally in New Mexico mountain ranges.	Unpublished data (large data sets with 1000+ captures dating back to the 1960s)	USFWS biologist, pers. comm.
		Myotis evotis		Relative frequency of capture of several bat species appears to be changing elevationally in New Mexico mountain ranges.	Unpublished data (large data sets with 1000+ captures dating back to the 1960s)	USFWS biologist, pers. comm.
		Myotis auriculus		Relative frequency of capture of several bat species appears to be changing elevationally in New Mexico mountain ranges.	Unpublished data (large data sets with 1000+ captures dating back to the 1960s)	USFWS biologist, pers. comm.
		Idionycteris phyllotus (Allen's big-eared bat)	Species (D-S)	Relative frequency of capture of several bat species appears to be changing elevationally in New Mexico mountain ranges.	Unpublished data (large data sets with 1000+ captures dating back to the 1960s)	USFWS biologist, pers. comm.
		Desert rodents and semi-arid grassland		Desert rodent community changing; e.g. Bailey's pocket mouse (typically viewed as a Mexican species) now is abundant at a long-term study site; change from grassland to shrubland linked to long-term increase in winter temperature and precipitation (SE Arizona, Apache Highlands ecoregion)	Peer-reviewed literature; Unpublished data	Brown et al. 1997 M. Ernest, pers. comm.
Phenological change	Bird	Mexican jay		Mean date of 1st clutch earlier by 10 days (1971-1997) as a function of rising mean minimum temperature in month before & during breeding season (Chiricahua Mountains, Apache Highlands ecoregion)	Peer-reviewed literature	Brown et al. 1999
	Plant	Species from 85 vascular plant species found along an elevational gradient		Shifting timing in blooms with increasing mean summer temperatures, especially at highest elevations (SE Arizona, Apache Highlands & Sonoran Desert ecoregions)	Unpublished data	Mau-Crimmins et al., *in review*
Evolutionary change	Mammal	White-throated woodrat		Statistically significant change in body size occurred with a shift in regional climate (Sevilleta National Wildlife Refuge, central NM, Chihuahuan Desert ecoregion)	Peer-reviewed literature	Smith et al. 1998, Smith & Betancourt 2006
Increase in invasive species	Riparian	Salt cedar invasion	Ecosystem	The exotic is out-competing stressed cottonwood individuals in riparian areas located throughout the Southwest; conclude that, with continued warming and increasingly severe droughts, the species is likely to displace broad-leaved cottonwoods.	Peer-reviewed literature	Gitlin & Whitham 2007
	Wetland	Salt cedar and Russian olive invasion	Ecosystem	Native species (Pecos sunflower) currently being out-competed by increase in exotic species and in the common reed (Blue Hole Cienega, Southern shortgrass prairie ecoregion)	Unpublished observation	New Mexico Environment Dept biologist, pers.comm.

Ecological Change	Species or Ecosystem	Name	Conservation Target	Trend and Geography	Source of Evidence	Citations
Increase in invasive species (continued)	Grassland & Desert	Lehmann's lovegrass, buffel grass	Ecosystem	Invasion of semi-arid grasslands by Lehmann's lovegrass exacerbated by warming temperatures (Apache Highlands & Chihuahuan Desert ecoregions) Invasion of sites in the Sonoran Desert by buffel grass exacerbated by warming temperatures	Peer-reviewed literature	Geiger & McPherson 2005 USGS and University of Arizona biologists, pers. comm.
	Grassland	Tree encroachment in montane grasslands	Ecosystem	While lack of fire is implicated on the steepest grassland slopes, the study points to years of higher mean summer minimum temperatures as a primary contributor to tree encroachment of montane grasslands (Jemez Mountains, Arizona-New Mexico Mountains ecoregion).	Peer-reviewed literature	Coop & Givnish 2007

APPENDIX 4. Key conservation areas that contain conservation target species already thought to be affected by climate change. Areas are sorted by descending climate exposure percentile rank.

ID	Key Conservation Area	Ecoregion	Allen's big-eared bat	Bell's vireo	Boreal owl	Chiricahua leopard frog	Jemez Mountains salamander*	Parish's alkali grass	Sacramento Mountains salamander*	Sacramento Mountains thistle*	SW willow flycatcher	White-tailed ptarmigan	Goat Peak pika	Knowlton's cactus	Mesa Verde cactus	Brack's hardwall cactus	# Species	Climate Exposure Rank
131	Jemez Mountains	Southern Rocky Mountains			X		X						X				3	100.0%
137	Rio Hondo	Southern Rocky Mountains										X					1	99.1%
139	Southern Sangre de Cristo Mountains	Southern Rocky Mountains			X							X					2	98.2%
149	Sierra San Luis/ Peloncillos Mountains	Apache Highlands				X											1	96.5%
90	Northern Black Range	Arizona - New Mexico Mountains	X			X											2	96.0%
88	Sacramento Mountains	Arizona - New Mexico Mountains							X	X							2	95.2%
222	Pecos River Headwaters	Southern Shortgrass Prairie			X							X					2	94.3%
92	San Mateo Mountains Complex	Arizona - New Mexico Mountains	X														1	93.4%
99	Ladder Ranch	Arizona - New Mexico Mountains				X											1	93.0%
100	Hillsboro West	Arizona - New Mexico Mountains				X											1	90.4%
84	Mogollon Divide	Arizona - New Mexico Mountains	X			X											2	89.5%
69	Mimbres River	Arizona - New Mexico Mountains	X														1	88.6%

ID	Key Conservation Area	Ecoregion	Allen's big-eared bat	Bell's vireo	Boreal owl	Chiricahua leopard frog	Jemez Mountains salamander *	Parish's alkali grass	Sacramento Mountains salamander *	Sacramento Mountains thistle*	SW willow flycatcher	White-tailed ptarmigan	Goat Peak pika	Knowlton's cactus	Mesa Verde cactus	Brack's hardwall cactus	# Species	Climate Exposure Rank
67	Gila River	Arizona - New Mexico Mountains	X	X		X					X						4	87.8%
110	San Juan River (Shiprock)	Colorado Plateau													X		1	86.5%
56	San Andres - Oscura Mountains	Chihuahuan Desert		X													1	85.2%
104	Canyon of the Ancients	Colorado Plateau													X		1	84.7%
109	Table Mesa	Colorado Plateau													X		1	79.1%
121	Los Pinos River	Colorado Plateau												X			1	78.2%
65	Blue River/ San Francisco River	Arizona - New Mexico Mountains				X											1	76.5%
2	Black River Basin	Chihuahuan Desert		X													1	69.1%
114	Angel Peak	Colorado Plateau														X	1	65.2%
37	Bosque Wilderness Area	Chihuahuan Desert		X							X						2	62.6%
128	Coyote Creek	Southern Rocky Mountains			X												1	60.0%
74	Mesa Prieta	Arizona - New Mexico Mountains						X									1	54.3%
15	Rio Grande Elephant Butte	Chihuahuan Desert		X							X						2	53.9%
143	Blue River/Eagle Creek	Chihuahuan Desert		X							X						2	35.6%
142	Agua Caliente	Southern Rocky Mountains									X						1	33.9%