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Vulnerability of Species to Climate Change in the Southwest: Threatened, Endangered, and At-Risk Species at Fort Huachuca, Arizona

Karen E. Bagne and Deborah M. Finch

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Abstract

Future climate change is anticipated to result in ecosystem changes, and consequently, many species are expected to become increasingly vulnerable to extinction. This scenario is of particular concern for threatened, endangered, and at-risk species (TER-S) or other rare species. The response of species to climate change is uncertain and will be the outcome of complex interactions and processes. Nevertheless, a simple flexible strategy is needed to help integrate climate change into management planning and actions. This assessment uses SAVS, a vulnerability scoring tool based on ecological principles, to rank individual species of interest within the Fort Huachuca region according to predicted climate change responses and associated population declines balanced with responses expected to incur resilience or population increases. Further, specific areas of vulnerability, research needs, and management implications are identified for each species. Based solely on predicted response to climate change, northern Mexican gartersnake and southwestern willow flycatcher are the most vulnerable to population declines. Results also suggest that climate change will make management of some TER-S more difficult. Several critical management areas are identified that can mitigate negative impacts to benefit multiple species, including fire and fuels, invasive species, natural and artificial waters, and landscape-scale planning. Management planning should be in place that will assist species impacted by extreme events such as prolonged drought, severe wildfires, and intense flooding. The assessment process was also used to identify areas where climate change may present opportunities, as opposed to challenges, for management of TER-S.

Keywords: climate change, vulnerability, Southwest, Arizona, endangered species, SAVS

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Cover photos: (clockwise from top) West Range, Fort Huachuca, Arizona. (Photo by Pam Landin.) Huachuca water umbel, Cochise County, Arizona. (Photo by Pam Landin.) Mexican spotted owl, Fort Huachuca, Arizona. (Photo by Colby Henley.) Chiricahua leopard frog, Cochise County, Arizona. (Photo by Pam Landin.) Photos are authorized for this publication only, and any further use requires authorization from the photographers.

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Introduction

A large number of species are imperiled and at risk of extinction if populations continue to decline (Wilcove and Master 2005). Of Federal landholdings, those managed by the Department of Defense (DoD) harbor the most endangered or threatened species. They also contain large numbers of species at risk—those that are imperiled but not yet listed by the U.S. Fish and Wildlife Service (USFWS) (NatureServe 2004). These species, also known as TER-S (threatened, endangered, and at-risk species), are an important element of natural resources management. For species that are not listed as Federally endangered or threatened, effective and proactive management of species at risk can prevent listing, reduce management costs, and protect biodiversity while insuring that critical military training is not disrupted (NatureServe 2004). Six threatened or endangered terrestrial vertebrate species and one endangered plant species are known to occur or potentially occur at the Fort Huachuca Army Installation in southeastern Arizona (ENRD 2006). Fort Huachuca is also among the top 20 DoD installations for highest numbers of species at risk (NatureServe 2004).

Over the past century, the climate in the southwestern United States has been becoming warmer and drier, and this trend is expected to continue (Field and others 2007). In fact, this region is projected to be subject to a significant change in climate that will have broad impacts on ecosystems. Because current climate conditions are already physiologically challenging, even small changes can exceed species' tolerances. There is a broad consensus among climate models that conditions will become more extreme (Archer and Predick 2008), which will have consequences for biodiversity. While the exact nature of these consequences is unknown, shifts in species' distributions and changes in populations are highly likely. Declining populations and eventual extinction is of increasing concern for species already at high extinction risk that will experience negative impacts from climate change.

Climate change is a new challenge for natural resources managers that has the potential to exacerbate existing management issues while creating new ones. Preservation of biodiversity will be particularly challenging, and few strategies have been proposed to guide managers (Lucier and others 2006). Species assessments of vulnerability or extinction risk are management tools used to help prioritize conservation needs so that actions can be directed in an effective and efficient manner (Glick and Stein 2010). Species can be ranked based on assessment outcome, but implementation of management actions will also be constrained by goals, economics, politics, and feasibility. To include climate change in a vulnerability assessment is a challenging task because the strongest climate change effects are not yet manifest, global carbon and nitrogen cycling are complex, species vary in sensitivity and adaptive capacity, and direct effects on relatively few species have been identified. To ignore climate change is to risk being unable to respond to a biodiversity crisis (McLaughlin and others 2002; Early and Sax 2011).

Climate Change Assessment

Purpose

Anticipation of future impacts of changing climate can help ameliorate those impacts through early intervention—a key factor for balancing ongoing and uninterrupted military operations with cost-effective natural resource management. Resources for management are also limited, thus priority targets and actions need to be identified (see Box 1). This assessment addresses the vulnerability of individual TER-S to population declines associated with projected changes in climate at Fort Huachuca in southeastern Arizona. Species are ranked by anticipated vulnerability, and potential management actions are identified based on the specific vulnerabilities identified. Interaction of climate change variables with currently known threats to species is also discussed.

Box 1. Why assess vulnerability?

Vulnerability is the susceptibility to negative impact. Vulnerability assessments help us identify where negative impacts are likely to occur and why. In this assessment, we define the vulnerability of terrestrial vertebrate species to climate change as likely declines in populations through either reduced survival or reproduction. Managers that use vulnerability assessments can:

1. help set priorities and prepare for the future;
2. identify adaptation strategies that target predicted effects; and
3. make more efficient use of scarce resources.

Modified from Glick and others (2011)

Approach

Vulnerability of species to climate change will depend on sensitivity, exposure, and adaptive capacity (Glick and others 2011). We used the System for Assessing Vulnerability of Species (SAVS) to rank vulnerability of terrestrial vertebrates to climate change (Bagne and others 2011). This tool scores individual species based on basic ecology and life history traits that are related to climate. Traits related to sensitivity and adaptive capacity are integrated into the system, and exposure, or future projection, is a key component of prediction but is taken from published sources prior to scoring. Scores are the balance of a set of 22 traits that predict vulnerability (i.e., reduced survival or reproduction), resilience (i.e., increased survival or reproduction), or no change. Because the same set of traits is applied to all species, scores can be used to compare vulnerability of a set of species. The system produces an overall score and four category scores for habitat, physiology, phenology, and interactions as well as uncertainty for these scores. Each score is the balance of the number of vulnerable versus resilient traits, with all traits weighted equally and adjusted to a common scale (see Bagne and others 2011 for details). Uncertainty is based on the availability of information or, in cases of opposing predictions, for an individual question. We used a spreadsheet to aid score calculations, but calculations can also be made by hand following Bagne and others (2011) or on the SAVS web site (http://www.fs.fed.us/rmrs/species-vulnerability/). Traits associated with vulnerability for an individual species or that are common across several species are used to identify management actions to reduce vulnerability.

We developed and used a similar, but separate, pilot scoring tool to predict individual plant species' vulnerability. The plant species vulnerability pilot tool is

Figure 1. The Huachuca water umbel only occurs in a few locations, placing it at a greater threat to extinction with population declines. Photo credit: B. Radke, USFWS.

available at: http://denix.osd.mil/nr/OtherConservationTopicsAH/ClimateChange.cfm. That tool produces an overall score and three category scores for habitat, physiology, and interactions as well as uncertainty for these scores in the same manner as SAVS.

Scope

Predicted species response and vulnerability scores are made based on available projections of how climate and related phenomena are expected to change in the region of interest. Unlike the vertebrate species tool, the plant vulnerability tool is integrated with specific climate projections and is, thus, restricted to the southwestern United States. For this assessment, we focused on projections within the next 50 years or less. Although scores are limited to the region, they are also generally applicable to adjacent lands to Fort Huachuca. The specific projections used follow this section.

We assessed species with known occurrence at Fort Huachuca listed by the USFWS as endangered or threatened. We included additional species that are either proposed for Federal listing, Federal species of concern, or of high conservation priority for Arizona as identified by the State Wildlife Action Plan (AGFD 2006). Only one plant species on Fort Huachuca was Federally listed: the endangered Huachuca water umbel (*Lilaeopsis schaffneriana* var. *recurva*) (Figure 1). One species, the willow flycatcher (*Empidonax trailii extimus*), that occurs adjacent to but not on the Fort was included along with three species for which there are no recent records: the desert massasauga (*Sistrurus catenatus edwardsi*), northern aplomado falcon (*Falco femoralis septentrionalis*), and the black-tailed prairie dog (*Cynomys ludovicianus*). Prioritization and identification of vulnerabilities are presented separately for vertebrates and plants.

Projections of Climate, Disturbance, and Biotic Communities

Current and Future Climate

The Southwest is characterized by a hot and arid climate, which is also highly variable because of its geographical location and positioning between two circulation regimes (Sheppard and others 2002). The current climate at Fort Huachuca is dry with warm summers and mild winters. Recorded temperatures already indicate that the region is warming at a rate unprecedented in the last 400 years (Sheppard and others 2002). With increasing levels of CO_2, temperatures are expected to rise in southeastern Arizona. Average annual temperature is expected to increase approximately 2.2 °C or 4 °F by 2050 (www.climatewizard.org, PRISM group, United States mid-century, 12 km resolution, downscaling based on Maurer and others 2007). These estimates may be too low as recent emission rates have exceeded those used to forecast future climate (from preliminary 2009 and 2010 global and national estimates of carbon emissions, http://cdiac.ornl.gov).

Rain falls in the summer and winter with the majority (~60%) arriving during summer monsoons for an average annual rainfall of 38 cm (ENRD 2006). Shifting of circulation patterns associated with the El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO) alters winter precipitation patterns in the Southwest. Winters are wetter during El Niño, when the westerly flow of moist air across North America shifts southward, and are drier during La Niña, when the flow shifts to the north. Changes in PDO enhance or dampen ENSO patterns (Shepperd and others 2002). During the summer, westerly winds diminish and a high-pressure ridge forms signaling the start of the monsoon season, which brings moisture to the region from the Gulf of Mexico and the Gulf of California (Shepperd and others 2002). Unlike the widespread gentle rains of winter, the monsoons bring intense thunderstorms with highly variable local rainfall, which affects water uptake by soil and vegetation. Monsoon patterns in this subregion differ from monsoons to the east in New Mexico, which come earlier, and monsoons to the south in Mexico, which last longer and have much higher precipitation totals (Figure 2; Comrie and Glenn 1998).

Projections for precipitation are more varied than those for temperature. In one set of models, projections for winter rain (December to February) are approximately unchanged and spring rain is reduced for 2050 under the current emissions rate and averaged circulation models (www.climatewizard.org, PRISM group, United States mid-century, 12-km resolution, downscaling based on Maurer and others 2007). However, even with no change in rainfall, predicted higher temperatures will increase evaporation, which will result in less available moisture for plants and animals. Other studies predict drying of the Southwest driven by changes in humidity and atmospheric circulation (Seager and others 2007). Periodic La Niña conditions in conjunction with a drying of the region are projected to bring severe and prolonged droughts (Seager and others 2007; Cook and others 2009). Predictions for summer monsoon rains are problematic (Mitchell and others 2002). Of note, however, is that annual monsoon rainfall has historically not been well correlated among the subregions (i.e., a dry summer does not tend to affect all subregions simultaneously), which has important implications for wide ranging and migratory animals.

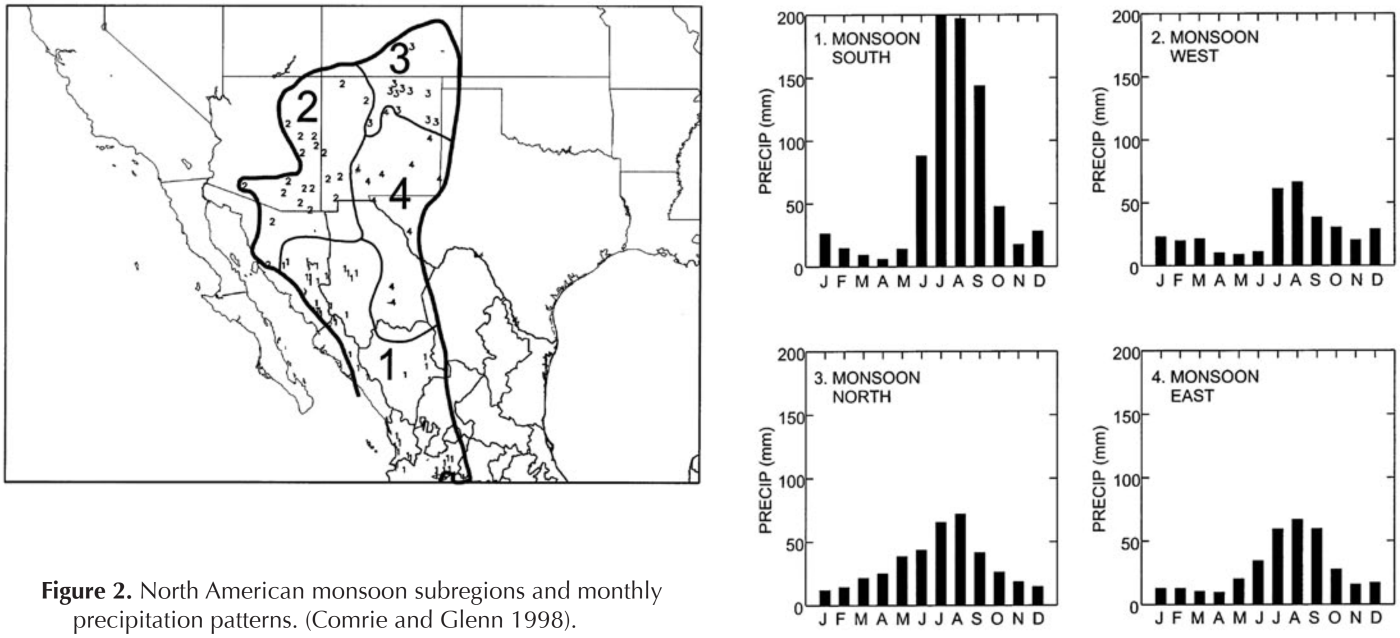

Figure 2. North American monsoon subregions and monthly precipitation patterns. (Comrie and Glenn 1998).

Water Sources

The Fort has mostly ephemeral streams that only flow during significant precipitation events. The perennial reaches are in Garden and Huachuca Canyons, though there are minor perennial reaches elsewhere. Flows are generally lowest in early spring before the summer monsoons arrive. Since 1930, this spring dry period has started earlier and lasted longer. These changes have been attributed to climate factors, such as earlier snow melt, and to changes in upland vegetation (ENRD 2006). The major perennial stream in the region is the San Pedro River, which is located outside the Fort boundaries (ENRD 2006). Stream flow simulations for the San Pedro River based on multiple climate models show significant decrease in base flows and alteration of riparian habitats even while keeping ground water extraction at current levels (Serrat-Capdevila and others 2007). Climate factors reducing stream flow on the San Pedro will likely affect streams on Fort Huachuca similarly. Decisions related to the amount and location of ground water withdrawals, both locally and from nearby communities, will affect future surface waters on Fort Huachuca, but increased demand from growing populations along with the current depression of the water table under the Fort and Sierra Vista points toward continued depletion of the aquifer (ENRD 2006).

Surface water is largely dependent on local rainfall and thus subject to considerable alteration as climate warms and circulation patterns change. Shallow water sources, such as ponds and pools, will be particularly vulnerable to drying. Unfortunately, rainfall is poorly projected, making it difficult to predict changes in natural water sources and run-off, but increasing rainfall variability will almost certainly result in greater interannual variation in the number and longevity of surface water sources. In addition, even with no change in rainfall, predicted higher temperatures will increase evaporation rates, resulting in less moisture available for plants and animals. Changes in vegetation influencing soil infiltration, such as root depth or cover, can further alter surface water and adds to the complexity of projections.

Disturbance

As the climate changes, greater flood risk from more intense storms is projected for the southwestern United States (Garfin and Lenart 2007; Seager and others 2007). Precipitation falling in intense rainfall events can decrease water available for mesic environments, while these events may increase soil water availability for xeric ones (Knapp and others 2008), which adds to the problems associated with predicting species' responses to climate change.

Wildfires are expected to become more frequent with projected increases in temperature (Rogers and Vint 1987; Swetnam and Betancourt 1990; Esser 1992; Westerling and others 2006). In addition to temperature interactions, projected increases in climate variability will also increase fire occurrence as years of high rainfall are followed by dry/hot years creating conditions conducive both to ignition and fuel accumulation (McLaughlin and Bowers 1982). Changes in vegetation structure and composition are also important to fire risk and are discussed in Biotic Communities.

Biotic Communities

There is considerable topographic variation on the Fort and, consequently, a variety of vegetation types and environmental conditions. Lower elevations at Fort Huachuca are dominated by Chihuahuan desert scrublands and open scrub-grasslands (ENRD 2006). Higher elevations are primarily Madrean oak and oak-pine woodlands (ENRD 2006). Riparian deciduous forest and montane conifer are also present and, although they cover a relatively small area of Fort Huachuca, these vegetation types are important to regional biodiversity. Future vegetation will depend on the quantity and season of precipitation, which is currently not well modeled, as well as the interaction of other factors such as fire, grazing, soils, and topography (McPherson and Weltzin 2000). Regardless, climate change is likely to result in widespread disruption of present biotic communities (Figure 3; Rehfeldt and others 2006). Ignoring small-scale variation not captured by these models, there is a strong tendency toward homogenization of a diverse set of communities toward a single climate regime currently associated with desert grasslands. This does not mean that all habitats will necessarily be replaced by desert grasslands, but that environmental conditions will favor desert grassland across an expanding area while other communities will experience conditions outside those they are currently associated with. Because different species vary in their tolerances, new mixes of species or novel species assemblages will likely result.

The relative dominance of shrubs (primarily C_3) versus grasses (primarily C_4) with climate change remains uncertain (McPherson and Weltzin 2000). C_3 shrubs are favored by increases in CO_2 and grazing and may be expected to remain dominant in many areas where they are already established (Archer and others 1995). Alternatively, C_4 grasses may be favored by increases in temperature and more frequent fire occurrence (Esser 1992). Summer rains are not well projected, but are particularly important to annuals and succulents, while woody plants tend to rely on winter precipitation (Ehleringer and others 1991). Greater variability in rainfall may induce recurring shifts between grasslands and shrublands, although shrubs will take longer to reestablish after disturbance. In corraboration with projections based on climate (Figure 3), we assumed for this assessment that increasing fires would favor grassland expansion in the next 50 years. Future vegetation trajectories also depend on current vegetation, which, in turn, has been influenced by the heavy grazing that occurred in the past. For example, areas with greater quantities

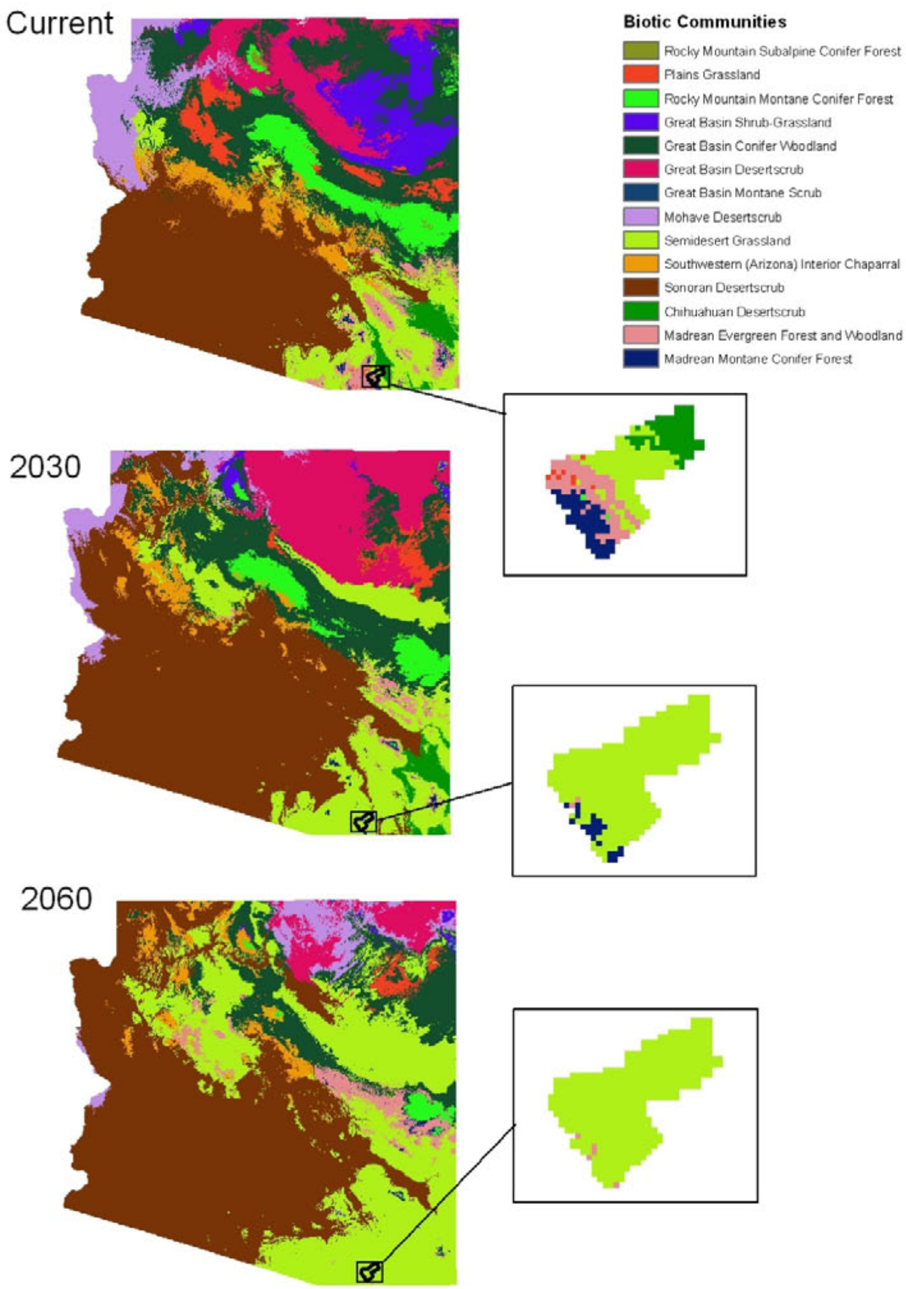

Figure 3. Current and projected climate change as modeled for the biotic communities of Arizona. Inset shows Fort Huachuca. Projections are from Rehfeldt and others (2006). Projections were used to identify future trends for biotic communities.

of fine fuel species such as grasses will be more prone to fire and a continued grassland trajectory, while more sparsely vegetated scrublands will be prone to periodic shrub die-offs during drought conditions.

Fire regimes in the region have also been altered by introduced grasses, particularly African species—a process that is likely to continue. One of these species, Lehmann's lovegrass (*Eragrostis lehmanniana*), is already common on portions of the Fort (ENRD 2006). Buffelgrass (*Pennisetum ciliare*), also responsible for changing fire regimes, has not yet been documented on Fort Huachuca, but occurs within at least a 100-km radius around nearby Tucson (Van Devender and Dimmitt 2006). Spread of African grasses, along with increased fires, will encourage further conversion of native habitats to non-native grasslands.

Although CAM (crassulacean acid metabolism) plants, such as cactus and agaves, will be resilient to increasing hot and dry conditions (Smith and others 1986), they are prone to increased mortality with increasing fires (Thomas 2006), and frequent burning can harm agave seedlings and encourage Lehmann's lovegrass (Robinett 1994). Flowering phenology is also strongly related to climate. Less precipitation and increases in extreme temperatures can shorten the length of cactus flowering season, which has a direct effect on fruit production and nectar availability (Bustamante and Búrquez 2008).

Riparian habitats in the region are predicted to decline due to decreased average stream flows, increased evaporation, and changes to the flood regime (Stromberg and others 2006; Serrat-Capdevila and others 2007). Surface water diversions from nearby communities also contribute to decline (Stromberg and others 1996). In particular, Stromberg and others (2006) predicted a decrease in cottonwood and willow, an increase of mesquite, and no change in salt cedar (Tamarix spp.). Comparisons of salt cedar-dominated versus cottonwood-willow-dominated habitats on the San Pedro River indicate that surface flow permanence was the most important determinant of plant species dominance (Lite and Stromberg 2005); thus, with warmer temperatures and continued water table withdrawals (Stromberg and others 1996), we may expect greater dominance of salt cedar. Ironically, very high water levels have also been associated with declines in willows and cottonwoods on the Colorado River (Laymon and Halterman 1987).

Forest and woodlands types are generally projected to shift upward in elevation as temperatures warm (Kelly and Goulden 2008; Lenoir and others 2008). With the relatively small and isolated mountain ranges that occur in this region, upward shifts will inevitably shrink forest habitats. The highest elevations, here montane conifer forest, will be at the greatest risk. The lower elevation Madrean oak and pine-oak communities are also at risk for considerable change. Projections shown in Figure 3, based on Rehfeldt and others (2006), show the trajectory and future stress on biotic communities with limited Madrean woodlands and no coniferous forest by 2060. These projections, however, are of future climate correlated with the current environment in which biotic communities occur, which cannot capture the fundamental niche of all species nor their complex ecological relationships. Thus, for this assessment, we viewed these projections as trends (e.g., less forest) rather than as the ultimate spatial extent of future communities.

Mexico and Central and South America

A number of species in this assessment, primarily birds, migrate long distances and are subject to changing climate in distant regions. Projected changes in pertinent regions are summarized below.

Much of Mexico also has a monsoonal precipitation pattern, but annual rainfall is considerably higher to the south than in the border area near Arizona and New Mexico (Comrie and Glenn 1998). Projecting changes in the climate in Mexico is difficult because many General Circulation Models (GCMs) are unable to adequately describe the current climate. Examining a number of models, it is clear that temperatures will increase for all times of year and most dramatically in northern parts of Mexico. Modeling precipitation is less certain, but most models predict reduced annual and summer rainfall with higher temperatures that will exacerbate drying through evaporation (Liverman and O'Brien 1991). At least currently, monsoons are generally asynchronous between northern to central Mexico and the Southwest borderlands (Figure 2; Comrie and Glenn 1998).

Increases in temperature are also projected for Central America and, although precipitation projections are again more variable, most models indicate reduced rainfall in wet and dry seasons (Magrin and others 2007). Dry periods are also projected to become more extreme and accompanied by increases in extreme events, including intense rain, flooding, and hurricanes (Magrin and others 2007). Central America is also at high risk for forest loss associated with increasing temperatures (Scholze and others 2005). Increases in temperature may lead to conversion of semi-arid regions to arid and the shifting of high-elevation pine and pine-oak forests upslope. Increases in fire, resulting from increased temperatures and more variable rainfall, will reduce some tree species such as oaks and sycamores although mature pines should be resistant to all but high severity fires.

Toward the southern part of South America, the climate is projected to become more suitable for tropical vegetation, but toward the north, the climate is projected to become drier (Magrin and others 2007). As in North America, wildfires are expected to increase in frequency. In northern South America, it is projected that tropical forests will be replaced by savannahs (Magrin and others 2007). Mangroves and other coastal habitats are vulnerable to sea level rise throughout the region (Magrin and others 2007).

Scoring Results

Vertebrate Species

The vulnerability of 21 vertebrate species to climate change was scored for Fort Huachuca, Arizona. Full score details and information related to individual species is in Appendix A. Almost all species scored were vulnerable rather than resilient to climate change (Table 1). It is likely that this result is partly due to climate change exacerbating some of the current impacts already responsible for declines in these species. The highest score, or the species most vulnerable to population decline, was the northern Mexican gartersnake (*Thamnophis eques megalops*) followed by the southwestern willow flycatcher (Table 1). Species with high vulnerability tended to be vulnerable across multiple factors or categories rather than have many predictors of vulnerability within a single factor (Table 1). The lowest score was for the black-tailed prairie dog, the only species with a negative score, indicating a prediction of more favorable conditions and potentially increasing populations in the absence of other threats. The aplomado falcon (*Falco femoralis septentrionalis*) had the second lowest score, but at 1.2, we expect a relatively neutral response to climate change conditions in this region. Scores do not directly translate to linear population projections, because we do not know the relative importance of each trait considered nor was every possible predictor of population response to climate change included. Also note that the highest overall score recorded here, 10.8, is well below the highest possible score of 20. However, a score of 20 would require the species to possess all 22 traits and that each of those traits predicts population decline, which is biologically improbable.

Scores are the balance of traits associated with vulnerability minus those associated with resilience; thus, the sign of a score indicates the overall predicted direction of change while its magnitude is an indication of how far the balance is skewed towards vulnerable (positive) or resilient (negative) traits. Thus, it is not just areas of vulnerability but also resilience that affect overall and category scores. For example, Mexican spotted owl (*Strix occidentalis lucida*) has fewer areas of vulnerability than the Sonoran tiger salamander (*Ambystoma tigrinum stebbinsi*),

Table 1. Climate change vulnerability scores for TER-S at Fort Huachuca, Arizona, listed from most vulnerable (positive scores) to most resilient (negative scores). Possible scores range from -20 to 20 for overall and -5 to 5 for each factor. Uncertainty is a percentage of scoring questions with limited information or contradictory predictions. Full scoring and scientific names are available in Appendix A.

Species	Habitat	Physiology	Phenology	Interactions	Overall Score	Uncertainty (%)
Northern Mexican gartersnake	2.9	2.3	2.5	3.0	10.8	27.0
Southwestern willow flycatcher	2.7	1.7	3.8	2.0	9.9	36.0
Arizona treefrog	3.6	0.7	2.5	1.0	8.0	23.0
Arizona ridge-nosed rattlesnake	2.1	1.5	3.8	1.0	8.0	41.0
Chiricahua leopard frog	2.7	0.7	2.1	2.0	7.8	9.0
Arizona shrew	2.1	2.5	1.3	0.0	6.4	55.0
Western yellow-billed cuckoo	1.3	2.5	3.8	-1.0	6.1	45.0
Buff-breasted flycatcher	1.3	0.8	3.8	0.0	5.3	41.0
Mexican spotted owl	1.3	0.8	2.5	1.0	5.3	27.0
Sonoran tiger salamander	2.1	-0.3	2.1	1.0	5.0	45.0
Western barking frog	2.1	0.5	2.1	0.0	5.0	14.0
Mexican long-tongued bat	1.3	0.7	0.8	1.0	4.1	27.0
Elegant trogon	2.0	-1.2	3.8	0.0	4.1	32.0
Peregrine falcon	-0.1	0.8	2.5	1.0	3.5	23.0
Lesser long-nosed bat	0.5	0.7	0.8	1.0	3.1	9.0
Bald eagle	1.3	0.8	-0.4	0.0	2.4	23.0
Northern goshawk	1.3	-1.0	2.5	0.0	2.4	27.0
Cave myotis	-1.1	-0.2	3.8	1.0	2.2	32.0
Desert massasauga	-1.8	1.5	3.8	0.0	2.2	41.0
Aplomado falcon	-2.6	0.8	2.5	2.0	1.2	23.0
Black-tailed prairie dog	-2.5	-1.0	2.5	0.0	-2.4	23.0

but because the salamander has more areas of resilience, its overall score is lower (Table 2). Similarly, a low overall score may be a result of neutral effects across several categories (i.e., few vulnerabilities) or a combination of vulnerable traits balanced by resilient traits, such as for the aplomado falcon (*Falco femoralis septentrionalis*) (Table 2). This has important implications for management and is critical to score interpretation because species can be vulnerable for very different reasons and, although treated as equal during scoring, the relative influence of each of the individual traits on populations is unknown.

Amphibians (average = 6.5) and reptiles (average = 7.0) had the highest vulnerability on average while vulnerability of birds was lower (average = 4.5). This trend exists despite recognition in the scoring system of the metabolic resilience of ectotherms. Mammals, on average, were the least vulnerable (average = 2.7), with the most vulnerable being Arizona shrew (*Sorex arizonae*) (Table 1). A more striking pattern is that related species did not group together in the assessment, and taxonomic group members are scattered throughout the rankings. For example, the three reptile species assessed, all snakes, ranged from 2.2 to 10.8. Bird species were both near the top and the bottom of the list. More ecologically aligned species were similarly vulnerable as exemplified by the two nectivorous bats, the lesser long-nosed (*Leptonycteris yerbabuenae*) and the Mexican long-tongued (*Choeronycteris mexicana*).

Table 2. Predicted effect of climate change on individual criteria from SAVS designated by shading and letter (n = neutral, v = vulnerable, and r = resilient) for TER-S at Fort Huachuca. Details on SAVS are found in Bagne and others (2011). See Appendix A for more details.

Common name	**Scientific name**	Changes to Breeding Habitat	Changes to Non-breeding Habitat	Changes to Breeding Habitat Components	Changes to Non-breeding Habitat Components	Changes to Habitat Quality	Dispersal Ability	Migration Habitats	PS1. Limiting Physiological Conditions	PS2. Temperature-Determined Sex Ratios	PS3. Disturbance Events	PS4. Daily Activity Period	PS5. Adaptive Strategies	PS6. Metabolic Rate	PH1. Reliance on Climate Cues	PH2. Reliance on Discrete Resource Peaks	PH3. Separation Between Activities and Resources	PH4. # of Reproductive Events per Year	Changes in Food Resources	Changes in Predation	Symbiotic Relationships	Changes in Disease	Changes in Competition
Northern Mexican gartersnake	*Thamnophis eques megalops*	v	v	n	v	v	n	n	v	n	v	v	v	r	n	v	n	v	v	v	n	n	v
Southwestern willow flycatcher	*Empidonax trailii extimus*	v	v	v	n	v	r	v	v	n	n	n	v	n	n	v	v	v	v	n	n	v	n
Arizona treefrog	*Hyla wrightorum*	v	v	v	v	n	v	n	v	n	n	n	n	r	n	v	n	v	n	n	n	v	n
Arizona ridge-nosed rattlesnake	*Crotalis willardi willardi*	v	v	n	n	n	v	n	v	n	n	v	v	r	v	v	n	v	n	n	v	n	n
Chiricahua leopard frog	*Lithobates chiricahuensis*	v	v	v	v	r	v	n	n	n	v	v	n	r	v	v	r	v	n	v	n	n	v
Arizona shrew	*Sorex arizonae*	v	v	n	n	n	v	n	v	n	n	n	v	v	n	n	n	v	n	n	n	n	n
Western yellow-billed cuckoo	*Coccyzus americanus occidentalis*	v	n	v	n	n	r	v	v	n	v	n	v	n	n	v	v	v	r	n	n	n	n
Buff-breasted flycatcher	*Empidonax fulvifrons pygmaeus*	v	v	n	n	n	r	v	n	n	n	n	v	n	n	v	v	v	n	n	n	n	n
Mexican spotted owl	*Strix occidentalis lucida*	v	v	n	n	v	r	n	v	n	n	n	n	n	n	v	n	v	v	n	n	n	n
Sonoran tiger salamander	*Ambystoma tigrinum stebbinsi*	n	n	v	n	v	v	n	v	n	n	v	r	r	v	v	r	v	n	v	n	n	n
Western barking frog	*Eleutherodactylus augusti cactorum*	v	v	n	n	n	v	n	v	n	v	v	r	r	v	v	r	v	n	n	n	n	n
Mexican long-tongued bat	*Choeronycteris mexicana*	v	v	n	n	n	r	v	r	n	v	n	v	n	n	v	r	v	v	n	n	n	n
Elegant trogon	*Trogon elegans*	v	v	v	n	n	r	v	r	n	v	n	r	n	n	v	v	v	n	n	n	n	n
Peregrine falcon	*Falco peregrinus anatum*	n	n	n	n	n	r	v	n	n	n	n	v	n	n	v	n	v	n	n	n	v	n
Lesser long-nosed bat	*Leptonycteris yerbabuenae*	v	v	n	n	r	r	v	r	n	v	n	v	n	n	v	r	v	v	n	n	n	n
Bald eagle	*Haliaeetus leucocephalus*	n	v	n	v	n	r	v	n	n	n	n	v	n	n	r	n	n	n	n	n	n	n
Northern goshawk	*Accipiter gentilis atricipillus*	v	n	n	v	v	r	n	n	n	n	n	r	n	n	v	n	v	n	n	n	n	n
Cave myotis	*Myotis velifer*	r	r	n	n	v	r	v	v	n	n	n	r	n	n	v	v	v	n	n	n	v	n
Desert massasauga	*Sistrurus catenatus edwardsi*	r	r	n	n	v	r	n	v	n	n	v	v	r	v	v	n	v	n	n	n	n	n
Aplomado falcon	*Falco femoralis septentrionalis*	r	r	v	n	r	r	n	n	n	n	n	v	n	n	v	n	v	v	n	n	v	n
Black-tailed prairie dog	*Cynomys ludovicianus*	r	r	n	n	n	r	n	n	n	n	n	r	n	n	v	n	v	n	n	n	n	n

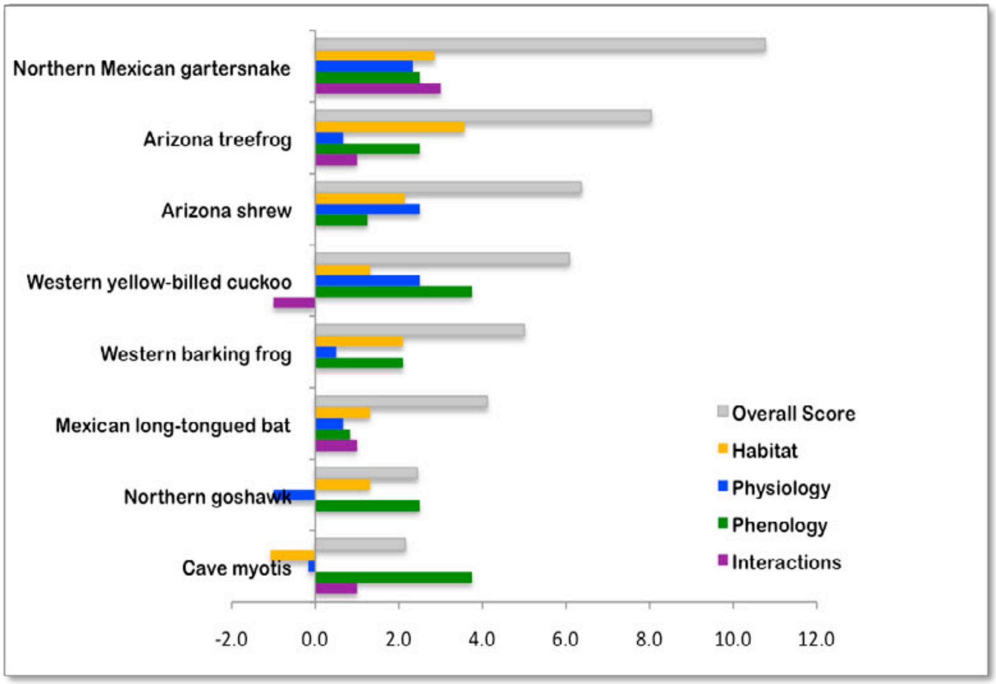

Figure 4. Vulnerability category and overall scores for Federal candidate species or Federal species of concern at Fort Huachuca.

Examination of the category scores reveals more details on vulnerability (Table 1, Figure 4). Note that category scores are adjusted to be on a comparable scale because a different number of questions comprise each category. Phenology was consistently an important factor in vulnerability for many species (Table 1). The phenology factor score reflects the relative influence of climate on species' phenology, timing of resources, and the potential for timing flexibility. Ultimate outcome of these relationships is difficult to project because synchronicity of species to resources can depend on the degree of timing shifts from multiple elements. Absence of favorable timing predictions is partly due to the lack of knowledge about cues and temporal resources for many species, but we also know that timing is sensitive to warming and has already been detected in a broad range of species (Bradley and others 1999; Jenni and Kery 2003; Millar and Herdman 2004). Habitat scores tended to mirror, with some exceptions, projected habitat change for the Southwest with more resilience in grassland species and higher vulnerability in riparian and semi-aquatic species. Climate change exacerbates habitat threats that are already implicated in species declines such as the loss of habitats vulnerable to fire or subject to water withdrawals. Importantly, even where habitat was expected to expand, a species could still be found vulnerable because of the diverse criteria used in the scoring system. Physiology tended to be an important factor for high scoring species. Although the two most vulnerable species had high scores for interactions, many species had neutral interaction scores, but uncertainty was also high as information on key biological interactions was often limited (Appendix A).

The four Federally endangered species, the southwestern willow flycatcher, the lesser long-nosed bat, the aplomado falcon, and the Sonoran tiger salamander were vulnerable to further population declines but were not all the highest scored. Those species currently considered at increased risk of extinction, but without Federal protection may be of particular interest to managers. The two candidate species for endangered species listing, yellow-billed cuckoo and Arizona treefrog, were highly vulnerable to further decline associated with climate change, but climate change was only listed as a threat warranting candidacy for the treefrog (USFWS 2001,

Table 3. Climate change vulnerability scores for threatened and endangered plant species at Fort Huachuca, Arizona, listed from most vulnerable (positive scores) to most resilient (negative scores). Possible scores range from -10 to 10 for overall and -3 to 3 for each factor. Uncertainty is a percentage of scoring questions with limited information or contradictory predictions. Full scoring and scientific names are available in Appendix A.

Species	Habitat	Physiology	Interactions	Overall score	Uncertainty (%)
Lemmon fleabane	-0.3	2	1	**2.9**	60
Huachuca water umbel	0.5	1	1	**2.8**	30

2012). Several species designated as at-risk or currently in review by USFWS were also identified as vulnerable to declines associated with climate change, including the highest scoring species, northern Mexican gartersnake (Figure 4).

Vascular Plants

Only two plant species were assessed—one endangered and the other a candidate for listing. Both received almost identical scores that indicated greater vulnerability with climate change (Table 3). Although population responses may ultimately be similar, these species were vulnerable for very different reasons. The Huachuca water umbel will be exposed to greater drying of its required wetland and riparian habitats, but its ability to disperse via rhizomes and with floods may give it some advantage under projected changes. It is also thought that rhizomes are resistant to drought, although this will depend on drought duration and/or severity. Assessing vulnerability for Lemmon fleabane (*Erigeron lemmonii*) was limited by lack of information. Although conditions in Scheelite Canyon were expected to remain suitable into the near future, this species also seems to possess few attributes that could be considered resilient. Pollination and reproduction, as for many species, is vulnerable as insects will also be subject to changing conditions resulting in changes in timing and/or numbers.

Management Implications: Using Assessment Results

This assessment seeks to help clarify the threat of climate change to individual species and identify potential management actions. Management of TER-S, however, is not exclusively based on vulnerability nor is climate change the only potential threat to species. Feasibility, economics, and political considerations all play a role in management decisions but are outside the scope of this assessment. Other aspects of prioritization such as population trends or genetic uniqueness are also factors (Given and Norton 1993). Management actions are likely to be more effective and targeted if priorities and potential impacts are clear.

During scoring, we kept our focus on the coming decades that, while more conservative than longer outlooks, are of more practical use to current management and more projectable. Below, we summarize management themes gleaned from the individual species accounts, which contain detailed information for each species (see Appendix A). These themes suggested target areas for management that were common to multiple species (Table 4). For example, habitats threatened by increased fire may be protected by removing invasive plants or creating fire breaks. Often called adaptation strategies, these actions reduce the impacts of climate

Table 4. Summary of common management target areas for reducing anticipated climate change threats to individual species on Fort Huachuca. This list is not comprehensive but includes target areas that were shared by multiple species and that have the potential to reduce climate change vulnerability. Specific management actions may differ for species within the same target area. "Timing restrictions" refers to altering dates when potentially disruptive activities are restricted. Scientific names appear in Appendix A.

Species	Fire/fuels/ invasive plants	Water/riparian	Post-fire rehabilitation	Corridors/ dispersal	Timing restrictions	Upland microsites
Northern Mexican gartersnake	x	x		x		
Southwestern willow flycatcher		x			x	
Arizona treefrog	x	x	x	x		
Arizona ridge-nosed rattlesnake	x					
Chiricahua leopard frog	x	x	x	x		
Arizona shrew	x	x	x			x
Western yellow-billed cuckoo	x	x				
Buff-breasted flycatcher	x		x			
Mexican spotted owl	x		x		x	x
Sonoran tiger salamander	x	x		x		x
Western barking frog	x			x		x
Mexican long-tongued bat	x				x	
Elegant trogon	x	x	x		x	
Peregrine falcon		x			x	
Lesser long-nosed bat	x				x	
Bald eagle	x					
Northern goshawk	x				x	
Cave myotis		x			x	x
Desert massasauga	x	x				
Aplomado falcon	x					
Black-tailed prairie dog				x		
Huachuca water umbel		x		x		
Lemmon's fleabane				x		x

change or increase resilience of species or their habitats. Other management strategies may focus on reducing current threats to species, including those that may be exacerbated by climate change such as water withdrawals, border traffic, and energy development. Management implications are general recommendations from the assessment that should be considered for species management and not as a critique of current management programs.

Fire, Fuels, and Invasive Species Management

As previously noted, conditions conducive to fire ignition and spread are expected to increase. Because individual species respond differently to fire, those fires that burn very large areas or encourage habitat conversion, particularly to non-native vegetation, are of the most concern from a biodiversity perspective. Of particular concern in this region is the interplay among climate, fire, and invasive grasses, which could degrade habitats for some species such as the lesser long-nosed bat. Other species may benefit from expanding grasslands, but conversion from native to primarily non-native grasses alters ecosystem processes and relationships (D'Antonio and Vitousek 1992; Geiger and McPherson 2005; Van Devender and Dimmit 2006). Changes in grassland fire regimes will also affect adjacent woodland and forest habitats as fires spread and communities shift upward. Thus, habitats for forest species such as Mexican spotted owl and Arizona ridge-nosed rattlesnake (*Crotalis willardi willardi*) may be affected. Overall, management related to fire has the potential to increase resilience or improve habitat for most of the species in this assessment (Table 4).

Fuel management, either through prescribed burning or mechanical treatment, can be used to help reduce fire severity and spread (Graham and others 2004). Management that focuses primarily on suppression is often counterproductive as this approach eventually encourages greater fire severity (Minnich and Chou 1997; Stephens and Ruth 2005). Because fires of high severity are also inevitable, plans should be in place to reduce potential impacts from fire-fighting efforts (e.g., backfiring and chemical suppressants) and rehabilitate habitats following fire if needed.

Management of non-native plants, particularly invasive grasses, will also be key as non-natives play a major role in altering fire regimes and can outcompete native grasses and forbs. In addition, measures that prevent introductions and spread will be essential and less costly than control measures. Critical areas for control may include locations of known TER-S or adjacent to habitats with TER-S, dispersal sources such as along roads, and areas with increased ignition risk. Elevated CO_2 may also exacerbate competitive dominance of non-natives, particularly during wet years, and managers should anticipate annual variability in the need for invasive species control measures. Increasing drought periods, however, may reduce red brome and other invasives that lack persistent seed banks and can present opportunities for effective control (Burgess and others 1991; Salo 2004).

Artificial and Natural Waters

Surface water is already severely limited in the region and native species with aquatic life stages have already declined significantly. Natural and artificial waters on Fort Huachuca should be evaluated for availability to species under drought conditions to plan for limiting conditions. Evaluation should consider substrates, capacity and annual longevity, habitat surroundings, special species requirements, disease transmission, and potential for supplemental inputs. Artificial waters are widely used in wildlife management in the Southwest, although the benefits and

Figure 5. Warmer conditions and increasing drought threaten waters occupied by the Chiricahua leopard frog. Photo credit: J. Rorabaugh, USFWS.

potential negative impacts are not well quantified (Broyles 1995). Regardless, increasing droughts and high temperatures will likely make these water sources critical to many species, not just those that have aquatic life stages. Depending on availability of projected surface waters, artificial waters may accordingly need to be expanded or modified.

Several TER-S require riparian or aquatic habitats. Management that can maintain water tables and streamflows will be important to these species, but the ability to influence current hydrologic processes is limited and likely to become increasingly difficult as temperatures rise and human demand increases. Project proposals affecting water withdrawals in the region need to be considered carefully, because of the exacerbating stress on TER-S and rare habitats. Managing water with climate change includes identifying incompatibilities between human and ecosystem needs (Richter and others 2003).

For some TER-S in this assessment, drying of waters also presents an opportunity. West Nile virus spread by mosquitoes could be reduced improving conditions for susceptible species. A number of aquatic breeders, including the Chiricahua leopard frog (*Lithobates chiricahuensis*), Arizona treefrog (*Hyla wrightorum*), and the Sonoran tiger salamander, have been extirpated from permanent water sources by invasive predators and competitors such as fish or American bullfrogs (*Rana catesbeiana*), but they are often more tolerant of drying conditions and are currently restricted to temporary waters (Figure 5). As water sources become increasingly intermittent, they may become more suitable for some species, and further enhancements, such as invasive species control measures or creating corridors, can make the most of this situation and allow the critical shift of species from drying habitats to newly suitable ones (Box 2).

Box 2. Seizing Opportunity

Although climate change will present challenges to species and their management, there will likely be opportunities as well. The shifting of species distributions can mean a local reduction in an undesirable species, such as an alien plant species (Bradley 2009), or an improvement for a new species arriving, such as for a species that shifts from a degraded habitat to a protected area. Natural resource managers can take advantage of increasing climate variability to implement actions during the most favorable conditions. For example, drought in arid systems can sometimes favor native species over non-native species, assisting weed control (Salo 2004). During wet periods, planting or natural recruitment in combination with grazing may improve seedling establishment of woody species (Holmgren and Sheffer 2001). Translocation or corridor enhancements to encourage animal dispersal may be most successful during wet years associated with high reproductive success. The climate change challenge may also serve as a catalyst to promote adaptive management strategies, highlight sustainability, and foster partnerships.

Anticipating Shifts in Distribution

Depending on a wide variety of factors, including dispersal ability, physiological thresholds, and vegetation response, populations may shift in distribution as local climate changes. From the perspective of a management unit, these shifts will be observed as a change in numbers regardless of the greater population. Management efforts will be better spent on species that are less able to shift with changing habitats than on those that are disappearing from Fort Huachuca but increasing elsewhere. Shifting of habitats or populations should also be anticipated for geographically based protected areas or designated critical habitat. Managers will need to reevaluate the future suitability of current or proposed protected areas that target individual species. Cave myotis (*Myotis velifer*) roosts in cool and moist caves, and as conditions change so will the locations of suitable caves. Although it is difficult to project what new species may disperse to and occupy Fort Huachuca in the future, they may be species that require inclusion in management planning. We identified black-tailed prairie dog as potentially expanding based on climate change resilience, depending on impacts from other sources and dispersal barriers. Birds can also be anticipated to be some of the first to shift. Monitoring can help identify species in the early stages of expansion.

Movements and migrations are partly adaptations to changing conditions; thus, species can reduce negative impacts by shifting with climate. To facilitate population shifts, corridors will be an important part of managing species under climate change. It may be necessary, in some cases, to assist the migration process to prevent extinction. Generally known as assisted migration, individuals are moved to new, presumably favorable, locations outside of their historic geographic or elevational range. Costs can be high and the nature of climate change is such that new locations cannot be expected to remain suitable in the long term. Introduction of species to new regions is also fraught with problems, including disruption of species interactions, hybridization, and unpredictable outcomes (Ricciardi and Simberloff 2009). Translocations that include recent historical range (i.e., reintroductions) or higher elevations within the current range eliminate many of these issues but may be of questionable benefit in the long term. Conversely, translocations may be beneficial for climate change management as new locations may include more favorable microsites, help reduce risk of stochastic events, or offer better natural dispersal opportunities. Both plants in this assessment could likely be established at new locations, although questions remain as to the desirability of these actions. Falk and others (1996) provided guidelines for rare plant reintroductions.

Coping With Physiological Thresholds

In the absence of dispersal, physiological limitations can result in additional environmental stress manifested as poor survival or reproduction (Bernardo and Spotila 2006). TER-S are at a particular disadvantage for physiological stress, as small population sizes will limit adaptation through natural selection. Although an entire management area can become physiologically unsuitable, it is likely that some favorable microsites will remain, at least for the near future. Besides the management of artificial and natural waters already discussed, managers can take advantage of variation in environmental conditions across the landscape and direct protection or enhancements to favorable microsites. In this assessment, limitations of high heat or low moisture were the most concerning; thus, priority should be given to microsites with suitable habitat that are cool and moist, such as north-facing slopes or canyon bottoms. Microsites that provide shade are important to thermoregulation (Walsberg 1993), and management that encourages shade plants could be of benefit to some species. Protection of areas with greater litter accumulation or water-retaining soil types could help species such as the Arizona treefrog. Fort Huachuca and surrounding areas have varied topography conducive to diverse microclimates, thus there is good potential to use this strategy. In addition, because drought is a limiting factor for many of these species, it may be best to add drought effects to planning documents and anticipate possible interventions.

Anticipating Shifts in Timing

Phenology is an important aspect of life history and is often sensitive to climate conditions. It also was the most sensitive factor to changes for vertebrate species in this assessment (Table 1) and is a potential issue for plant species that are pollinated or dispersed by animals. Management that is time sensitive, such as restricting activities during breeding of a target species, needs to anticipate that timing will change and restrictions need to track these changes. Although timing of individual activities is not readily managed, in some cases, management can affect the timing of resources. An example with potential for intervention and critical to a number of species in this assessment is the presence and duration of temporary pools.

Prioritization

The apparent vulnerability of TER-S to climate change highlights the challenges that will face managers. Managers already need to make choices about where to focus resources, but as stresses on species magnify, there will likely be an increasing need to prioritize species, actions, or both. Scores from this assessment can be used to aid decisions by identifying species most vulnerable to the additional impact of climate change and the species' traits associated with vulnerabilities. Species that are expected to be resilient may also require management if they negatively impact TER-S. Ranks in this assessment are based on the number of predicted vulnerabilities across species for the same set of criteria but likely do not directly translate to a linear progression of population change because some traits may have threshold effects or may be limiting factors. Predictions of climate and vulnerability are uncertain, but an assessment, even if limited, can provide input when no other information is available and can serve as a starting point to address species management under climate change.

Landscape-Scale Management and Partners

Perhaps one of the greatest challenges for managing species under a future climate is that, with continued greenhouse gas emissions, the future is not a steady state. Most management planning, however, focuses on the next 10 to 20 years and we assessed species with that timeline in mind. Partners will be extremely valuable and managers from adjacent lands will be experiencing similar climate conditions and issues. Management at a landscape scale is well suited for climate change issues, as well as being cost effective. Cooperative approaches can help to balance costs and benefits of competing needs. For example, cooperative monitoring at a large scale can separate population shifts from regional declines and detect newly arriving species early. Fort Huachuca is already part of the Huachuca FireScape, a regional effort to address fuels reduction and a good example of a landscape-scale management plan that can begin to address adaptation to climate change (USFS 2009). Similar landscape efforts are needed to address climate change threats to species and related factors, including wildlife corridors, invasive species, water availability, and microsite diversity.

Uncertainty

Although drawn from basic life history and ecology, in many instances, scoring was sometimes uncertain because of lack of information. Deficiencies were common in a few key areas for vertebrates but were more extensive for plant species and limited the scoring criteria used. Physiological thresholds for vertebrates in natural environments are known for few species and thus limited our ability to score this important trait. More uncertainty is added when scoring depends on a secondary prediction for another species (e.g., predators, pollinators, and disease vectors). Although predictions may be limited by information gaps, we felt it was important to include critical relationships of species with climate. Uncertainties were used to identify research priorities, which are noted in the individual species accounts (Appendix A). Resource managers can accomadate uncertainty to a large extent by employing monitoring programs to identify critical impacts early and taking an adaptive management approach that can adjust to complex response. Predicting the future is inherently uncertain, but the exercise of prediction will improve as better models are developed and more research is done.

Next Steps

Vulnerability and resilience predictions are based on responses that are likely a matter of degree and are dependent on the strength or duration of projected changes. This assessment is not meant to substitute for more thorough and complex analyses of the climate change response of individual species, but those approaches will also be limited in their ability to predict the future. Predictions for plant species were particularly difficult to make using this approach and may be more suitable for modeling based on climate envelope or niche modeling than vertebrate species. The scoring systems used in this assessment are simple and flexible by design. Scores can easily be modified to reflect any future changes in projections, although we suspect these will make little difference to the outcome. Managers are encouraged to apply scoring to additional species or to use their knowledge to modify the scoring of species included here. By focusing on ecology and life history traits, these scoring systems can take advantage of the considerable knowledge of local resource managers rather than depend on expertise in modeling or computer simulations that need to be tailored to particular species or regions.

This assessment can help identify management targets including species and actions. Information from assessments can also be used as part of more complex multi-species or landscape planning such as outlined by Lawson and others (2008). In addition, this vulnerability assessment highlights different pathways by which populations can be affected by climate, which is important for initiating dialogue and finding solutions. Predicting effects on individual species is inherently complex and primarily speculative at this point, but we believe that the need for managers to address climate change is becoming more urgent (Thomas and others 2004) and that tools, regardless of their limitations, are needed now. We also want to emphasize that managing for climate change is not just about challenges but also about opportunity (Box 2). Although the process and the product are inherently imprecise, this effort is an important first step toward anticipating and responding to climate change and provides a framework for integrating new research and information.

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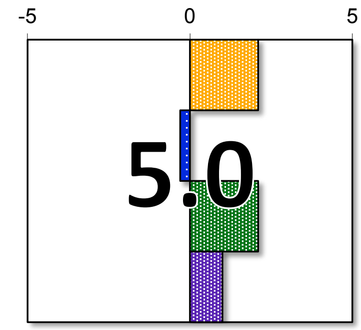
Appendix A: Species Accounts

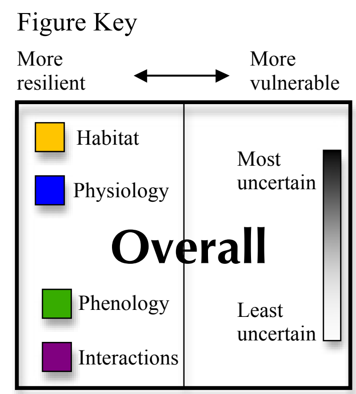
Sonoran Tiger Salamander
(*Ambystoma tigrinum stebbinsi*)



SUMMARY

Declines in amphibians are associated with interactions of multiple threats and the threat due to climate change is likely to contribute to further declines. Life history strategies, such as having both terrestrial and aquatic life forms, may give this species some resilience to fluctuating rainfall patterns and drought. Unfortunately, this species range is already very restricted locally and is vulnerable to extirpation as habitat suitability fluctuates. Vulnerability to climate change could conversely be an opportunity for management to aid in the removal of non-native barred salamanders.

VULNERABILITY	Score	Uncertainty
Habitat	**2.1**	43%
Physiology	**-0.3**	33%
Phenology	**2.1**	50%
Interactions	**1.0**	60%
Overall	**5.0**	**45%**



Introduction

The Sonoran subspecies of tiger salamander is currently listed by the U.S. Fish and Wildlife Service (USFWS) as endangered. No critical habitat has been designated as of the time of this report. It is a species of greatest conservation need, Tier 1B, in Arizona State Wildlife Action Plan or SWAP (AGFD 2006). Currently, Sonoran tiger salamanders are found mostly in human-made ponds or cattle tanks and occur in ponds in the San Rafael Valley, Arizona. Following European settlement, erosion and alterations to the hydrology within the species' range are thought to have destroyed most of the temporary pond habitats. Permanent water, although suitable, often has introduced fish and bullfrogs, which prey on salamanders. Most salamanders on Fort Huachuca are thought to be barred tiger salamanders except for one pond near the San Rafael Valley in the Upper Garden Canyon (USFWS 2002).

Fort Huachuca Climate and Projections

- Annual increase in temperature 2.2 °C or 4 °F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell and others 2002)
- More droughts and intense storms (Seager and others 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager and others 2007)
- Riparian habitats decline (Stromberg and others 2006, Serrat-Capdevila and others 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)

- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir and others 2008)
- Reductions in Madrean woodlands (Rehfeldt and others 2006)

A detailed review of projections is in the "Projections of Climate, Disturbance, and Biotic Communities" section of the main document.

Other Threats and Interactions With Climate

Tiger salamanders are threatened by loss of habitat, introduced predators, and hybridization with barred tiger salamanders (USFWS 2002). Threats such as ultra-violet (UV) radiation, water pH, pesticides, and disease may interact and increase susceptibility to declines. A number of these threats will likely be exacerbated in the future by climate change. Although most threats identified are associated with aquatic habitats, terrestrial habitats may also be vulnerable to drier conditions, which will limit their suitability.

This species is restricted to only a few locations, and introduced predators and barred tiger salamanders, with which it can hybridize, limit dispersal to new locations. Dispersal among aquatic habitats, however, will become increasingly important as these habitats vary in susceptibility to drying. Drought can further disrupt dispersal by removing potential corridors and altering habitat suitability. Monsoons likely play a role in providing dispersal opportunities, but are not well projected for the future. It is likely that monsoon rainfall will become more variable so dispersal opportunity is expected to likewise fluctuate widely from year to year.

Research Needs

Periodic die-offs associated with Ambystoma Tigrinum Virus (ATV) have no known relationship to climate or habitat, but this virus has only been recently identified and little field study has been conducted. Habitat features associated with favorable terrestrial habitats have received little attention. An assessment related to future condition of wetlands and dispersal corridors will be important to identifying suitable habitat of the future and planning management.

Management Implications

Management related to maintaining water tables and pond duration is important. The only known salamander population on Fort Huachuca occurs in an artificial pond. This pond has shrunk and even dried in past years, but the population has survived these episodes (ENRD 2006). Longer dry periods, however, will likely be detrimental, though critical limits are not known for the species. Although options for this particular pond are unknown, some ponds may be suitable for artificial water inputs should they dry for too long a period. Additionally, factors related to tank construction and pond substrates can likely be used to increase water retention of ponds. Attention should also be given to protection of terrestrial habitats adjacent to temporary ponds used by terrestrial salamanders. Litter and debris as well as low levels of disturbance are likely important factors that can be managed to maintain favorable microclimate of these habitats.

Currently occupied habitats are those that dry periodically to discourage non-native predators and competitors while still staying moist long enough to allow development of larval salamanders. These areas will be subject to further drying that can eventually make them unsuitable. Some areas that currently sustain permanent waters may actually increase in suitability as drying occurs and aquatic non-natives are extirpated. Dispersal will then be critical to survival in the future. Removal of barred tiger salamanders and introduced fish from suitable dispersal habitats could also be implemented to increase available habitats and resiliency of populations to declines. Aspects of vulnerability outlined for the Sonoran subspecies could aid in extirpation of barred tiger salamanders or hybrids where they occur and can be encouraged where appropriate. Translocation could be a viable option for future management of this species and should be planned based on predicted future wetland conditions along with potential for increased predation. The status of this species as a carrier of chytrid fungus should be considered in relation to proximity of susceptible TER frogs and during any assisted migration programs.

Habitat: Sonoran Tiger Salamander (*Ambystoma tigrinum stebbinsi*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Terrestrial adults live in oak woodlands and grasslands (USFWS 2002). Grasslands may expand, but woodlands will be vulnerable to increasing fires and upslope shifts. Overall, no change projected.	**0**
2. Area and distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Same as above.	**0**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Eggs are laid in water of permanent or temporary sources and attached to vegetation, debris, or rocks (USFWS 2002). Water availability is expected to be reduced.	**1**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	Terrestrial adults use mammal burrows or bury themselves in soft soils to escape desiccation. Soils suitable for burrows are not expected to change.	**0**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Better survival is associated with more emergent vegetation, some shallow water, and soft substrates (Sarell 2004). Emergent vegetation may be reduced with warmer temperatures and greater evaporation, although this will depend on hydrology of specific sites.	**1**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Little information on site fidelity, but other congeneric salamanders generally return to the ponds where they were born. Dispersal has been observed up to 3-4 km from source populations (USFWS 2002). Others note that tiger salamanders have a minimal capacity for dispersal and they usually migrate 162 m to 229 m from breeding pond to aestivation sites over 3 days (AmphibiaWeb 2008). Dispersal is also thought to be limited by distribution of temporary ponds. Overall, limited ability to disperse as habitats change.	**1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Moves between terrestrial and aquatic environments, but no specific transitory habitats required.	**0**

Physiology: Sonoran Tiger Salamander (*Ambystoma tigrinum stebbinsi*)

Trait/Quality	Question	Background Info & Explanation of Score	Points
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Eggs are prone to freezing and dehydration (USFWS 2000). Adults are tolerant temperature from 5 °C to 30 °C in ponds and in terrestrial environments can survive below freezing to above 35 °C (USFWS 2002). Terrestrial amphibians are prone to desiccation, which will increase with warmer temperatures.	**1**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g., severe storms, fires, floods) that affect survival or reproduction expected to change?	Although floods may occur more frequently along stream courses, currently occupied ponds are not vulnerable to flooding. No effects of fires are known.	**0**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Terrestrial movements are limited by moisture and may be decreased by warmer temperatures and greater evaporation. Aquatic movements probably will not be limited.	**1**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	Mostly adults are terrestrial while larvae are aquatic. Mature individuals can remain aquatic (branchiate adults or neotenes) with gills or metamorphose into gill-less terrestrial adults. Branchiate adults occur in permanent water sources and although pond drying can induce metamorphosis, many branchiate adults die during the process (USFWS 2002). In permanent water, only 17% metamorphose into terrestrial adults, while all that are large enough will in drying ponds (Collins and others 1988). 200 to 2000 eggs are laid (USFWS 2000) and can have large reproductive output in favorable years.	**-1**
6. Metabolic rates	What is this species metabolic rate?	Ectothermic.	**-1**

Phenology: Sonoran Tiger Salamander (*Ambystoma tigrinum stebbinsi*)

Trait/Quality	Question	Background Info & Explanation of Score	Points
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g., hibernation, migration, breeding)?	Temperature is a cue for adult emergence and migration (AmphibiaWeb 2008).	**1**

Phenology: Sonoran Tiger Salamander (*Ambystoma tigrinum stebbinsi*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g., food, breeding sites) that are expected to change?	Requires standing water from January through June for aquatic young to develop (USFWS 2002). Rarely breeds after monsoon rains (USFWS 2002). Standing water likely related to timing of winter rainfall, which is likely to change.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Eggs take longer to develop in colder water (USFWS 2002), thus development may keep up with changing pond duration to some extent. Favorable migration conditions directly trigger migration.	**-1**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	Most report one reproductive event per year (Sarell 2004), though some cite two if habitat is available. However, Church and others (2007) suggested the latter is prohibitively costly for females.	**1**

Biotic Interactions: Sonoran Tiger Salamander (*Ambystoma tigrinum stebbinsi*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Adults eat a variety of invertebrates. Branchiate adults eat zooplankton and macroinvertebrates. No expected changes in overall levels of diverse prey species.	**0**
2. Predators	Are important predator populations expected to change?	Predation is considered a major threat to this species. Predators included caddis flies, dragonfly naiads, predaceous diving beetles, giant water bugs, newts, conspecifics (cannibalistic morphs), snakes, predatory, wading and shore birds, badgers, raccoons, coyotes, opossums, and humans (AmphibiaWeb 2008). Predators, particularly American bullfrog and introduced fish, pose significant threat and considerable impact on salamanders (USFWS 2002). Currently mostly occupies habitats without fish and few bullfrogs (USFWS 2002), but impacts from American bullfrogs may increase as they are expected to be resilient to climate change.	**1**
3. Symbionts	Are populations of symbiotic species expected to change?	No symbionts.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected	Frequent disease outbreaks attributed to a ranavirus, ATV (Jancovitch and others 1997). Frogs and fish could not be artificially infected and are not likely carriers for this disease (Jancovitch and others 2001). No research was found to indicate that these ranaviruses would increase with warmer temperatures. Note that this	**0**

Biotic Interactions: Sonoran Tiger Salamander (*Ambystoma tigrinum stebbinsi*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
	to change?	species, although unaffected, is a carrier for chytrid fungus.	
5. Competitors	Are populations of important competing species expected to change?	Fish are not only predators, but also a primary competitor (Sarell 2004). Fish do not occur in current habitats. Barred salamanders may also compete, but are expected to have similar response to climate change.	**0**

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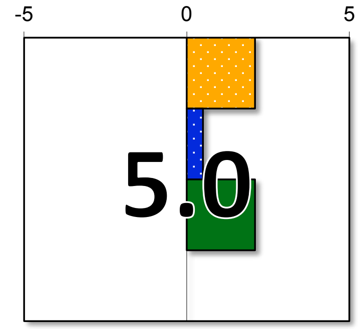
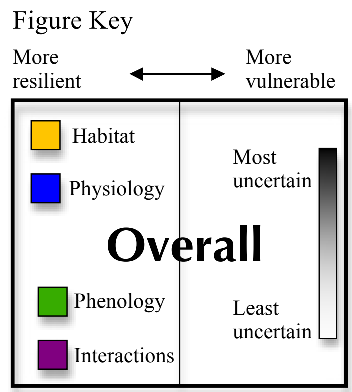
Western Barking Frog
(*Eleutherodactylus augusti cactorum*)



SUMMARY

The barking frog is unusual compared to other frogs in Arizona. It is a terrestrial species with direct development of the young from eggs, which also receive parental care. These features, along with its lack of reliance on aquatic habitats, may incur resilience to climate change in comparison with some frog species. Conversely, dependence on rainfall and moist habitats along with low dispersal ability will likely increase this species' vulnerability to declines with climate change. Balancing these traits overall, this species was assessed to be vulnerable to population declines associated with projected climate change.

VULNERABILITY	Score	Uncertainty
Habitat	**2.1**	14%
Physiology	**0.5**	17%
Phenology	**2.1**	0%
Interactions	**0.0**	20%
Overall	**5.0**	14%



Introduction

Populations of western barking frog were discovered on Fort Huachuca in 2002. It is a species of greatest conservation need, Tier 1B, in Arizona State Wildlife Action Plan or SWAP (AGFD 2006) and designated as a species at risk (SWESA 2006). Range in the United States is Arizona, New Mexico, and Texas along the Mexico border (AmphibiaWeb 2010). It is the only representative of this mostly tropical family in Arizona. There is currently unresolved taxonomy for subspecies (AmphibiaWeb 2010) and individuals in Arizona differ from those found in New Mexico and Texas (Goldberg 2003).

Fort Huachuca Climate and Projections

- Annual increase in temperature 2.2 °C or 4 °F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell and others 2002)
- More droughts and intense storms (Seager and others 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager and others 2007)
- Riparian habitats decline (Stromberg and others 2006, Serrat-Capdevila and others 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir and others 2008)
- Reductions in Madrean woodlands (Rehfeldt and others 2006)

A detailed review of projections is in the "Projections of Climate, Disturbance, and Biotic Communities" section of the main document.

Other Threats and Interactions With Climate

Habitat loss may be the greatest current threat to this species. Open pit copper mining has been implicated in the loss of Arizona habitat (Goldberg 2003), but mining does not occur on or adjacent to Fort Huachuca. Other habitat loss, such as through disturbance, will likely increase with climate change as fires increase and rainfall becomes more variable. Although vegetation associated with this species will be vulnerable to changes, species' presence may be more closely linked to geologic features such as rock outcrops. This species' association with oak woodlands and mixed pine-oak forests may be more related to moisture than vegetation type. Changes in the amount of rainfall, especially the summer rains that are tied to breeding in this species, are difficult to project, but drier conditions on average are likely with increased evaporation from higher temperatures and changes in rainfall timing.

Research Needs

Little is known about this species and monitoring populations is difficult because of their cryptic behavior (Goldberg and Schwalbe 2004). Full species' range in Arizona is unknown, because this species may be undetected in additional locations (Goldberg 2003).

Management Implications

This species may be difficult to manage if climate change brings drier conditions. Its association with particular geologic features and low dispersal ability make it unlikely to move upslope or to new locations. It may, however, currently occur in more locations than are known making any monitoring of population trends difficult. This species' association with moist habitats rather than permanent waters and its ability to remain inactive for extended periods will help it cope with dry years better than many of the semi-aquatic amphibian species. Extent of vulnerability in this species will depend on monsoonal rain patterns and drought intensity. Because these climate events are not well projected, management may be best focused on documenting habitat and presence of the species. Planning that includes contingency plans for assisting species during extreme conditions should consider actions to assist this species. Although a controversial method, this species may be a good candidate for localized translocations with transfer from drier locales to more mesic locales.

Habitat: Western Barking Frog (*Eleutherodactylus augusti cactorum*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	In Arizona, occupies elevations from 1280 to 1890 m (Degenhardt and others 1996). In Arizona, barking frogs have been found in rock outcrops within Madrean evergreen woodlands (Goldberg and Schwalbe 2004) and pine-oak woodlands (Brennan and Holycross 2006).	**1**
2. Area and distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Same as above.	**1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated getation type?	Eggs are laid in moist and protected locations such as rain-filled cracks, fissures, and moist caves or under rocks (AmphibaWeb 2010). Rock outcrops and fissures unlikely to change (see Physiology Question 3 and Phenology Question 2).	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	Winter or dry season refugia are required. Generally associated with cliffs and caves. Rock outcrops and caves are unlikely to change.	**0**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Not known.	**0**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Very limited movements.	**1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Move between overwintering and summer activity sites up to 50 m (AmphibiaWeb 2010). No transitional habitats required.	**0**

Physiology: Western Barking Frog (*Eleutherodactylus augusti cactorum*)

Trait/Quality	Question	Background Info & Explanation of Score	Points
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Although terrestrial, like many amphibians, this species is prone to dessication.	**1**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g., severe storms, fires, floods) that affect survival or reproduction expected to change?	No known disturbance interactions. Moist, rocky habitats are not fire prone. It is speculated that females may stay with the eggs and excrete urine to maintain moisture (Brennan and Holycross 2006, AmphibiaWeb 2010), thus this may help eggs to survive more variable rainfall and drying conditions. Extended droughts likely limit reproduction and survival.	**1**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Activity is limited by moisture. Drier conditions are likely with warmer temperatures.	**1**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	May go several years without breeding and then has clutches containing from 50–76 eggs (AmphibiaWeb 2010). Tadpoles develop inside the egg and emerge fully developed. In addition, females may tend the eggs and keep them moist (Brennan and Holycross 2006). These strategies may help this species survive during dry years.	**-1**
6. Metabolic rates	What is this species metabolic rate?	Ectothermic and may be able to use torpor facultatively (AmphibiaWeb 2010).	**-1**

Phenology: Western Barking Frog (*Eleutherodactylus augusti cactorum*)

Trait/Quality	Question	Background Info & Explanation of Score	Points
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g., hibernation, migration, breeding)?	Males generally call during rainfall and in Arizona typically with summer rains beginning in June or July (AmphibiaWeb 2010).	**1**
2. Event timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g., food, breeding sites) that are expected to change?	Breeding coincides with rainfall likely because of moist conditions needed for successful egg laying and development (AmphibiaWeb 2010). Foraging may also be limited by moisture. Timing of rainfall is likely to change.	**1**

Phenology: Western Barking Frog (*Eleutherodactylus augusti cactorum*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Breeding appears to be triggered directly by rainfall, which provides required moisture for egg development, thus there is a close match between cues and resources.	**-1**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	One breeding event per year.	**1**

Biotic Interactions: Western Barking Frog (*Eleutherodactylus augusti cactorum*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Eats a variety of invertebrates including grasshoppers, centipedes, and crickets (AmphibiaWeb 2010). Wide variety of prey, likely have differing responses to climate change.	**0**
2. Predators	Are important predator populations expected to change?	Unknown predators (AmphibiaWeb 2010).	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	No symbionts.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	No known diseases. Terrestrial habits likely reduce risk of chytridiomycosis.	**0**
5. Competitors	Are populations of important competing species expected to change?	No known competitors. Very different associations than other local frogs.	**0**

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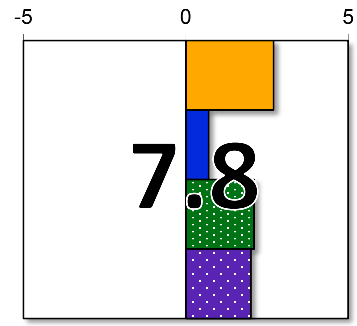
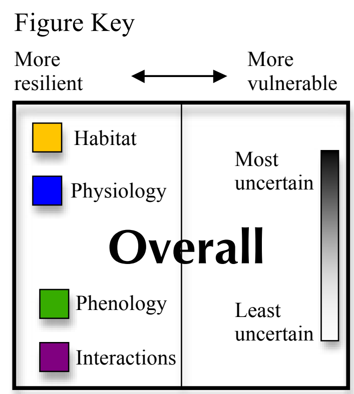
Chiricahua Leopard Frog
(*Lithobates* or *Rana chiricahuensis*)



SUMMARY

Chiricahua leopard frogs only remain extant in small, scattered ponds and stock tanks because larger and more permanent water sources generally contain more native and non-native predators and competitors. Unfortunately, the currently occupied habitats will be at greater risk to drying as temperatures warm. Conversely, increased temperatures may offer a number of advantages as drying of water sources for short periods can help reduce non-native predators, higher temperatures reduce susceptibility to chytridiomycosis, and warmer waters increase growth rates. Many questions surround prediction of climate change effects in this species because of the complex interaction of threats and climate. Management will be critical, because location of suitable habitats is expected to shift.

VULNERABILITY	Score	Uncertainty
Habitat	**2.7**	0%
Physiology	**0.7**	0%
Phenology	**2.1**	25%
Interactions	**2.0**	20%
Overall	**7.8**	**9%**



Introduction

Genus was changed from *Rana* to *Lithobates* (Frost and others 2006), but *Rana* is still in common use. Chiricahua leopard frog was listed as threatened by USFWS in 2002. Populations previously identified as Ramsey Canyon leopard frog (*Rana subaquavocolis*) are now considered a population of the Chiricahua leopard frog (Goldberg and others 2004, Hillis and Wilcox 2005). Ramsey Canyon leopard frog is designated as a species at risk (SWESA 2006). There are two disjunct metapopulations: montane populations along the Mogollon rim and western New Mexico and southern populations in the border region of Arizona, New Mexico, and Mexico (USWFS 2007). They have disappeared from many of their historic locations and appear be present at less than 20% of those sites (USFWS 2007).

Fort Huachuca Climate and Projections

- Annual increase in temperature 2.2 °C or 4 °F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell and others 2002)
- More droughts and intense storms (Seager and others 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager and others 2007)
- Riparian habitats decline (Stromberg and others 2006, Serrat-Capdevila and others 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)

- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir and others 2008)
- Reductions in Madrean woodlands (Rehfeldt and others 2006)

A detailed review of projections is in the "Projections of Climate, Disturbance, and Biotic Communities" section of the main document.

Other Threats and Interactions With Climate

We focus on those impacts expected to interact with climate change and refer the reader to Southwest Endangered Species Act Team (2008) report on this species for a thorough overview of impacts and management recommendations regarding the Chiricahua leopard frog. Also note that the climate change vulnerability score was based on currently occupied habitats and several additional traits would have been considered vulnerable if we had included formerly occupied habitats during scoring. This species is threatened by invasive species, water regulation, mining, fire in upland habitats, pesticides, UV radiation, and chytridiomycosis (USFWS 2007). In addition, life history predisposes this species to ongoing extirpation and recolonization of populations, thus any disruption of metapopulation dynamics can result in the loss of the species from entire regions (USFWS 2007). Although not currently overlapping with the range of the Chiricahua leopard frog, the Rio Grande leopard frog (*Rana berlandieri*) has been introduced in other parts of Arizona (Platz and others 1990). Expansion of the larger Rio Grande leopard frog could negatively impact populations. Many of these threats are expected to interact with climate.

Individual localities are subject to extirpation and recolonization with metapopulation dynamics is important to long-term persistence. In addition, Maintenance of corridors for dispersal of juveniles and adults is thought to be critical to preserving populations (Jennings and Scott 1991, USFWS 2007). Drought can disrupt dispersal by removing potential corridors and altering habitat suitability. Changes in habitat suitability are complicated by the association of Chiricahua leopard frog presence with complexes of permenant and ephemeral waters. Temporary pools that do not support non-native predators may provide the best conditions for dispersal. Monsoons likely play a role in providing dispersal opportunities, but are not well projected for the future. It is likely that monsoon rainfall will become more variable so dispersal opportunity is expected to likewise fluctuate widely from year to year.

Fires, particularly those of high severity, can negatively impact leopard frog populations, particularly through indirect effects from burned upland habitats. Leopard frog habitat is lost or degraded following fire through sedimentation and high run-off events such as those which occurred in Miller Canyon following the 1977 wildfire and the 2011 Monument Fire where sediment increased by almost 1000% (SWESA 2008, USFS 2011). Increased fire occurrence and severity in upland habitats and increased storm intensity are more likely to occur with future climate, resulting in an increased risk to Chiricahua leopard frog habitats. Depending on fire season and severity, fire can also have positive impacts through increases in water availability (Neary and others 2005), but these increases are generally temporary. Chemicals used in fire suppression are toxic to tadpoles and may concentrate in ponds and pools such as those favored by the Chiricahua leopard frog (Calfee and Little 2003).

Research Needs

There are conflicting predictions for the interaction of chytrid fungus and climate change that need to be resolved. Better information is needed on the interactions of chytrid fungus and temperature in effects on disease prevalence and population dynamics as well as other important variables such as bullfrogs and water permanence. Local landscape predictions of future wetland distributions will be important to evaluating dispersal and effective management options. The role of permanent versus ephemeral waters in long-term persistence of leopard frogs needs to be explored.

Management Implications

Substrate of water sources, such as those that can maintain wet mud layers, may be important in survival during periods when surface waters dry. Concrete substrates may maintain surface water longer, but would not provide refuge for burrowing during dry periods. These sites that are prone to drying are also where the species remains extant due to absence of aquatic predators (USFWS 2007); thus, management attention to water depth and duration as well as substrate may be critical with increasing droughts and evaporation. Monitoring of water sources will be critical during droughts or following wildfires and some locations may be suitable for artificial water inputs.

Currently occupied habitats are those that dry periodically to discourage non-native predators and competitors while still staying moist enough to allow survival of leopard frogs. These areas will be subject to further drying that will eventually make them unsuitable. Some areas that currently sustain permanent waters may actually increase in suitability for leopard frogs as drying occurs and non-natives are extirpated. Warmer waters are associated with higher resilience to chytrid fungus, thus higher elevations may become increasingly suitable. Dispersal will be critical to survival in the future as habitats change. Translocations could be a viable option for future management of this species and should be planned based on predicted future wetland conditions along with potential for increased predation or incidence of disease.

Reduction of fuels in upland habitats and adjacent to ponds may help reduce negative impacts on downslope leopard frog habitats. Impacts from fire suppression efforts such as construction of fuel breaks or use of fire retardants in areas upstream of leopard frog habitats should be minimized. Placement of straw bales or other erosion control measures are recommended to protect leopard frog habitats following wildfires (SWESA 2008). Conversely, sedimentation may alter hydrology of ponds favorably if non-native predators are displaced. Fuel reduction recommendations are not new, but predictions related to future fire occurrence make this a critical planning topic.

Habitat: Chiricahua Leopard Frog (*Lithobates chiricahuensis*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Chiricahua leopard frogs are found in wetland habitats in oak, pine forests, and mixed woodlands with some range extensions into chaparral, grassland, and desert habitats at elevations from 1000–2710 m (USFWS 2007). They occur in various permanent and near-permanent waters. Wetland habitat area is expected to be reduced in all these associated upland vegetation types.	**1**
2. Area and distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Same as above.	**1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Adults breed in various natural and human-made still waters including livestock tanks and backyard ponds. Shallow water with emergent vegetation is used for egg laying in adults (USFWS 2007). Waters need to be large enough to sustain tadpoles several months through metamorphosis. Suitable breeding waters are expected to be reduced with greater evaporation from increased temperatures.	**1**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	Moist locations are required for hibernation. Deeper waters and undercut banks provide escape from predators and potential hibernacula (SWESA 2008). Other leopard frogs hibernate buried in mud of well-oxygenated streams and ponds (USFWS 2007). We assume similar behavior in the Chiricahua leopard frog. Moist locations and deep waters are expected to be reduced.	**1**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Cover provided by vegetation along the water's edge might provide escape from visual predators while increasing presence of other predators such as snakes (SWESA 2008). Shallow water with emergent vegetation is used for thermoregulation in adults (USFWS 2007). Aquatic vegetation that is too dense can be detrimental by reducing water temperatures and availability of basking sites (SWESA 2008). Changes will depend on size and hydrology of current waters, but may increase as larger permanent water sources become more intermittent, warmer, and shallower.	**-1**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Temporary pools may be important during movements (SWESA 2008). Based on other ranids in the region, adults can likely move 1 mile overland, 3 miles with intermittent water sources, and 5 miles along permanent waters (USFWS 2007). Dispersal will depend on landscape variables, but this species has a low ability to disperse compared to other vertebrates.	**1**

Habitat: Chiricahua Leopard Frog (*Lithobates chiricahuensis*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Does not require transitional habitats to move between breeding and non-breeding areas.	**0**

Physiology: Chiricahua Leopard Frog (*Lithobates chiricahuensis*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Adults are semi-aquatic and larvae are entirely aquatic. Chiricahua leopard frogs occur in hot arid environments of Arizona, New Mexico, and Mexico although distribution of species is fragmented by aridity that limits pond habitats (Lannoo 2005). Water temperatures at which eggs have been found in the wild generally range from about 13 °C to 30 °C (55 °F to 85 °F) (Zweifel 1968, USFWS 2007). Temperatures are not likely to be limiting in aquatic habitats and this species does not occur away from water where it is prone to dessication.	**0**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g., severe storms, fires, floods) that affect survival or reproduction expected to change?	Periodic drying of individual localities, in part, drives metapopulation dynamics. Jones and Sredl (2005) observed apparent local extirpations that coincided with drought. Extirpation of populations in the Baboquivari Mountains was attributed to drought and drying of stock tanks (USFWS 2007). Species generally breeds away from areas prone to flooding. High severity wildfires have also resulted in extirpation of populations (USFWS 2007). Fires are expected to increase in intensity.	**1**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Studies of diurnal surveys indicate that this species is active early in the day and avoids activity during warmer air temperatures (USFWS 2007). May be further limitations to activities during the day.	**1**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	None known.	**0**
6. Metabolic rates	What is this species metabolic rate?	Ectothermic.	**-1**

Phenology: Chiricahua Leopard Frog (*Lithobates chiricahuensis*)

Trait/Quality	Question	Background Info & Explanation of Score	Points
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g., hibernation, migration, breeding)?	Water temperature is likely related to timing of egg laying. Although hibernation has not been studied in this species, adults are generally inactive when water temperature is below 52 °F (14 °C) from November through February (USFWS 2007). One unpublished report noted that oviposition appeared to be correlated with changes in water temperature, and not precipitation (Lannoo 2005). Supporting this view is the observation that oviposition occurs earlier at lower elevations (Frost and Platz 1983) and Elliott and others (2009) found that breeding can occur whenever the water temperature exceeds about 57 °F (14 °C). Uses temperature cues for breeding and hibernation.	**1**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g., food, breeding sites) that are expected to change?	Seasonal activity seems to be limited by temperature with year-round activity and breeding noted at one site in New Mexico with thermal springs (USFWS 2007, SWESA 2008). Egg masses have been reported in all months except November, December, and January (USFWS 2007). Populations previously identified as the Ramsey Canyon leopard frog lay eggs February to November (SWESA 2008). Populations below approximately 1800 m generally deposited eggs mostly before June, whereas above 1800 m eggs were laid in June, July, and August (Frost and Platz 1983). Expected changes to favorable breeding times.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Work by Jennings found that frogs were most abundant when water temperatures were warmer and more egg masses were found in areas with warmer water, an effect likely related to increased development of tadpoles (SWSAT 2008). Egg hatching and tadpole development are faster in warmer temperatures (Jennings 1990). This may help time breeding to favorable conditions as the cue (water temperature) is directly related to favorable water conditions for egg and tadpole development.	**-1**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	One breeding event a year and although breeding can occur during most of the year it generally is limited within a region and few populations breed year round.	**1**

Biotic Interactions: Chiricahua Leopard Frog (*Lithobates chiricahuensis*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Larvae are herbivorous and adults eat a diverse array of insects (Degenhardt and others 1996, USFWS 2007). Christman and Cummer (2005) examined stomach contents of museum specimens and found the majority to be aquatic and terrestrial invertebrates. Changes in invertebrates are expected to be species specific. Larvae eat algae, which may increase with warmer waters although too much algae removes oxygen. Based on mixed predictions, no overall effect is applied.	**0**
2. Predators	Are important predator populations expected to change?	There are a large variety of predators for larvae and adults. Juvenile and adult frogs are likely preyed upon by fish (native and non-native), American bullfrogs, garter snakes, birds, variety of mammals (Lannoo 2005). Presence of American bullfrogs, crayfish, and predatory fish are negatively correlated with presence of this species (USFWS 2007). Although this species currently only occupies habitats where these predators are not present, but future interactions are expected to intensify as aquatic habitats decline.	**1**
3. Symbionts	Are populations of symbiotic species expected to change?	None.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Chytridiomycosis has been identified in populations of the Chiricahua leopard frog including some from those previously identified as Ramsey Canyon leopard frog (USFWS 2007). In late 1980s, high mortality of this species in earthen cattle tanks in New Mexico was observed and "post-metamorphic death syndrome" was implicated although chytrid fungus may have played a role (Lannoo 2005). Although implicated in declines in numerous amphibian species including this one, there are also cases where this species is coexisting with this disease, thus infection may act synergistically with other stressors (USFWS 2007). In Arizona, die-offs of ranids are correlated with cooler months (Bradley and others 2002). Survival of frogs with chytrid infection is improved at sites with warmer waters (USFWS 2007). American bullfrogs, which are important reservoirs for the disease, however, are expected to be resilient to climate change increasing transmission rates as limited water sources become more crowded. Although increase of susceptibility of amphibians to chytrid fungus with climate change remains controversial, in this case rather than predicting a decreased mortality, because of the effect of warmer waters, we feel any positive effect will be counterbalanced with increased transmission and potentially synergistic effects with other stressors related to greater variability in rainfall.	**0**

Biotic Interactions: Chiricahua Leopard Frog (*Lithobates chiricahuensis*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
5. Competitors	Are populations of important competing species expected to change?	Current range is considered limited by presence of non-native predators such as crayfish, bullfrogs, and fish (USFWS 2007). American bullfrog tadpoles reduce algae food resources available for leopard frog tadpoles (Boone and others 2004). Although competition with non-natives is currently low in habitats occupied, we do expect competition with larvae or tadpoles of other amphibians such as tiger salamander to increase as wetland areas shrink.	**1**

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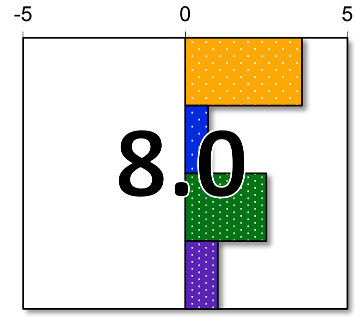
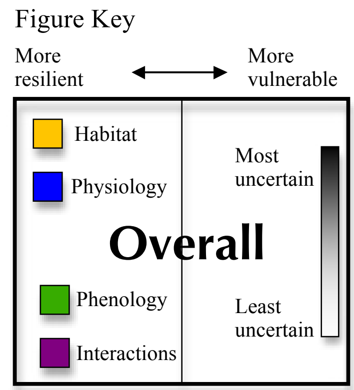
Arizona Treefrog (*Hyla wrightorum*)



SUMMARY

Threats related to habitat for the Arizona treefrog will likely increase with projected climate change. In addition, small population size and isolation from other populations will intensify extinction risk. Reduced rainfall and increased temperatures will threaten important temporary waters but may increase suitability of some currently permanent waters by creating more intermittent reaches. Reproductive failure from alteration of monsoon timing is additionally a concern. Potential benefits are likely to be overshadowed by the large number of intensifying threats expected.

VULNERABILITY	Score	Uncertainty
Habitat	**3.6**	14%
Physiology	**0.7**	17%
Phenology	**2.5**	25%
Interactions	**1.0**	40%
Overall	**8.0**	**23%**



Introduction

In the past, Arizona treefrog was grouped with *Hyla eximia*. It inhabits wetlands or streams in pine, oak, and mixed forests in Arizona, mostly at elevations above 5000 ft (Brennan and Holycross 2006). Populations in the Huachuca Mountains and Canelo Hills are disjunct from other populations in Arizona and Mexico and may be a separate species based on genetic, call, and morphological differences (Gergus and others 2004, ENRD 2006). Known as the Huachuca treefrog (ENRD 2006), these disjunct populations are candidates for Federal listing, reviewed as of November 2009. Breeding habitats currently very limited. The Huachuca/Canelo distinct population segment is known from fewer than 20 localities, 11 of which have confirmed observations of the frog in the last 10 years (USFWS 2008).

Fort Huachuca Climate and Projections

- Annual increase in temperature 2.2 °C or 4 °F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell and others 2002)
- More droughts and intense storms (Seager and others 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager and others 2007)
- Riparian habitats decline (Stromberg and others 2006, Serrat-Capdevila and others 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir and others 2008)
- Reductions in Madrean woodlands (Rehfeldt and others 2006)

A detailed review of projections is in the "Projections of Climate, Disturbance, and Biotic Communities" section of the main document.

Other Threats and Interactions With Climate

The USFWS (2008) has identified a number of threats to this species. The most significant threats are high severity wildfires that result in habitat loss or direct mortality; drought; floods; introduced predator species; and habitat degradation caused by livestock grazing, off-highway vehicles, and environmental contamination. Limb deformities have been observed in this species (USFWS 2008). High severity wildfire, drought, and floods will all likely become more frequent or intense with climate change projected for the region, thus increasing these threats. Habitat decline and physiological stress due to drought and drying associated with future climate change were also noted as warranting review of this species for endangered status (USFWS 2012). Long-term survival of this species is also threatened by its occurrence in small, disjunct populations. Climate change will likely further reduce connectivity among populations and exacerbate this problem.

Research Needs

Monitoring of this species difficult, because breeding choruses of male Arizona treefrogs only last 2-3 days (Brennan and Holycross 2006). To restore or expand populations, there is a need to know if predator removal would be effective to increase suitable habitats. A related question that needs study is if the current use of temporary pools is a recent response to increased predation, or are permanent waters unsuitable for other reasons? These questions have implications for effective management of this species.

Management Implications

Forest management to reduce the risk of high intensity wildfires will help to protect treefrog habitats. In addition, management that promotes isolating temporary pools from sources of predators and competitors will be beneficial. A multispecies approach to management will be required because of the conflicting needs of species of more permanent waters. It may be, however, that increasingly dry conditions may increase suitability of some currently permanent water sources that support large numbers of aquatic predators. Potential suitable habitats of the future should be evaluated based on surface water projections, proximity to current treefrog populations, aquatic predator population projections, and potential for dispersal. Reproductive failure from alteration of monsoon timing is additionally a concern, particularly if rainfall quantity is greatly reduced or arrival is late. Monitoring and/or intervention may be needed during years of weak or late monsoons especially if these periods are prolonged or occur over several years. Management actions related to stock tanks should consider impacts and benefits to this species including the potential for breeding and disease transmission.

Habitat: Arizona treefrog (*Hyla wrightorum*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Live in ponderosa pine, oak, and mixed forests. Seem to prefer mesic oak habitats and wet seeps during the day (USFWS 2008). Also heard calling from tree tops and found under rocks and logs. Ponderosa pine, oak, and mixed forests are subject to increasing fire occurrence with climate change, which is likely to reduce habitats.	**1**
2. Area and distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Same as above.	**1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Breed mostly in temporary water sources that lack predators (Brennan and Holycross 2006), including stock tanks and intermittent streams. Not known if these are required breeding habitats or if they have been extirpated from more permanent waters because of large numbers of native and non-native predators. Eggs have been found in permanent waters (NatureServe 2009). Egg masses attached to vegetation just below the surface (NatureServe 2009). Use waters with abundant vegetation along the shoreline (USFWS 2008). Permanent and temporary water likely to be reduced with higher temperatures.	**1**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	Non-breeding individuals are found in trees or in moist locations such as leaf litter or burrowed in the soil. One individual found wintering in a debris pile (Brennan and Holycross 2006). Also been found in winter under boulders and in a deep rock fissure (USFWS 2008). Trees, leaf litter, and debris are prone to fires.	**1**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Not known.	**0**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Movements are generally limited in hylid frogs (NatureServe 2009). Low mobility.	**1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	No transitional habitats.	**0**

Physiology: Arizona treefrog (*Hyla wrightorum*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Inactive in cold or dry weather (NatureServe 2009) May be prone to desiccation in non-breeding habitats. Although there may be some reduction for low temperature limits, this species is likely prone to desiccation away from water.	**1**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g., severe storms, fires, floods) that affect survival or reproduction expected to change?	Not known.	**0**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Nocturnal behavior may help buffer from very hot conditions. No anticipated limitations for daily activity.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	No flexible strategies known.	**1**
6. Metabolic rates	What is this species metabolic rate?	Ectothermic.	**-1**

Phenology: Arizona treefrog (*Hyla wrightorum*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g., hibernation, migration, breeding)?	Breed at the beginning of the summer monsoon season. Breeding is short, lasting 2-8 days in *H. eximia* (BISON-M). Adults leave breeding habitats shortly after breeding. Metamorphosis takes 6 to 11 weeks (Brennan and Holycross 2006). Breeding may not be solely triggered by rain as individuals in Scotia Canyon failed to breed in a year when temporary pools formed late and despite presence of permanent water sources (USFWS 2008). Breeding seems to be triggered by more than just rainfall. Maybe temperature or circadian rhythms, but cues unknown.	**0**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g., food, breeding sites) that are expected to change?	Needs ponds from January to June for breeding. Timing of availability of ponds is likely to change with changes in seasonal rainfall.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Failure to breed with late monsoons indicates some lack of timing flexibility, although breeding is not distant from resources.	**0**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	One reproductive event per year (NatureServe 2009).	**1**

Biotic Interactions: Arizona treefrog (*Hyla wrightorum*)

Trait/Quality	Question	Background Info & Explanation of Score	Points
1. Food resources	Are important food resources for this species expected to change?	Adults probably eat various small invertebrates. Larvae probably eat algae, organic debris, and plant tissue (NatureServe 2009). No overall prediction for wide variety of food resources.	**0**
2. Predators	Are important predator populations expected to change?	Predation thought to be reduced by use of terrestrial refuges during the day (USFWS 2008). Eaten by tiger salamanders. Ponds where they breed are generally too ephemeral for bullfrogs, thus reduced predation threat as compared to some other frog species (USFWS 2008). Mostly avoid aquatic predation in temporary ponds and terrestrial habits. Other sources of predation are not known.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	No symbionts.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Limb deformities are often caused by trematode, *Ribeiroia ondatrae*, possibly interacting in synergy with toxins or introduced fish (Johnson and Sutherland 2003). Snails are an intermediate host and are often abundant in cattle ponds (Johnson and Lunde 2005 in USFWS 2008). Presence of intermediate hosts such as snails, other amphibians, and wading birds as well as factors related to transmission to growing tadpoles such as low growth rates or inactivity in response to predators (Johnson and Sutherland 2003). Chytridiomycosis not identified in wild populations, but individuals have been infected in laboratory setting (USFWS 2008). Exposure to chytridiomycosis as transferred from leopard frogs or bullfrogs is likely small in temporary ponds, but the role of this species as a carrier should be noted. Exposure to trematodes in stock tanks and although there is no known relationship of infection/limb deformity with projected climate change, use of stock tanks may increase as natural waters decline.	**1**
5. Competitors	Are populations of important competing species expected to change?	May compete with American bullfrog, but competition limited by use of terrestrial retreats.	**0**

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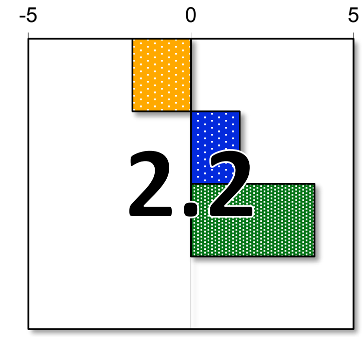
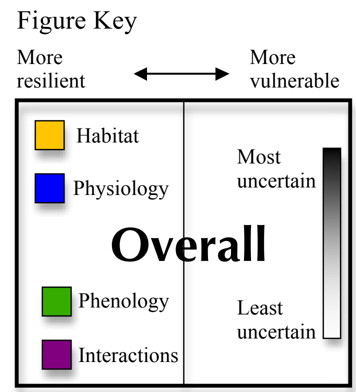
Desert Massasauga
(*Sistrurus catenatus edwardsi*)



SUMMARY

Desert massasauga has very limited populations and is vulnerable to extirpation from the United States, thus any increase in threat is of concern. Habitat requirements for desert massasauga are not well understood making predictions about climate change effects uncertain although an increase in overall vulnerability is expected. This species may experience some expansion of habitats as local climate change conditions favor grasslands. At the same time, however, invasive grasses are expected to increase with unknown consequences for suitability of this species' habitats. Additionally, this species is vulnerable to declines based on phenological characteristics, particularly timing of monsoonal rains.

VULNERABILITY	Score	Uncertainty
Habitat	**-1.8**	29%
Physiology	**1.5**	33%
Phenology	**3.8**	50%
Interactions	**0.0**	60%
Overall	**2.2**	**41%**



Introduction

Desert massasauga is designated as a species of greatest conservation need, Tier 1A, in Arizona State Wildlife Action Plan or SWAP (AGFD 2006) and as sensitive by the USDA Forest Service. It is currently only known in Arizona from Sulphur Springs and San Bernardino Valleys (AGFD 2001). There is an historic record from Fort Huachuca, but this species may now be extirpated. The massasauga is widespread, but the desert subspecies is only found in a few disjunct populations in southeast Arizona, southeast Colorado, southern New Mexico and northern Mexico (Stebbins 1985).

Fort Huachuca Climate and Projections

- Annual increase in temperature 2.2 °C or 4 °F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell and others 2002)
- More droughts and intense storms (Seager and others 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager and others 2007)
- Riparian habitats decline (Stromberg and others 2006, Serrat-Capdevila and others 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir and others 2008)
- Reductions in Madrean woodlands (Rehfeldt and others 2006)

A detailed review of projections is in the "Projections of Climate, Disturbance, and Biotic Communities" section of the main document.

Other Threats and Interactions With Climate

Based on its association with seasonal wetlands and its very limited populations, this subspecies is considered vulnerable to extinction with a warming climate (Greene 1994). Limited distribution will interact with any declines associated with climate change or other threats to increase risk of extirpation. Habitat loss from agriculture cited as major factor in declines as well as habitat degradation due to overgrazing (AGFD 2001). The massasauga is also prone to mortality on highways. Grazing is likely to interact with climate change as behaviors and populations of grazing animals change along increasing variability in vegetative growth, but no information is available related to how grazing impacts these snakes.

Fires are expected to become more frequent as rainfall becomes more variable and temperatures rise. In addition to temperature interactions, projected increases in climate variability will also increase fire occurrence as years of high rainfall are followed by dry/hot years creating conditions conducive both to ignition and fuel accumulation. Buffelgrass (*Pennisetum ciliare*), in addition to the already common Lehmann's lovegrass (*Eragrostis lehmanniana*), is rapidly expanding and is becoming increasingly problematic in the Sonoran Desert. The invasion of African grasses and accompanying alteration of fire regimes will be exacerbated by climate change. African grasses will likely not be limited by climate changes in this region and any increase in fire and other disturbances will favor further conversion to grasslands. Fires and non-native grass invasions will encourage greater conversion to grasslands with unknown changes to habitat suitability for the desert massasauga.

Research Needs

Factors that led to population declines and the current disjunct distribution are mostly unknown. If grazing is a major threat, more information is needed on grazing variables that impact massasauga populations. Knowledge of the effects of non-native grasses on massasauga habitats will be critical as these grasses spread and invade native grasslands. Timing of monsoonal rains coincides with births, but the nature of this relationship is unknown making predictions difficult and beneficial management actions uncertain. Due to the current limited populations, an evaluation of suitable habitats and potential for dispersal is needed to design management intervention for this subspecies.

Management Implications

All populations are critical to survival of this subspecies in the United States, although massasauga is not generally of current management concern at Fort Huachuca as it appears to be extirpated. In addition, livestock grazing is limited at the Fort, thus any grazing impacts will be from native grazers. If massasaugas are found to be present in the area, management related to fire and invasive grasses will be critical to maintaining habitat for this species. Management actions that maintain water table levels will also be important to protecting seasonally wet grasslands.

Habitat: Desert Massasauga (*Sistrurus catenatus edwardsi*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	This subspecies occupies desert grasslands in Arizona, but also known from oak woodlands in New Mexico. Grasslands may increase as woodlands retreat to higher elevations and fires increase.	**-1**
2. Area and distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Same as above.	**-1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Availability of burrows is not expected to change. More specific requirements are unknown.	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	Hibernates and uses burrows, vegetation, or leaf litter for refuges (Holycross 2003). Availability of burrows expected to stay the same.	**0**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Associated with grasslands that are seasonally wet (Greene 1994), which may improve conditions for foraging. More mesic conditions are partly dependent on variables such as topography and soils, but drying is expected with warmer temperatures and greater evaporation.	**1**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Radio-tracked individuals (*S. catenatus*) had large home ranges and movements in Colorado (NatureServe 2009). Known to move seasonally between habitats in some regions (NatureServe 2009) suggesting that mobility is not limited.	**-1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Unknown if move seasonally in Arizona.	**0**

Physiology: Desert Massasauga (*Sistrurus catenatus edwardsi*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Limited information. Occurs in a wide range of habitats and conditions throughout range. Often in vegetation associations with wetland habitats (NatureServe 2009). Fort Huachuca is part of hottest and driest part of the range and conditions may be near thresholds.	**1**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g., severe storms, fires, floods) that affect survival or reproduction expected to change?	None known.	**0**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Primarily nocturnal in the summer, but also days when conditions are cooler. More surface activity is observed following monsoonal rains (Holycross 2003). Apparently is flexible in diurnalversus nocturnal activity preference (NatureServe 2009). Changes to rainfall timing and greater evaporation are likely to reduce wet periods associated with activity.	**1**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	No known strategies.	**1**
6. Metabolic rates	What is this species metabolic rate?	Ectothermic.	**-1**

Phenology: Desert Massasauga (*Sistrurus catenatus edwardsi*)

Trait/Quality	Question	Background Info & Explanation of Score	Points
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g., hibernation, migration, breeding)?	More surface activity is observed following monsoonal rains (Holycross 2003). Rainfall is potentially a cue. Temperature is likely a cue for hibernation.	**1**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g., food, breeding sites) that are expected to change?	Extended breeding season through much of the year although births may be limited to August and September (Holycross 2003). Not known if this timing relates to monsoonal rains, but seem possible considering the late dates of births. Monsoonal rains are subject to changes in timing.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Critical resources are not known.	**0**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	Females probably do not reproduce every year (Goldberg and Holycross 1999).	**1**

Biotic Interactions: Desert Massasauga (*Sistrurus catenatus edwardsi*)

Trait/Quality	Question	Background Info & Explanation of Score	Points
1. Food resources	Are important food resources for this species expected to change?	Venomous. Eats mostly lizards and small mammals, but also centipedes, spadefoots, and small snakes (Holycross 2003). No expected overall changes in wide variety of food items.	**0**
2. Predators	Are important predator populations expected to change?	No important predators known.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	No symbionts.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	None known.	**0**

Biotic Interactions: Desert Massasauga (*Sistrurus catenatus edwardsi*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
5. Competitors	Are populations of important competing species expected to change?	None known, although may compete with other snake species for food. Similar snake species are likely to have the same vulnerabilities to climate change.	**0**

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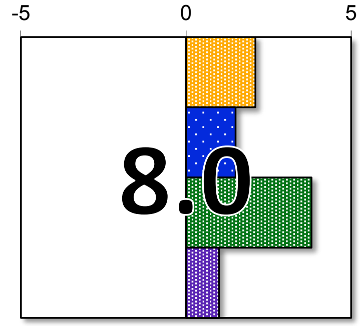
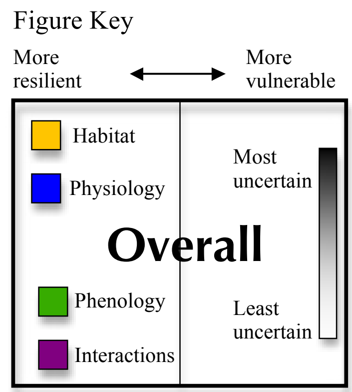
Arizona Ridge-nosed Rattlesnake (*Crotalis willardi willardi*)



SUMMARY

Arizona ridge-nosed rattlesnake occupies high mountain refugia in southeastern Arizona and is expected to be vulnerable to declines associated with future climate change. Various aspects of this species' life history contributed to vulnerability, but the largest contribution was traits associated with timing or phenology. Management related to increasing forest resiliency to high severity fires and drought will be important.

VULNERABILITY	Score	Uncertainty
Habitat	**2.1**	43%
Physiology	**1.5**	17%
Phenology	**3.8**	50%
Interactions	**1.0**	60%
Overall	**8.0**	**41%**



Introduction

Arizona ridge-nosed rattlesnake is known to occur on Fort Huachuca. It is a species of greatest conservation need, Tier 1A Arizona State Wildlife Action Plan or SWAP (AGFD 2006), and designated as a species at risk (SWESA 2006). It does not have Federal protection, but another subspecies, the New Mexican ridge-nosed rattlesnake, *C. w. obscurus*, is Federally threatened. Examination of systematics in these subspecies suggests that *C. w. willardi* may be the most distinct of the subspecies (Greene 1994).

Fort Huachuca Climate and Projections

- Annual increase in temperature 2.2 °C or 4 °F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell and others 2002)
- More droughts and intense storms (Seager and others 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager and others 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir and others 2008)
- Reductions in Madrean woodlands (Rehfeldt and others 2006)

A detailed review of projections is in the "Projections of Climate, Disturbance, and Biotic Communities" section of the main document.

Other Threats and Interactions With Climate

Collecting of the New Mexican subspecies is considered a major threat and is likely to also threaten this subspecies. It has been suggested that this species is moderately vulnerable to climate change but can survive in mountain refuges as it has during past climate change (Greene 1994). Isolation and shrinking habitats suggest future population declines, as does the outcome of this assessment. Small populations will be vulnerable to extirpation from various threats and Allee effects.

Research Needs

Many life history aspects and habitat requirements are not well known in this species. Variables related to canopy and fire history are important. Canopy or understory requirements and preferences are not known but will be important to guiding forest thinning or prescribed fire applications. Population dynamics, measures of habitat suitability, or energetics as measured along an elevational gradient would help predict future impacts.

Management Implications

Fuels and fire management will be important to the extent that vegetation associations and preferred habitats are maintained, but it is difficult to predict how this species will respond to fire. High severity fires that remove the majority of canopy cover and leave little refugia, however, are likely to be detrimental. High densities of trees can increase fire severity and susceptibility of trees to drought; thus, thinning or prescribed fire may be useful for increasing resiliency to climate change effects for this species.

Habitat: Arizona Ridge-nosed Rattlesnake (*Crotalis willardi willardi*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Occurs in Madrean oak and coniferous forests (Brennan and Holycross 2006). These habitats are expected to decline as they shift upslope.	**1**
2. Area and distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Same as above.	**1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	None known.	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	Dens are used for hibernation. Variety of types and locations not expected to change overall.	**0**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	None known.	**0**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Daily movements are limited (NatureServe 2009). Presence of roads was found to effectively isolate populations of timber rattlesnake (Clark and others 2010); thus, effective dispersal may be limited with current road networks.	**1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Not migratory.	**0**

Physiology: Arizona Ridge-nosed Rattlesnake (*Crotalis willardi willardi*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Apparently intolerant of desert conditions. Current genetic isolation and speciation in sky islands may be due to desertification of lower elevations (Holycross and Douglas 2007). May be physiologically intolerant of increasing temperatures.	**1**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g., severe storms, fires, floods) that affect survival or reproduction expected to change?	Hibernates during the extreme heat or cold (NatureServe 2009). No known response to fire or floods.	**0**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Activity appears to be somewhat flexible. Although mostly diurnal, also have some periods of nocturnal and crepuscular activity (Brennan and Holycross 2006). Greater activity, however, is also associated with rainfall (NatureServe 2009), which is expected to be reduced with warmer temperatures and greater evaporation.	**1**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	None known.	**1**
6. Metabolic rates	What is this species metabolic rate?	Ectothermic.	**-1**

Phenology: Arizona Ridge-nosed Rattlesnake (*Crotalis willardi willardi*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g., hibernation, migration, breeding)?	Timing of hibernation or aestivation is directly related to temperature.	**1**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g., food,	Births occur late July through August (Holycross and others 2001). This timing is coincident with monsoons, which may be important for obtaining greater amounts of prey. Expected changes to timing or variability of monsoons.	**1**

Phenology: Arizona Ridge-nosed Rattlesnake (*Crotalis willardi willardi*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
	breeding sites) that are expected to change?		
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Centipedes and lizards may be important food resources for juveniles, but unknown how timing affects survival. Not known if rainfall triggers breeding.	**0**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	One reproductive event per year, but individuals may only breed biennially (Holycross and others 2001)	**1**

Biotic Interactions: Arizona Ridge-nosed Rattlesnake (*Crotalis willardi willardi*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Eats primarily lizards, centipedes, mice, but also birds and other invertebrates (Brennan and Holycross 1996). Rodents are generally taken by adults, and centipedes and lizards are taken more by juveniles (Greene 1994). Wide variety of prey species with no overall expected change to prey levels.	**0**
2. Predators	Are important predator populations expected to change?	No major predators known.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	May den over winter with other individuals as in other rattlesnakes. More individuals could reduce metabolic needs and increase survival. Based on other sections of this assessment, populations may be reduced, thereby negatively impacting this behavior.	**1**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	None known.	**0**
5. Competitors	Are populations of important competing species expected to change?	None known.	**0**

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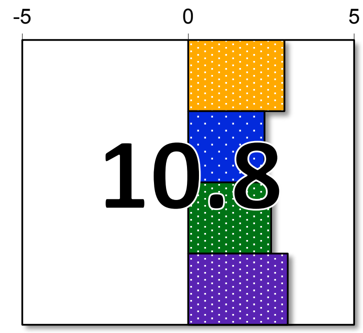
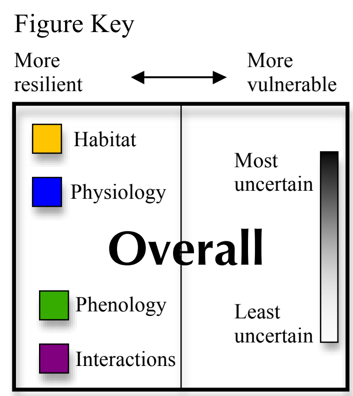
Northern Mexican Gartersnake
(*Thamnophis eques megalops*)



SUMMARY

The northern Mexican gartersnake is largely extirpated from its former range and now only occurs in a few isolated populations. We expect climate change to greatly increase its vulnerability to extinction through a variety of biological effects. In addition, a number of important current threats such as non-native species and loss of riparian habitats will likely be exacerbated. Management related to water table levels, protection of riparian areas, and control of invasive species will be critical.

VULNERABILITY	SCORE	Uncertainty
Habitat	**2.9**	29%
Physiology	**2.3**	17%
Phenology	**2.5**	25%
Interactions	**3.0**	40%
Overall	**10.8**	**27%**



Introduction

The northern Mexican gartersnake is a candidate species for Federal listing as endangered or threatened (current as of November 2009) and a species at risk (SWESA 2006). It is a species of greatest conservation need, Tier 1A, in Arizona State Wildlife Action Plan or SWAP (AGFD 2006). It occurs in Upper Scotia Canyon, Huachuca Mountains and historically occurred on the San Pedro River and Babocamari Cienega (USFWS 2006). Northern Mexican gartersnake has been extirpated from approximately 85% of historically occupied locations, which has been primarily attributed to the loss and degradation of riparian habitats (USFWS 2006). The northern Mexican gartersnake is one of 10 subspecies and the only one in the United States (USFWS 2006).

Fort Huachuca Climate and Projections

- Annual increase in temperature 2.2 °C or 4 °F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell and others 2002)
- More droughts and intense storms (Seager and others 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager and others 2007)
- Riparian habitats decline (Stromberg and others 2006, Serrat-Capdevila and others 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)

A detailed review of projections is in the "Projections of Climate, Disturbance, and Biotic Communities" section of the main document.

Other Threats and Interactions With Climate

Current threats include dams, diversions, groundwater pumping, introduction of non-native species (vertebrates, plants, and crayfish), woodcutting, mining, contaminants, urban and agricultural development, road construction, livestock grazing, wildfires, and undocumented immigration (USFWS 2006). Multiple threats occur at many locations and may work in synergy (USFWS 2006). Erosion and declining water tables, which are already implicated in declines, are likely to worsen with warmer temperatures, more severe flooding, and increased high severity wildfires. Grazing also can contribute to erosion and changes in hydrology as well as alter shoreline vegetation. Warmer temperatures and droughts may further concentrate grazing into mesic environments. There is also potential for increasing illegal immigration into the United States with climate change. Increased droughts predicted under future climate scenarios will result in failure of agricultural crops and put stress on growing human populations. Buffering of climate impacts varies with factors such as irrigation and government programs, both of which predict that drought impacts will be less severe in the United States as compared to Mexico (Vásquez-León and others 2003). In the absence of alterations to immigration policies, increased illegal traffic at the international border is expected with potentially negative impacts for this species.

Research Needs

A number of areas are not well studied in this species. The effect of non-native animal species as predators and competitors is well known, but the effect of non-native plants on gartersnake habitats is not well studied despite current and future increases in the dominance of these species. Because of the large number of threats to this species and synergistic effects, methods for identifying the most effective restoration measures are needed.

Management Implications

Management that restricts activities that can degrade riparian habitats will be important. Fuels management activities can reduce risk of high severity wildfires that are likely to threaten habitats and food sources. Management actions that mitigate climate change impacts for native amphibians and fish will be critical for the northern Mexican gartersnake in addition to those species. Control measures for non-native species in occupied habitats should improve survival. Declines in non-native fish may be expected with reductions in surface waters, which may improve habitats in some areas and could be used to increase success of control measures.

Although livestock grazing is limited on Fort Huachuca, native grazers may impact riparian areas during droughts. This potential should be evaluated. Stock tanks should be maintained and management should consider enhancements related to water retention and emergent vegetation. Protection of localities and targeting of management actions should anticipate future conditions and focus on those expected to be more resilient to drying.

Habitat: Northern Mexican Gartersnake (*Thamnophis eques megalops*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Occupies riparian habitats from 40 to 2590 m (USFWS 2006). Associated with a variety of riparian types from mesquite grasslands to cottonwood gallery forests (USFWS 2006). It also uses stock tanks (USFWS 2006). Riparian forests are likely to decline with warmer temperatures.	**1**
2. Area and distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Same as above.	**1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	None known.	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	Associated with ungrazed habitats with high vegetation density and organic debris. Dense emergent vegetation along banks is likely important for foraging (USWFS 2006). Likely to be reduced as water tables drop.	**1**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Small diameter trees may be important for thermoregulation and cover from predators (USFWS 2006). Vulnerable to water table declines.	**1**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Stock tanks may be important for dispersal (USFWS 2006) and likely restricted in dispersal because of habitat. May be able to disperse long distances during rainy periods. Likely restricted in ability to disperse although mobile.	**0**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	No.	**0**

Physiology: Northern Mexican Gartersnake (*Thamnophis eques megalops*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Limited information. Activity restricted to relatively cool conditions for this region and may indicate low critical thresholds. May not be tolerant of higher temperatures.	**1**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g., severe storms, fires, floods) that affect survival or reproduction expected to change?	Severe flooding is considered a threat to this species (USFWS 2006). Flooding is expected to become more intense.	**1**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	The northern Mexican gartersnake is surface active at ambient temperatures ranging from 22–33 °C (USFWS 2006). Time periods suitable for surface activity are likely to be reduced as temperatures warm.	**1**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	None known.	**1**
6. Metabolic rates	What is this species metabolic rate?	Ectothermic.	**-1**

Phenology: Northern Mexican Gartersnake (*Thamnophis eques megalops*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g., hibernation, migration, breeding)?	Cues not known, but likely combination of external and internal signals.	**0**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g., food, breeding sites) that are expected to change?	Mating occurs in April and May with birth of live young in July and August (USFWS 2006). This period may coincide with monsoonal rains and favorable conditions for surface activity. Likely to be timing changes.	**1**

Phenology: Northern Mexican Gartersnake (*Thamnophis eques megalops*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	No large separation between activities and events.	**0**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	Approximately half of females reproduce in a single year (USFWS 2006).	**1**

Biotic Interactions: Northern Mexican Gartersnake (*Thamnophis eques megalops*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Eats a variety of amphibians and fish, but thought to primarily prey on native species (USFWS 2006). Most native amphibians and fish are vulnerable to climate change and likely to decline.	**1**
2. Predators	Are important predator populations expected to change?	Large number of predators, but predation by introduced game fish and American bullfrogs are considered to be a major threat (USFWS 2006). These species are likely resilient to climate change, at least where water remains.	**1**
3. Symbionts	Are populations of symbiotic species expected to change?	No symbionts.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	No known major diseases (USFWS 2006).	**0**
5. Competitors	Are populations of important competing species expected to change?	Compete with American bullfrog for food (USFWS 2006). Bullfrogs are likely resilient to climate change.	**1**

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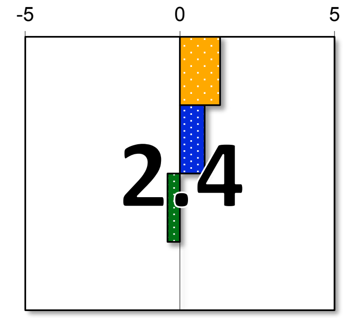
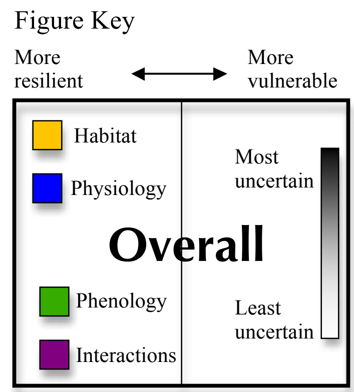
Bald Eagle (*Haliaeetus leucocephalus*)



SUMMARY

Bald eagles winter in southeastern Arizona and are only likely to use Fort Huachuca occasionally as the Fort does not support adequate aquatic resources. Warmer temperatures are projected with greater warming in winter than in other seasons; thus, changes will likely occur sooner on wintering grounds than in areas where eagles only occur in summer. Populations of bald eagles in Arizona were found to be only somewhat more vulnerable with climate change projections. Reservoir levels are likely to decline with increasing droughts and could impact wintering eagles in the Southwest.

VULNERABILITY	Score	Uncertainty
Habitat	**1.3**	14%
Physiology	**0.8**	33%
Phenology	**-0.4**	25%
Interactions	**0.0**	20%
Overall	**2.4**	**23%**



Introduction

Bald eagle was listed as endangered in 1967 in the lower 48 states of the United States, then for 43 states in 1978, and ultimately was delisted in the lower 48 states in 1999. In 2004, Southwest populations were petitioned as a distinct population segment. Populations in the Sonoran desert were proposed as a distinct population and endangered, but USFWS found listing was not warranted (February 2010) although the population segment briefly held a status as threatened from 2008 while the status was being reviewed. Individuals are only present in winter in southern Arizona. Wintering bald eagles have been seen at Willcox Playa, San Pedro, and Parker Canyon Lake, but any occurrence on the Fort is likely transitory (ENRD 2006).

Fort Huachuca Climate and Projections

- Annual increase in temperature 2.2 °C or 4 °F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell and others 2002)
- More droughts and intense storms (Seager and others 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager and others 2007)
- Riparian habitats decline (Stromberg and others 2006, Serrat-Capdevila and others 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir and others 2008)
- Reductions in Madrean woodlands (Rehfeldt and others 2006)

A detailed review of projections is in the “Projections of Climate, Disturbance, and Biotic Communities” section of the main document.

Other Threats and Interactions With Climate

DDT and shooting were important factors in past population declines, but now populations are increasing in many areas. Toxins from pesticides and heavy metals, however, continue to threaten this species through ingestion of contaminated prey (Buehler 2000). Habitat loss due to human development, particularly along shorelines, is still a major threat. On breeding grounds, climate change projections include earlier arrival of spring and increasing precipitation. Reproductive success can be reduced by wet and cold weather. The outcome will depend on the interaction of phenological changes in bald eagle arrival and phenology of spring weather conditions. In addition, earlier arrival on the breeding grounds is associated with better success because early individuals have access to the best sites. It is unknown how these timing changes will interact to affect breeding and, consequently, wintering populations in Arizona. Although we did not anticipate that food resources overall would be reduced, there may be some reductions in Arizona where eagles are primarily associated with reservoirs that will shrink with more frequent droughts and greater evaporation.

Research Needs

Many aspects of bald eagle ecology are well studied, but information is more limited on wintering ecology. Better information on how aspects of winter habitat may affect population dynamics would be useful. No information was available on how droughts may affect bald eagles, but this is an important interaction for populations that winter in the Southwest. Stopover requirements during migration are not well known and could be impacted by climate change differently than breeding or wintering habitats.

Management Implications

Fort Huachuca, although adjacent to a wintering area, probably provides only limited foraging habitat; thus, management activities are not expected to have much effect on local eagle populations. Availability of roost sites may encourage use of particular foraging areas. Forest management such as thinning and prescribed fire can enhance or be compatible with maintaining bald eagle roosting sites (DellaSala and others 1998).

Habitat: Bald Eagle (*Haliaeetus leucocephalus*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Breeds near aquatic habitats adjacent to forests or cliffs mostly in northern North America (Buehler 2000). Reductions in aquatic and shoreline habitats may be expected with sea level rise, but individuals in Arizona are more likely breed in inland in Canada and the Rocky Mountains where precipitation is expected to increase (www.climatewizard.com, A2 emissions, ensemble GCM). No change expected for interior aquatic breeding areas.	**0**
2. Area and distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Winters at rivers, reservoirs, and other aquatic habitats (Buehler 2000). Inland lakes and playas nearby to Fort Huachuca probably reduced by reduced precipitation and evaporation during warmer temperatures.	**1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Requires large trees for nesting. Breeding grounds for Arizona individuals are not known, but likely that large trees will remain available near interior aquatic habitats in northern locations.	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	Roost trees are generally large and protected from winds. These trees may be susceptible to mortality from drought or shoreline fluctuations.	**1**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Factors affecting reproductive success not well known, but most discussion is related to association with DDT levels. In an Alaska study, vegetative characteristics of the habitat were only weakly related to reproductive success (Hansen 1987).	**0**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Highly mobile.	**-1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Arizona individuals may move through intermountain region to breeding areas in the north. Use transitional habitats, although extent of reliance on stopover habitats is not well documented.	**1**

Physiology: Bald Eagle (*Haliaeetus leucocephalus*)

Trait/Quality	Question	Background Info & Explanation of Score	Points
1. Physiological thresholds	Are limiting physiological conditions expected to change?	No known limitations, although cold limiting conditions may improve. Cold not likely limiting in Arizona.	**0**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g., severe storms, fires, floods) that affect survival or reproduction expected to change?	Little recorded mortality related to exposure beyond indirect effects through food supply (Buehler 2000). Reproduction, however, may be reduced during cold, wet springs (Buehler 2000). Reproduction reduced during cold and wet springs. Warmer temperatures may reduce losses, but heavy precipitation events may alone be detrimental and become more common. Overall, no anticipated change.	**0**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	None known.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	No flexible strategies.	**1**
6. Metabolic rates	What is this species metabolic rate?	Moderate.	**0**

Phenology: Bald Eagle (*Haliaeetus leucocephalus*)

Trait/Quality	Question	Background Info & Explanation of Score	Points
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g., hibernation, migration, breeding)?	Leave breeding grounds based on food abundance (Buehler 2000).	**0**

Phenology: Bald Eagle (*Haliaeetus leucocephalus*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g., food, breeding sites) that are expected to change?	Migration routes and timing follow salmon runs in some regions. Prey availability is important. In some populations peak availability of spawning fish such as salmon may change, but interior populations, where salmon are extirpated, are probably most closely linked to fish populations that fluctuate less.	**-1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Movement from breeding grounds may be signaled by declines in food abundance. Already arrive in some areas to breed while waters are still frozen, but earlier arrival is advantageous to securing breeding sites (Buehler 2000). Cues are not distant from migration or breeding.	**0**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	One breeding event per year.	**1**

Biotic Interactions: Bald Eagle (*Haliaeetus leucocephalus*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Wide variety of prey items, including birds and mammals, but prefers fish. Often scavenges or steals prey from other predators (Buehler 2000). Probably eats both warm- and cold-water fishes in Arizona. No anticipated changes in overall prey availability in existing lakes. Fish are stocked at Fort Huachuca all species are non-native.	**0**
2. Predators	Are important predator populations expected to change?	Predation is not likely a major factor in mortality.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	None.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	No known diseases that affect populations. Most deaths are directly or indirectly related to humans (Buehler 2000).	**0**
5. Competitors	Are populations of important competing species expected to change?	Competes with other scavengers and raptors, but little information on these interactions. Steals prey from other carnivores. No overall change in competitive outcomes anticipated.	**0**

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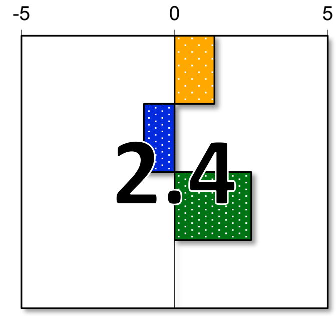
Northern Goshawk
(*Accipiter gentilis atricipillus*)

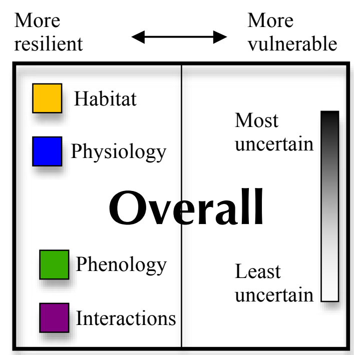


SUMMARY

Northern goshawks were assessed to be somewhat vulnerable to declines associated with climate change. Mature forests with high canopy closure, which are prefered breeding habitats, will be vulnerable to drought mortality and fires. Goshawks are fairly flexible in movements, winter habitats, and prey selection, which will help to balance negative impacts that are anticipated. Management related to fire severity will be important and future changes in breeding timing in this species should be anticipated.

VULNERABILITY	SCORE	Uncertainty
Habitat	1.3	14%
Physiology	-1.0	33%
Phenology	2.5	25%
Interactions	0.0	40%
Overall	**2.4**	**27%**

Figure Key



Introduction

The northern goshawk ranges widely in forests across most of North America. Goshawks in southern Arizona and Mexico are also sometimes identified as *A. g. apache*, but there is disagreement over the classification of the subspecies (Squires and Reynolds 1997). The Northern goshawk is a Federal species of concern and a species of greatest conservation need, Tier 1B, in the Arizona State Wildlife Action Plan or SWAP (AGFD 2006) and designated as a species at risk (SWESA 2006). It is also identified as sensitive by the USDA Forest Service.

Fort Huachuca Climate and Projections

- Annual increase in temperature 2.2 °C or 4 °F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell and others 2002)
- More droughts and intense storms (Seager and others 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager and others 2007)
- Riparian habitats decline (Stromberg and others 2006, Serrat-Capdevila and others 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir and others 2008)
- Reductions in Madrean woodlands (Rehfeldt and others 2006)

A detailed review of projections is in the “Projections of Climate, Disturbance, and Biotic Communities” section of the main document.

Other Threats and Interactions With Climate

Currently, there is no evidence that goshawk populations are declining in North America (Kennedy 2003). The largest current threat is generally considered to be logging of preferred habitats (Kennedy 2003).

Research Needs

Little is known about what level of fire occurrence is important for long-term sustainability of habitats at a landscape scale, which will be important in incurring resilience of forests as well as goshawk habitat to climate change. Information is also limited on physiological thresholds or timing of resources that affect breeding success.

Management Implications

Logging is often considered the greatest threat to this species and does not occur on Fort Huachuca. Fuel treatments may have negative impacts, but increasing fuels will be prone to high severity crown fires, which will leave habitats unsuitable for long periods. These and other actions related to fire management will be important as fire incidence is expected to increase with projected climate change. Additionally, dense stands will be more vulnerable to tree mortality during droughts than more open stands. Effective management planning for this species therefore needs to balance a number of impacts and benefits at a landscape scale. Management for this species often includes restriction of activities during the nesting season. Dates of activity restriction may need to be reevaluated as breeding phenology in this species may change.

Habitat: Northern Goshawk (*Accipiter gentilis atricipillus*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Nests in various mature pine and mixed pine-oak habitats (Squires and Reynolds 1997). Mature forests are vulnerable to upward elevation shifts and increasing high severity fires.	**1**
2. Area and distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Same as above, but may use additional non-forested habitats. Prey abundance may be more important than habitat for wintering goshawks (Squires and Reynolds 1997). No change in overall area expected for the broader range of winter habitats.	**0**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Requires large trees for nesting and mostly choose ponderosa pines in the Southwest (Squires and Reynolds 1997). No expected changes for large ponderosa pines within suitable breeding habitat.	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	In Arizona, choose forests with 60% and 69% canopy closure (Squires and Reynolds 1997). Association with closed canopy forests may reduce predation in this species (Squires and Reynolds 1997). Tree mortality associated with droughts and insect infestations may decrease canopy closure.	**1**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Moderately dense forests may be best foraging habitats (Squires and Reynolds 1997) and may be prone to loss from increasing fires as well as insect infestations.	**1**
6. Ability to colonize new areas	What is the potential for this species to disperse?	High mobility.	**-1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	No transitional habitats required, although seasonal movements are not well known.	**0**

Physiology: Northern Goshawk (*Accipiter gentilis atricipillus*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Little information, but thresholds not expected to be exceeded.	**0**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g., severe storms, fires, floods) that affect survival or reproduction expected to change?	Cold and wet conditions result in nest failures although this is mostly from studies in Europe. Severe rainstorms may increase but may not co-occur with nesting, which is early in the year. No anticipated increases in disturbance mortality	**0**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Activity is generally linked with prey activity periods (Squires and Reynolds 1997). Although these periods may change, goshawks appear flexible in activity timing. No anticipated changes overall.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	At northern latitudes, this species sometimes has irruptive movements related to resource availability. We assume a similar flexibility is present in southern populations and may allow it to cope with fluctuating resources.	**-1**
6. Metabolic rates	What is this species metabolic rate?	Moderate endothermic.	**0**

Phenology: Northern Goshawk (*Accipiter gentilis atricipillus*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g., hibernation, migration, breeding)?	Not known, but likely a combination of internal and external signals.	**0**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g., food, breeding sites) that are expected to change?	Eggs laid late April to early May with some weather-associated variability (Squires and Reynolds 1997). May be timed to coincide feeding of young with availability of young birds and mammals. Phenology of these events is likely to change.	**1**

Phenology: Northern Goshawk (*Accipiter gentilis atricipillus*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Breeding does not occur far in advance or at distant location from wintering areas.	**0**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	One brood per season (Squires and Reynolds 1997).	**1**

Biotic Interactions: Northern Goshawk (*Accipiter gentilis atricipillus*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Opportunistic carnivore. Main food items include birds, rabbits, and squirrels. Starvation is the most common cause of mortality (Squires and Reynolds 1997). Variety of prey items, not all expected to decline or increase simultaneously.	**0**
2. Predators	Are important predator populations expected to change?	Few predators for adults, but some predation from larger raptors (Squires and Reynolds 1997). No expected change.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	None.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	No major diseases known that affect populations.	**0**
5. Competitors	Are populations of important competing species expected to change?	May compete with other predators for food. Will attack and kill other raptors, including red-tailed hawks. No important competitive interaction known.	**0**

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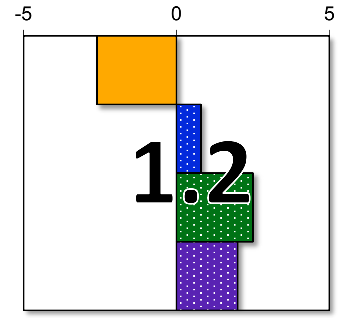
Williams, D. G., and Z. Baruch. 2000. African grass invasion in the Americas: ecosystem consequences and the role of ecophysiology. Biological Invasions 2:123–140.

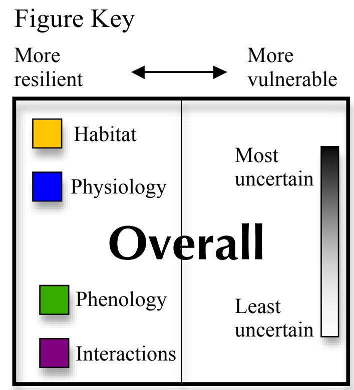
Northern Aplomado Falcon
(*Falco femoralis septentrionalis*)



SUMMARY

The aplomado falcon, although not currently present on Fort Huachuca, has potential for future occurrence. This falcon could benefit if grasslands increase with a warming climate, but important habitat associates, such as woodlands and riparian forests, will be threatened by increased occurrence of high severity wildfires and declining water tables. Aspects of the future threats to this species, such as dependence on riparian areas or effects of drought, are poorly known and made assessing vulnerability uncertain.

VULNERABILITY	SCORE	Uncertainty
Habitat	**-2.6**	0%
Physiology	**0.8**	33%
Phenology	**2.5**	25%
Interactions	**2.0**	40%
Overall	**1.2**	23%



Introduction

The northern aplomado falcon is a Federally endangered species, and although it is not known to occur on Fort Huachuca, potential habitat is present (ENRD 2006). Individuals were reintroduced in Texas in the 1990s and in New Mexico beginning in 2006. Southwestern populations are considered experimental and non-essential although they may not truly be isolated from wild populations. Aplomado falcon is subject to status review as of March 2010 (Federal Register: 75 FR 15454–15456).

The Peregrine Fund reports more than 40 wild pairs nested in Texas in 2008. Individuals in the United States may be part of captive breeding programs but there is also evidence of migration from Mexican populations (Keddy-Hector 2000). Any individuals located at Fort Huachuca could be from those released in New Mexico, but could also migrate from wild populations in Mexico. Population status and trends are mostly unknown because of limited historic information and lack of contemporary population monitoring.

Fort Huachuca Climate and Projections

- Annual increase in temperature 2.2 °C or 4 °F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell and others 2002)
- More droughts and intense storms (Seager and others 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager and others 2007)
- Riparian habitats decline (Stromberg and others 2006, Serrat-Capdevila and others 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)

- Reductions in Madrean woodlands (Rehfeldt and others 2006)
- CAM plants (succulents, cacti) will be resilient to increasing temperatures (Smith and others 1984)

A detailed review of projections is in the “Projections of Climate, Disturbance, and Biotic Communities” section of the main document.

Other Threats and Interactions With Climate

DDT and secondary lead poisoning are thought to be important sources of mortality (Keddy-Hector 1990). Populations in the United States are still contaminated with heavy loads of organochlorines, heavy metals, and PCBs, which has limited recovery efforts (Keddy-Hector 2000). Extirpation of prairie dogs from much of their range may also be a factor in declines (Keddy-Hector 2000). Low reproductive rates that limit expansion of populations from Mexico into the United States are thought to be linked to drought. To the extent that droughts are limiting to expansion of aplomado falcon, populations in the Fort Huachuca area may decline further in the future as droughts become more severe. Encroachment of grasslands by shrubs, often associated with overgrazing, has been cited as a cause of habitat losses along with loss due to agriculture and water diversions (Keddy-Hector 2000). Although for the purposes of this document we assumed a warmer climate would favor grasses over shrubs, season of precipitation, current vegetation, fires, and various other factors will interplay to affect the future vegetation trajectory. There is potential, however, that suitable grassland habitats will increase in the region.

Research Needs

Information is needed on pesticide levels and interactions with falcons for various prey items (Keddy-Hector 2000). This threat may interact with climate as relative prey availability is likely to fluctuate and, thus, exposure to these compounds may change. Invasive grasses are increasing in Arizona and may be encouraged by climate change, but information on their effect on aplomado falcon habitat is needed. In addition, drought and degradation of riparian areas are generally cited as responsible for declines, but the mechanism behind this response is unknown and needs to be elucidated to effectively manage this species.

Management Implications

Aplomado falcons are not currently protected under the Endangered Species Act because the origin of Arizona individuals is usually considered to be from the experimental population. Fires that accompany higher temperatures and more variable rainfall could help increase grasslands, thus increasing habitat for the falcon. An increasing proportion of these grasslands may be made up of non-native species, but this has an unknown effect on falcon populations. Use of prescribed fire is likely compatible with habitat preservation especially if intensities are low enough to not burn nesting substrates. A number of identified vulnerabilities were related to timing and quantity of prey. Management is unlikely to affect timing of peak prey availability, but protection of a variety of prey sources may help increase resilience. Larger areas of suitable habitat potentially could help this species survive drought conditions or variable prey populations. If falcons are present on Fort Huachuca then management measures such as timing of military activities and protection of stick nests may be necessary. These measures, if implemented, also need to anticipate phenological change in response to a warming climate.

Habitat: Northern Aplomado Falcon (*Falco femoralis septentrionalis*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	The aplomado falcon inhabits various desert grasslands and coastal prairies in the United States-Mexico border region, the Gulf Coast of Mexico, and parts of Central America. Suitable grassland habitats often are associated with scattered trees and shrubs or edges of riparian woodlands (Keddy-Hector 2000). In the United States, associated with scattered mesquite and yuccas (Keddy-Hector 1990). Grassland habitats may benefit from more frequent fires and warmer temperatures.	**-1**
2. Area and distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Same as above.	**-1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within the associated vegetation type?	Nests are in stick platforms built in trees or other structures by other raptors or corvids. They are also known to use nests in cliffs or on power lines (Keddy-Hector 2000). Yuccas are often used for nesting in the United States (Peregrine Fund website). High severity fires may threaten plants with suitable structures for nest platforms such as yuccas or trees.	**1**
4. Habitat components: *non-breeding*	Are specific habitat components required for survival during non-breeding periods expected to change within the associated vegetation type?	None.	**0**
5. Habitat quality and reproduction	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Generally associated with more open habitats, which are probably improves success for hunting of ground feeding birds. Increasing droughts and fires may open habitats.	**-1**
6. Ability to colonize new areas	What is this species' capacity and tendency to disperse?	Highly mobile.	**-1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	No transitional habitats required.	**0**

Physiology: Northern Aplomado Falcon (*Falco femoralis septentrionalis*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	U.S. populations are at the northern limit of current range and former range is not well known (Keddy-Hector 2000). Occupies various habitats, including deserts. No physiological limitations known.	**0**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g., severe storms, fires, floods) that affect survival or reproduction expected to change?	None known.	**0**
4. Limitations to active period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Adults are most active at dawn and dusk, and may hunt well before or after dark (Keddy-Hector 2000). Hunting activity does not seem to be strictly limited to this period. Spends much of the day perched.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	No. Cache prey items and retrieve them to feed to nestlings (Keddy-Hector 2000). Food caching behavior is likely limited to feeding of young.	**1**
6. Metabolic rates	What is this species metabolic rate?	Endothermic, moderate.	**0**

Phenology: Northern Aplomado Falcon (*Falco femoralis septentrionalis*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g., hibernation, migration, breeding)?	Not known, but likely combination of internal and external cues.	**0**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g., food, breeding sites) that are expected to change?	In the United States, most aplomado falcons lay eggs in April-May, but in eastern Mexico, they lay eggs in January-June during the dry season (Keddy-Hector 1990). Nesting may be timed to occur just before nesting of resident birds and arrival of spring migrants (Keddy-Hector 2000). Timing of breeding to fledgling of other bird species and spring emergence of insects is likely important. Both these events may vary with changes in temperature.	**1**

Phenology: Northern Aplomado Falcon (*Falco femoralis septentrionalis*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Cues to initiate breeding are not known but species is resident, so not distant from breeding grounds.	**0**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	Second broods are possible, but not documented (Keddy-Hector 2000).	**1**

Biotic Interactions: Northern Aplomado Falcon (*Falco femoralis septentrionalis*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Eats mostly small birds and insects (Keddy-Hector 2000). Dominant bird prey are those that feed on the ground or in short direct flights. These species include grackles, doves, nighthawks, and meadowlarks (Keddy-Hector 1990). They also steal kills from other avian predators (Keddy-Hector 2000). Diet is various, but birds likely make up most of the biomass consumed. Loss of riparian woodlands is thought to have contributed to declines because of reductions in available avian prey (Keddy-Hector 1990). Further loss of riparian areas and dependent bird populations with climate change may reduce avian prey.	**1**
2. Predators	Are important predator populations expected to change?	Predators of nests are likely various and larger raptors may prey on adults (Keddy-Hector 2000). Predation was a major cause of death of released birds in Texas (Keddy-Hector 2000), but susceptibility of captive-raised falcons may differ from wild-born. No important predators known.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	Generally dependent on other birds to build large platform nests (Keddy-Hector 2000). These include nests of various species including ravens and red-tailed hawks. Both these species are widespread and tolerant of human activities, thus perhaps tolerant of changing climate.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Prone to trichomoniasis transmitted by dove populations. There is some potential for greater transmission as doves concentrate at fewer water sources and with increasing urban development.	**1**

Biotic Interactions: Northern Aplomado Falcon (*Falco femoralis septentrionalis*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
5. Competitors	Are populations of important competing species expected to change?	May compete for stick nests, but no information on this potential issue. Also steals prey from other raptors so apparently a strong competitor.	**0**

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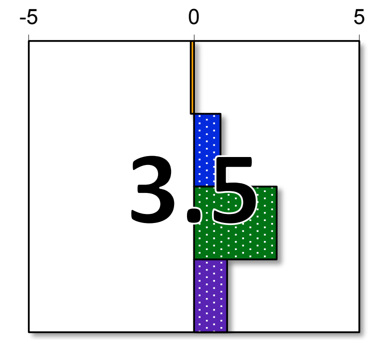
American Peregrine Falcon
(*Falco peregrinus anatum*)

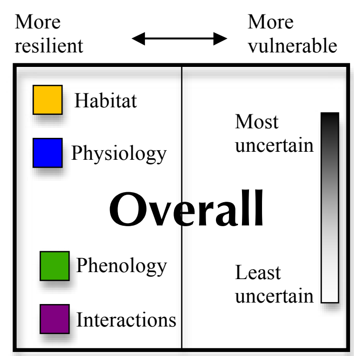


SUMMARY

Peregrine falcons are flexible in habitat use, which will help them cope with climate change effects to some extent. Phenology, as related to prey levels, is an area of potential vulnerability depending on if different aspects of timing relationships shift in synchrony or become mismatched. Although Arizona habitats are expected to remain suitable, peregrine falcons will be exposed to other climate change effects at wintering and stopover sites. Restriction of activities at nesting sites needs to adjust for future timing changes.

VULNERABILITY	Score	Uncertainty
Habitat	**-0.1**	0%
Physiology	**0.8**	33%
Phenology	**2.5**	25%
Interactions	**1.0**	40%
Overall	**3.5**	23%

Figure Key



Introduction

Peregrine falcons have nested on Fort Huachuca in recent years (at least one pair), and there are other breeding territories in nearby surroundings (ENRD 2006). The species was Federally listed in 1970 and delisted in 1999. Peregrine falcons are a species of greatest conservation need, Tier 1B, in Arizona State Wildlife Action Plan or SWAP (AGFD 2006) and are designated as a species at risk (SWESA 2006).

Fort Huachuca Climate and Projections

- Annual increase in temperature 2.2 °C or 4 °F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell and others 2002)
- More droughts and intense storms (Seager and others 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager and others 2007)
- Riparian habitats decline (Stromberg and others 2006, Serrat-Capdevila and others 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Reductions in Madrean woodlands (Rehfeldt and others 2006)
- Warmer temperatures and decreased soil moisture in Mexico (Liverman and O'Brien 1991)
- Decreased annual rainfall in Central America (Magrin and others 2007)
- Conversion of tropical forest to savannah in northern South America (Magrin and others 2007)

A detailed review of projections is in the "Projections of Climate, Disturbance, and Biotic Communities" section of the main document.

Other Threats and Interactions With Climate

Population declines in the past are thought to be primarily due to DDT and populations are currently recovering. Because this species is migratory, climate or land use changes in Mexico and Central America will affect populations at Fort Huachuca.

Research Needs

Wintering habitat requirements for this species are not well known. Migration routes and destinations are also not well known for populations in the Southwest. In addition, physiological thresholds as they relate to increasing temperatures in hot portions of their range are needed to predict climate change response.

Management Implications

Territory size and spacing is related to nest site and prey availability (White and others 2002), which is probably relatively low in this region. Thus, it is unlikely that local management actions will affect more than a few individuals. Peregrine falcons drink frequently (White and others 2002) and water needs will likely increase in the future; thus, management related to water sources, including artificial waters, will be important. Restriction of activities at suitable nesting sites is important and managers should plan for shifts in breeding timing.

Habitat: American Peregrine Falcon (*Falco peregrinus anatum*)

Trait/Quality	Question	Background Info & Explanation of Score	Points
1. Area and distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Occupies a wide variety of habitats including forests, grasslands, and scrublands (White and others 2002). Most of Fort Huachuca is suitable vegetation and should continue to remain suitable despite proportional changes in specific vegetation types.	**0**
2. Area and distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Occupies even wider range of habitats in winter. No expected changes.	**0**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Vertical substrate with ledges for nesting. Mostly cliffs, but will also use buildings in urban areas. No projected changes to cliffs.	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	Uses perches to scan for prey. Wide variety of perch locations with no expected change in availability.	**0**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Reproductive success has been related to female age, but not habitat variables (White and others 2002).	**0**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Highly mobile.	**-1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Migratory. Birds that breed in more southerly locations may actually travel less south into Mexico than those that breed in the far north, which may travel to Central America to winter (White and others 2002).	**1**

Physiology: American Peregrine Falcon (*Falco peregrinus anatum*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Limited information. One of the most widely distributed vertebrate species, peregrine falcons are tolerant of a wide range of conditions (White and others 2002). Convective cooling through the bare tarsus is considered important, and this surface area varies with region (White and others 2002). Not expected to be limited.	**0**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g., severe storms, fires, floods) that affect survival or reproduction expected to change?	Thought to be less prone to mortality from adverse weather during migration than many other bird species (White and others 2002). Nestlings vulnerable to late wet springs (White and others 2002). Spring expected to occur earlier rather than later, although this may not be a major factor in warmer climates.	**0**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Most cooling is through behaviors such as orientation, erection of feathers, and panting. No known limitations to daily active period.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	None known. Only rare records of cooperative breeding (White and others 2002).	**1**
6. Metabolic rates	What is this species metabolic rate?	Moderate endothermic, although higher than congeneric species (White and others 2002).	**0**

Phenology: American Peregrine Falcon (*Falco peregrinus anatum*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g., hibernation, migration, breeding)?	Timing of migration and breeding seems to be in response to a wide variety of signals, including climate, photoperiod, and prey levels (White and others 2002). Not directly in response to temperature alone.	**0**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g., food, breeding sites) that are expected to change?	Based on areas with similar climates, egg laying occurs from March to April (White and others 2002). Likely that breeding is timed to prey levels that fluctuate with breeding of other species, which, in turn, is subject to climate-related changes.	**1**

Phenology: American Peregrine Falcon (*Falco peregrinus anatum*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	In some areas, migratory behaviors seem to be directly in response to prey levels (White and others 2002). This seems to be limited to leaving breeding grounds and breeding timing is not likely to be very flexible to resource timing.	**0**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	One brood per year.	**1**

Biotic Interactions: American Peregrine Falcon (*Falco peregrinus anatum*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Most important prey items are birds although a wide variety of species from various taxonomic groups are also eaten (White and others 2002). Doves are likely important prey in this region and may benefit from developed areas of the Fort. No expected overall changes in prey available.	**0**
2. Predators	Are important predator populations expected to change?	Great horned owls are an important predator on young, but predation for adults is probably not frequent. No expected changes in predation levels.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	No symbionts.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Some secondary infection through prey of *Trichomonas* (White and others 2002). May increase with increased transmission in doves from crowding at artificial feeders or shrinking water sources.	**1**
5. Competitors	Are populations of important competing species expected to change?	No major competitors known.	**0**

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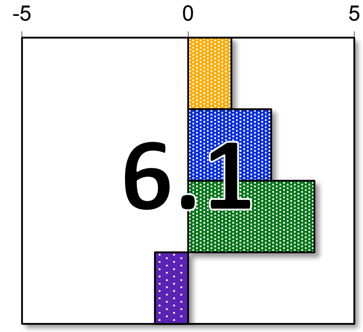
Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*)

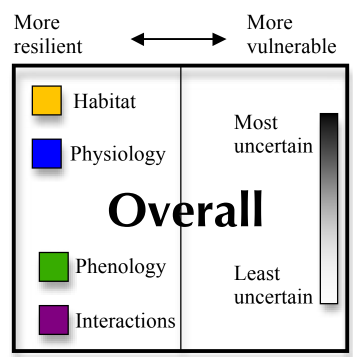


SUMMARY

Western yellow-billed cuckoos have small, fragmented populations and are likely to be subject to greater stress with projected climate change. Riparian habitats, which yellow-billed cuckoos rely on, have already greatly declined and are expected to be exposed to further degradation and loss. Physiological aspects as well as timing and reproduction were both identified as vulnerable areas for this species. Of potential benefit, periodical cicadas are an important food resource in some years and will likely be tolerant of projected changes. Facultative brood parasitism has the potential to increase populations during periods of high resource levels, but very little incidence of this behavior has been recorded. Overall, many life history aspects are poorly studied in this species, thus vulnerability prediction is relatively uncertain.

VULNERABILITY	Score	Uncertainty
Habitat	**1.3**	43%
Physiology	**2.5**	50%
Phenology	**3.8**	50%
Interactions	**-1.0**	40%
Overall	**6.1**	**45%**

Figure Key



Introduction

Historically, yellow-billed cuckoos bred throughout the United States but have now declined and, in the West, only occur in fragmented populations. The western population of the yellow-billed cuckoo is considered distinct from eastern populations and has been a candidate for Federal listing by the USFWS since 2001. Although there has been some disagreement over whether the there are valid eastern and western subspecies, USFWS (2001), citing Franzreb and Laymon (1993), recognized the western subspecies (*C. a. occidentalis*). Sufficient evidence was obtained for listing, but it was precluded by other higher priority listing actions (66 Federal Register 38611). It is also identified as a species of greatest conservation need, Tier 1A, in the Arizona State Wildlife Action Plan or SWAP (AGFD 2006) and a species at risk (SWESA 2006). Yellow-billed cuckoos occur at Fort Huachuca, although much larger numbers are present nearby on the San Pedro River. Primary riparian areas on the Fort are in Garden, Huachuca, and McClure Canyons (ENRD 2006).

Fort Huachuca Climate and Projections

- Annual increase in temperature 2.2 °C or 4 °F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell and others 2002)
- More droughts and intense storms (Seager and others 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager and others 2007)
- Riparian habitats decline (Stromberg and others 2006, Serrat-Capdevila and others 2007)
- Grasses favored over shrubs (Esser 1992)

- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir and others 2008)
- Reductions in Madrean woodlands (Rehfeldt and others 2006)
- Warmer temperatures and decreased soil moisture in Mexico (Liverman and O'Brien 1991)
- Decreased annual rainfall in Central America (Magrin and others 2007)
- Conversion of tropical forest to savannah in northern South America (Magrin and others 2007)

A detailed review of projections is in the "Projections of Climate, Disturbance, and Biotic Communities" section of the main document.

Other Threats and Interactions With Climate

In arid regions, yellow-billed cuckoos occur in riparian habitats. Continued loss and degradation of riparian habitats is a major concern, including invasion by salt cedar (*Tamarix* spp.). Without considering climate, water tables are likely to be lower on the Upper San Pedro even with conservation measures (Steinitz and others 2005). Comparisons of salt cedar dominated versus cottonwood-willow-dominated habitats on the San Pedro indicate that surface flow permanence was the most important determinant of plant species dominance (Lite and Stromberg 2005); thus, with warmer temperatures and continued water table withdrawals (Stromberg and others 1996), we may expect greater dominance of salt cedar on the San Pedro River. Fires are also a concern in riparian habitats as cottonwoods are prone to fire mortality, but regrowth of shrubs following fire may attract cuckoos. Western populations are very small and fragmented, so they are more vulnerable to stochastic events, including those related to extreme climate events.

Water diversion will likely increase with hotter and drier conditions placing more stress on riparian systems. Pesticides have been implicated in mortality and population declines (Hughes 1999). The migratory habits of this species make coordinated conservation efforts that span the entire species' range difficult. Also, many deaths due to collisions have been reported, which may be an issue if wind farm developments within the species' range increase to create more sustainable forms of energy.

Historically, yellow-billed cuckoos nested in a wider range of habitats than today, including non-riparian habitats. One possible explanation for this pattern is that exposure to pesticides has increased moisture loss in eggs causing reduced hatchability and making drier habitats unsuitable (Laymon and Halterman 1987). Pesticide restrictions in the United States are limited in their protection for neotropical migrants. Hotter and drier conditions will exacerbate egg drying and restrict cuckoos further to moist riparian areas.

Research Needs

The effect of pesticides and interaction with increasing temperatures are potentially of importance with warming climate but have not been studied. More information is also needed on the role of brood parasitism (both intra- and inter- specific) in population dynamics. Effects of pesticides on egg hatching and interactions with a drier climate need more study and consideration.

Management Implications

Fort Huachuca has a wetlands management program specifically to protect wetland resources including riparian habitats (ENRD 2006). Fort Huachuca has implemented water conservation to reduce ground water pumping, which may help protect riparian habitats for yellow-billed cuckoo on Fort Huachuca, although the relation of ground water to San Pedro surface flows is unresolved (ENRD 2006). At the Fort, ground water levels are monitored (ENRD 2006). Some upland land manipulations can also increase surface flows, but these effects are usually temporary. Because cuckoos are restricted to riparian areas, military exercises probably have little direct impact on this species. Indirect negative impacts of military activities such as increases in ignition sources, invasive species spread, and water withdrawals should be limited when possible. Fire management and invasive species control will be important to preserve riparian forests.

Habitat: Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Yellow-billed cuckoos prefer open woodlands with low, dense shrubby vegetation at elevations up to 1500 m (Hughes 1999). Proximity to water appears important, either directly or indirectly, in all preferred habitats. The majority of nests were found by Arizona Breeding Bird Atlas (Corman and Wise-Gervais 2005) along perennial drainages. In Arizona, the species prefers desert riparian forests of the Sonoran Zone, comprised of willow, Fremont cottonwood, and dense mesquite (Hughes 1999). For 2-3 weeks before breeding, they may occupy upland vegetation, including pinyon, oak, juniper, and manzanita (Hughes 1999). Associated with riparian habitats with willow and cottonwood, which are expected to decrease with reduced stream flows, lower water tables, higher temperatures, and changing flood regimes. Higher temperatures are also associated with an increase in fire, which generally kills cottonwoods, although there would be some benefit in increasing shrubby habitats if fire area is not too extensive.	**1**
2. Area and distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	It is thought that this subspecies winters primarily in northwest South America (Hughes 1999). Overall, wintering birds occupy a wide variety of forests, woodlands, and scrubby areas, preferring "woody vegetation bordering fresh water (Rappole and others 1983 and Stotz and others 1996 in Hughes 1999). Winter habitat is reported as mangroves and riparian habitats in Surinam and Guyana (Tostain and others 1992, Haverschmidt and Mees 1994 in Hughes 1999). In Venezuela, they have been observed in open woodlands, second growth, and thickets (Meyer de Schauensee and Phelps 1978 in Hughes 1999). Not well known, but seem to be associated with a number of scrub and woodland habitats in South America. In some regions, savannahs are expected to replace tropical forest, which may increase wintering habitats, but also associated with mangroves, which are vulnerable to sea level rise. Overall, no predicted change in winter habitat area.	**0**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Cottonwoods are used extensively for foraging, and nests are often placed in willows. In western United States, nests in Fremont cottonwood, mesquite, hackberry, soapberry, alder, and cultivated fruit trees, but trees need to be large enough with horizontal branches for support (Laymon 1980 in Hughes 1999). Lowering of water tables and increases in fires are likely to reduce trees large enough to support nests.	**1**

Habitat: Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	No information.	**0**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Cuckoos typically select nest sites with very dense cover, particularly overhead. Although there may be a relationship, it is not known if this is associated with reproductive success, but not expected to change within suitable habitat.	**0**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Both sexes are highly mobile.	**-1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Long-distance migrant through Mexico and Central America. In addition, for 2-3 weeks before breeding, they may occupy upland vegetation including pinyon, oak, juniper, and manzanita.	**1**

Physiology: Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Southern Arizona is in the southeastern portion of the sub-species range in the United States. Western populations are very local in scattered riparian areas from Montana to Mexico. The species formerly bred throughout most of North American from southern Canada to northern Mexico (USFWS 2001). This subspecies breeds in riparian areas in western United States, which provide shade and a relatively cooler microclimate. Incubating adults and nestlings have been observed panting on hot days (Hughes 1999). Some have proposed that pesticide use has made eggs prone to detrimental effects of drying (Laymon and Halterman 1987), but no experimental data are available. Very little known. Restricted to riparian areas in hot regions, which are cooler and more humid than surroundings. Taken together, these facts may indicate a relative intolerance to hot dry conditions, which are expected to increase on the breeding grounds.	**1**

Physiology: Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g., severe storms, fires, floods) that affect survival or reproduction expected to change?	Veit and Petersen (1993, in Hughes 1999) reported that in 1954, many weakened and starving yellow-billed cuckoos were observed in northeastern states following the passage of 3 hurricanes. Hurricane intensity is expected to increase under global climate change, but hurricane frequency predictions, which are more likely to increase mortality, are inconsistent (Emanuel 2005). Populations migrating to Arizona likely remain inland where they are more protected from hurricanes than those crossing the Gulf of Mexico. Several intense rainfall events have been reported for Venezuela, which may also result in mortality. These occurred in September (Columbia) and February (Venezuela), and thus may coincide with yellow-billed cuckoo presence. May be increased mortality with increased exposure to hurricanes, but exposure is probably not high for western populations. More intense rain storms are also predicted for South America, which may increase mortality for some species, although effect on cuckoos is largely unknown	**1**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	The western subspecies breeds in riparian areas, which provide shade, thus escaping highest temperatures. No other information on activity in relation to climate variables.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	Brood parasitism is facultative in this species. Rates of brood parasitism and consequences for reproductive success are not known. There is some suggestion that periods of high resource availability during breeding such as emergence of cicadas may allow for larger clutches and increased intraspecific brood parasitism (Fleischer and others 1985). Resource availability might then also be expected to be related to interspecific brood parasitism as well. Has both inter- and intra-specific brood parasitism. May be able to lay larger clutches and lay extra eggs in nests of other individuals. This behavior has the potential to increase breeding success during years of high resource levels. Increased breeding opportunities through brood parasitism may be expected to increase populations during high resource years, but no effect of this behavior on populations has yet been documented. Rates of brood parasitism are also not well known, but currently there are few records of occurrence, which may indicate this behavior is too rare to affect populations.	**1**

Physiology: Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
6. Metabolic rates	What is this species metabolic rate?	Moderate endothermic.	**0**

Phenology: Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g., hibernation, migration, breeding)?	No information. Assume combination of external and internal signals for migration and breeding.	**0**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g., food, breeding sites) that are expected to change?	Breeding initiation often coincides with rainfall and is thought to be related to food availability (Nolan and Thompson 1975 in Hughes 1995). In the West, yellow-billed cuckoos arrive relatively late in spring (mid May) compared to the eastern subspecies or many other migratory birds (Hughes 1999). Viet and Petersen (1993) reported that birds may not breed in years when food supply is low, and these periods may increase as droughts become more frequent. Breeding initiation may be correlated with abundance of local food or periods of greatest precipitation. Changes in precipitation and temperature may alter timing of insect emergence.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Migration and breeding separated by large temporal and spatial gap.	**1**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	Populations in the western United States are believed to raise only one brood per season and breeding season is shorter than in the eastern United States (Hughes 1999). Recent information indicated that yellow-billed cuckoos may breed a second time in western Mexico after migrating from the north (Rohwer and others 2009), which may allow this species take advantage of seasonal resources in multiple locations. Because very little is known about this second breeding, we assume only one brood per year.	**1**

Biotic Interactions: Western Yellow-billed Cuckoo (*Coccyzus americanus occidentalis*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Cuckoos feed primarily on large insects such as caterpillars, grasshoppers, crickets, katydids, cicadas, and sometimes on small lizards, frogs, eggs, and nestlings (Hughes 1999). Cuckoos on wintering grounds also feed on fruits and seeds in addition to insects (Hughes 1999). Populations fluctuate greatly with food availability and can increase dramatically in years of highest insect abundance such as tent caterpillar infestations and cicada cycles (Hughes 1999). Cicadas are behaviorally and physiologically tolerant of high temperatures (Heath and Wilkin 1970). In addition, cuckoos have high reproduction in salt cedar (Glinski and Ohmart 1984) and, thus, may be expected to be resilient to projected climate changes in the breeding range.	**-1**
2. Predators	Are important predator populations expected to change?	Raptors may be an important predator during migration and upon arrival on wintering grounds (Hector 1985 in Hughes 1999). Snakes, mammals, and avian predators depredate nests (Hughes 1999). Wide variety of predators and climate influences, thus probably no overall change in predation rate.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	Use of other bird's nests for eggs, but brood parasitism is only facultative in this species and seems to only occur rarely.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Numerous diseases and parasites have been documented, but no information indicating significant negative effects on populations. Seldom subject to brood parasitism by brown-headed cowbird (*Molothrus ater*) as nesting duration is short (Hughes 1999). Also lays eggs in the nests of other conspecifics or other species, but there are few records (Hughes 1999).	**0**
5. Competitors	Are populations of important competing species expected to change?	No information on competitors.	**0**

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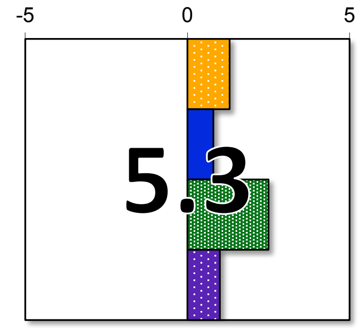
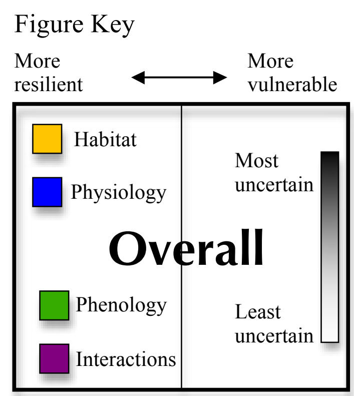
Mexican Spotted Owl
(*Strix occidentalis lucida*)



SUMMARY

Spotted owls were assessed to be vulnerable to declines associated with future climate change. Significant vulnerabilities are related to upward shifts of forest habitats, physiological thresholds, and fluctuations in prey populations. Management with climate change will depend on balancing various risks related to fire severity, cool microsites, drought mortality of trees, and factors that affect prey populations.



VULNERABILITY	Score	Uncertainty
Habitat	**1.3**	29%
Physiology	**0.8**	0%
Phenology	**2.5**	50%
Interactions	**1.0**	40%
Overall	**5.3**	**27%**

Introduction
Mexican spotted owls are geographically isolated and genetically distinct from the other two spotted owl subspecies: northern and California. The Mexican spotted owl was listed as a threatened species in 1993 (USFWS 1995). It is a species of greatest conservation need, Tier 1A, in Arizona State Wildlife Action Plan or SWAP (AGFD 2006). Main threats to current populations have been identified as habitat alteration from silvicultural practices and catastrophic wildfires.

Fort Huachuca Climate and Projections
- Annual increase in temperature 2.2 °C or 4 °F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell and others 2002)
- More droughts and intense storms (Seager and others 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager and others 2007)
- Riparian habitats decline (Stromberg and others 2006, Serrat-Capdevila and others 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir and others 2008)
- Reductions in Madrean woodlands (Rehfeldt and others 2006)

A detailed review of projections is in the “Projections of Climate, Disturbance, and Biotic Communities” section of the main document.

Other Threats and Interactions With Climate

There have been considerable changes in fire regimes at Fort Huachuca since the 1870s (Danzer and others 1996). Fires of varying intensities were common in the past, but fire-free intervals have been lengthened considerably through fire suppression (Danzer and others 1996). With fewer fires, recruitment has increased for shade-tolerant species such as Douglas fir and Gambel's oak. Additional changes in forest composition occurred when the more accessible slopes were logged (Danzer and others 1996). Although fire-suppressed forests are suitable habitat for Mexican spotted owls, they are also more prone to high intensity, stand-replacing fires, which will remove suitable habitat for long periods, as well as drought mortality. In the short term, owls remained on their territories and reproduced successfully following large fires in California, Arizona, and New Mexico (Bond and others 2002), thus this species may be at least partly resilient to increasing fires. Conversely, interactions of fire with drought mortality in trees and invasion by grass species will likely shift fire regimes and habitats outside the range of suitability for spotted owls. Hotter temperatures, especially during dry periods, will increase ignition of fuels. Variable rainfall (i.e., wet years followed by dry years) will also encourage fire. Fires more frequently occur at lower elevations where precipitation is lower and there is the additional interaction of invasive grass species that favor frequent fire. Fires can then spread upslope.

Research Needs

Interaction among drought, fire, vegetation, climate, and suitable owl habitat adds complexity to predicting the future of Mexican spotted owls. Dense vegetation and shade characterisitics of habitats are thought to be important for thermoregulation and may affect habitat selection but have not been studied in detail. Although studied to some extent, more detailed study and risk assessment are needed to assess how to best maintain dense forest habitats suitable for spotted owls as climate changes. Woodland and canyon habitats, which are additionally used by owls, also need more detailed study. A risk assessment of climate effects on spotted owl habitats should include landscape variables such as topography, adjacent vegetation types, and proximity of weed infestations.

Management Implications

Management related to fuels and fire is likely important to this species, particularly because a number of vulnerabilities to climate change are habitat related. Prescribed fire or thinning may be helpful to increase resilience of forests to stand-replacing fires that can encourage conversion to other vegetation types and resilience of large trees to drought mortality. Protection of cool microsites and canyon bottoms will be important as temperatures increase. Management that enhances prey populations through changes in forest debris or encourages understory vegetation may also enhance resilience.

Restrictions in activities during breeding are common management actions for this species. Changes in breeding timing should be anticipated and restrictions altered accordingly.

Habitat: Mexican Spotted Owl (*Strix occidentalis lucida*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Mexican spotted owls occur mostly in montane forests and canyons. Preferred forest types include ponderosa pine, mixed-conifer, and pine-oak forests with highest densities in mixed-conifer forests (USFWS 1995). At Fort Huachuca, Mexican spotted owls occur in canyons with ponderosa pine and Douglas fir although they probably also use oak woodlands particularly in winter. Coniferous forest types are limited to higher elevations (>7000 ft) of Fort Huachuca where precipitation is higher (Wallmo 1955). Following wildfires, most owls remained on their territories and reproduced successfully (Bond and others 2002). Projected changes in climate indicate that mixed conifer and pine-oak habitats will be reduced as they shift to higher elevations.	**1**
2. Area and distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	May forage in a wider range of habitats than are usually described for nesting (Ganey and Balda 1994). Coniferous forests in the region are likely to be reduced.	**1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Nests are built in large trees or in cliffs within closed-canopy forests or canyons. The most common nest sites are old raptor nests and witches brooms (USFWS 1995). Availability of nest sites within forests is not expected to change.	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	None known.	**0**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Old growth forests with large trees and complex structure are preferred (Fletcher and Hollis 1994). Use of these microsites may be to escape high temperatures (Ganey and others 1993). Favorable microsites may be reduced with tree mortality associated with drought, particularly in dense stands.	**1**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Adults generally have high site fidelity with most dispersal by juveniles of both sexes (USFWS 1995). Some owls also migrate to lower elevations in winter. The recovery plan indicates owls may have very few movements to adjacent habitat patches but are more likely to disperse within patches (USFWS 1995). Territorial individuals often have high site fidelity, but juveniles of both sexes may disperse relatively long distances.	**-1**

Habitat: Mexican Spotted Owl (*Strix occidentalis lucida*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Although observed, most individuals do not migrate or use specific transitional habitats.	**0**

Physiology: Mexican Spotted Owl (*Strix occidentalis lucida*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Arizona is in the southern portion of the distribution, but they also occur farther south in northern and central Mexico. Mexican spotted owls may be less able to dissipate heat than great horned owls and thus select cooler microsites (Ganey and others 1993). Fairly intolerant of high temperatures. Predicted increases in temperatures, particularly during summer, may exceed thresholds.	**1**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g., severe storms, fires, floods) that affect survival or reproduction expected to change?	Starvation and predation are the most common mortality causes (USFWS 1995). No records of large mortality events associated with storms or fire were found.	**0**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Primarily nocturnal when temperatures are cooler. Activities not likely to be limited.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	No flexible strategies known.	**0**
6. Metabolic rates	What is this species metabolic rate?	Moderate endothermic.	**0**

Phenology: Mexican Spotted Owl (*Strix occidentalis lucida*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g., hibernation, migration, breeding)?	Probably initiate breeding based on photoperiod with some flexibility with temperature.	**0**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g., food, breeding sites) that are expected to change?	Eggs are laid in late March, hatch at the beginning of May with young fledging around mid-June (Ganey 1988). Breeding and nesting likely timed to prey abundance, which is likely to have changes in peak abundance related to temperature.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Breeding is not distant from nesting locations but not in direct response to resource levels.	**0**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	Two eggs are most commonly laid though most pairs do not breed every year (Ganey 1988).	**1**

Biotic Interactions: Mexican Spotted Owl (*Strix occidentalis lucida*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Spotted owls eat a wide variety of prey, but a large portion of the diet is from small to medium-sized rodents. A review of diet studies indicated that in the Fort Huachucua region, the most common prey item was *Peromyscus* species followed by woodrats, which by weight were the most important component of the diet (USFWS 1995). Small rodent abundance generally fluctuates with rainfall and may be reduced by higher temperatures and more variable rainfall.	**1**
2. Predators	Are important predator populations expected to change?	Predation is probably low in adults. Preyed upon by a variety of raptors, especially great horned owls. No expected changes in predation rates.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	No symbionts.	**0**

Biotic Interactions: Mexican Spotted Owl (*Strix occidentalis lucida*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Little information is available on disease in spotted owls (USFWS 1995).	**0**
5. Competitors	Are populations of important competing species expected to change?	Known to compete with barred owls but do not occur in this region.	**0**

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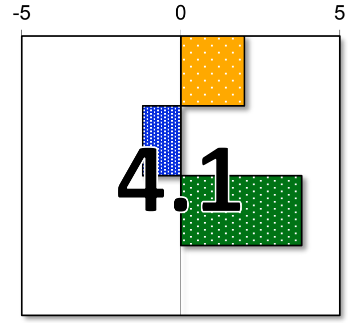
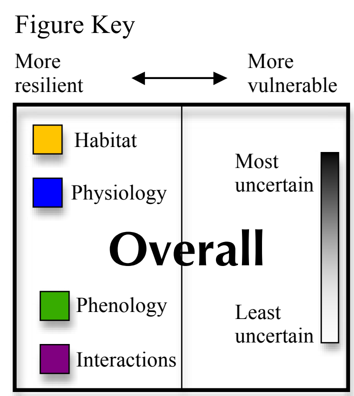
Elegant Trogon (*Trogon elegans*)



SUMMARY

Currently an uncommon migrant in Arizona, warmer winters may improve conditions for the elegant trogon, which could become a year-round resident at Fort Huachuca. Although abiotic conditions may improve, suitable forest habitats and trogon populations overall are vulnerable to declines. Management related to fire and invasive grasses will be important to preservation of suitable habitats. The possibility of year-round residency should also be anticipated in management plans.

VULNERABILITY	Score	Uncertainty
Habitat	**2.0**	14%
Physiology	**-1.2**	50%
Phenology	**3.8**	25%
Interactions	**0.0**	60%
Overall	**4.1**	**32%**



Introduction

The elegant trogon has no Federal status but is a USFS sensitive species and a species of greatest conservation concern, Tier 1B, in Arizona (AGFD 2006). It is also designated as a species as risk (SWESA 2006). Breeding distribution in the United States is limited to a small area in southern Arizona and New Mexico. Overall population trend seems to be stable but may have large annual fluctuations in Arizona, although these may be related to variation in census methods (Kunzmann and others 1998).

Fort Huachuca Climate and Projections

- Annual increase in temperature 2.2 °C or 4 °F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell and others 2002)
- More droughts and intense storms (Seager and others 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager and others 2007)
- Riparian habitats decline (Stromberg and others 2006, Serrat-Capdevila and others 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir and others 2008)
- Reductions in Madrean woodlands (Rehfeldt and others 2006)
- Warmer temperatures and decreased soil moisture in Mexico (Liverman and O'Brien 1991)
- Decreased annual rainfall in Central America (Magrin and others 2007)
- Conversion of tropical forest to savannah in northern South America (Magrin and others 2007)

A detailed review of projections is in the "Projections of Climate, Disturbance, and Biotic Communities" section of the main document.

Other Threats and Interactions With Climate

Fires, particularly those of high severity, can negatively impact vegetation types preferred by trogons as well as suitable substrates for nesting cavities. Where forests are adjacent to grasslands, fires can occur more frequently through fire spread. Wildfires are expected to become more frequent with projected increases in temperature and, in particular, may be more frequent in mesic environments where fire spread has generally been more limited (Rogers and Vint 1987, Swetnam and Betancourt 1990). In addition to temperature interactions, projected increases in climate variability will also increase fire occurrence when years of high rainfall are followed by dry/hot conditions, creating conditions conducive both to fire ignition and fuel accumulation. Buffelgrass (*Pennisetum ciliare*) is a native perennial of Africa introduced for livestock grazing that is rapidly expanding and becoming increasingly problematic in the Sonoran Desert. Buffelgrass promotes a frequent high severity fire regime, which encourages further growth of these grasses while negatively impacting native desert vegetation (Williams and Baruch 2000). Drought mortality in forests can also encourage fires but can increase snags available for nesting cavities.

Research Needs

Many life history aspects are not well known for this species, and there have been few studies outside Arizona (Kunzmann and others 1998). Basic life history information related to energetics and migration would be particularly relevant to climate change.

Management Implications

The potential for increasing impacts from invasive African grasses and increasing fires warrants inclusion in management planning and implementation of preventative actions. Prescribed fires and mechanical treatments, as well as invasive grass control, may increase forest resiliency to stand-replacing wildfires that would reduce habitat availability.

Like many secondary cavity nesters, elegant trogons may be limited by cavity availability. A study by Hakes (1983) showed trogons did not use any of 30 nestboxes in the Huachuca Mountains over 4 years. Nest boxes are not likely to alleviate this scarcity although competition would be reduced if competing species use nest boxes preferentially. Suitable substrates for cavity creation should be protected.

Populations of elegant trogons in southeastern Arizona are thought to be migratory because they are intolerant of cold winter temperatures. Winter temperatures are projected to increase and year-round populations occur in nearby northern Mexico. Thus, there is some potential that elegant trogons may begin to use habitats at Fort Huachuca year round. The prediction of shifting populations is supported by records of nesting in 2008 and 2009 at Montezuma Castle National Monument, far north of previous records. Mitigation measures based on assumption of seasonal presence, such as activities that are restricted by date, would then need to be reconsidered.

Habitat: Elegant Trogon (*Trogon elegans*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	In Arizona, reported to breed regularly in Atascosas, Chiricahua, Huachuca, and Santa Rita mountain ranges (Kunzmann and others 1998). In United States, breeding habitat includes high elevation pine and pine-oak forests and Arizona sycamore (*Platanus wrightii*) riparian woodland (Hall 1996 in Kunzmann and others 1998). In Arizona, abundance is greatest in canyons with riparian vegetation dominated by sycamores, pinyons, junipers, or pines (Hall 1996 in Kunzmann and others 1998). Upland areas also used and are often dominated by mesquite (*Prosopis* sp.) (Hall and Mannan 1999). Riparian areas and associated vegetation are likely to decline with higher temperatures and reduced winter precipitation.	**1**
2. Area and distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Some records of overwintering in Arizona, but generally winter in Mexico and Central America where trogons are also year-round residents (Kunzmann and others 1998). No information on what region U.S. individuals migrate to. Semiarid pine-oak and scrub forests to high elevation pine forests in Mexico and Central America (Kunzmann and others 1998). High elevation forest types are expected to shift upslope, reducing area, and woody species in semiarid regions will likely decline with higher temperatures and increased fire occurrence.	**1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	They nest primarily in abandoned woodpecker cavities, preferably in large sycamores, but also in oaks or pines within 300 m of water (Kunzmann and others 1998). There are old reports of this species nesting in banks, but Kunzmann and others (1998) found no reliable evidence to support this. Large trees take a long time to regrow and are vulnerable to fire, drought mortality, and declining water tables.	**1**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	None known.	**0**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Higher nest success was observed in nests in cavities in trees with larger diameters and height of vegetation to south of nest tree was greater (Hall 1996 in Kunzmann and others 1998). Dense understory vegetation was also associated with greater reproductive success (Hall and Mannan 1999). Dense understory vegetation is expected to remain unchanged within suitable habitats.	**0**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Both sexes are highly mobile.	**-1**

Habitat: Elegant Trogon (*Trogon elegans*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Most of the U.S. population migrates in winter, but unknown migration routes and distance. Regardless, the species likely uses transitional habitats between winter and breeding grounds.	**1**

Physiology: Elegant Trogon (*Trogon elegans*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Members of the Trogonidae family are not tolerant of cold temperatures, which likely limit their northern distribution (Kunzmann and others 1998). When migrant trogons arrive in Arizona to breed, mountain ranges used by this species are nearly free of snow (Kunzmann and others 1998). Low resting metabolic rate of a related species (*Trogon rufus*) relative to other bird families may reflect low ability to generate heat (Kunzmann and others 1998). Warmer winters may improve winter conditions, although currently no trogons present in Arizona year-round. Fort Huachuca, therefore, may become more suitable for wintering birds. Use of semi-arid regions indicates they may be fairly tolerant of hot conditions, but no data available.	**-1**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g., severe storms, fires, floods) that affect survival or reproduction expected to change?	No information on mortality related to storms, but they are often associated with mortality in birds. Central America (wintering grounds) is already subject to increased hurricanes, heavy rains, and dry periods. Drought was suggested as a factor behind low population numbers in the 1950s. Increasing drought duration is projected for the southwestern United States.	**1**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	No limitations known.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	This species seems to have flexible migratory behaviors, which may help it cope with regional variability in resources. Extent of this flexibility in the population, however, is unknown.	**-1**
6. Metabolic rates	What is this species metabolic rate?	Moderate endothermic (relative to other vertebrates).	**0**

Phenology: Elegant Trogon (*Trogon elegans*)

Trait/Quality	Question	Background Info & Explanation of Score	Points
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g., hibernation, migration, breeding)?	Cues not known. Likely a combination of internal and external signals.	**0**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g., food, breeding sites) that are expected to change?	Nesting in Alamos in the Mexican state of Sonora is reported to be timed with the summer rainy season (Kunzmann and others 1998). In Arizona, breeding initiation dates reported variable among pairs in a two-year study, with nests begun in May, June, and July (Hall and Karubian 1996). Timing of breeding to rainy season may be correlated with insect abundance. Timing and quantities of summer precipitation in the future are mostly unknown, but likely to become more variable.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Migration and initiation of breeding are separated geographically and temporally.	**1**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	In Arizona, most pairs rear one brood per season (Kunzmann and others 1998).	**1**

Biotic Interactions: Elegant Trogon (*Trogon elegans*)

Trait/Quality	Question	Background Info & Explanation of Score	Points
1. Food resources	Are important food resources for this species expected to change?	Wide variety of foods taken, but mainly fruit, grasshoppers, and other insects (Kunzmann and others 1998). Less likely that all food resources will be synchronously reduced or enhanced.	**0**
2. Predators	Are important predator populations expected to change?	Predation on adults not well documented and may be uncommon (Kunzmann and others 1998) but likely includes squirrels and raptors. Nest predation is fairly rare (Hall and Kurubian 1996) and is likely opportunistic by a variety of species.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	They require other species to excavate cavities. Often nest in cavities excavated by woodpeckers. No evidence that cavity creating birds will all decline.	**0**

Biotic Interactions: Elegant Trogon (*Trogon elegans*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	No known diseases that cause widespread mortality.	**0**
5. Competitors	Are populations of important competing species expected to change?	Intra-specific competition observed in apparent competition for nest cavities. Both males and females defend nest cavities against other species of primary and secondary cavity nesters (e.g., sulphur-bellied flycatcher, northern flicker, eared trogon, screech owl) (Kunzmann and others 1998). Competes with other species for cavities, but no evidence that this is limiting for trogon populations.	**0**

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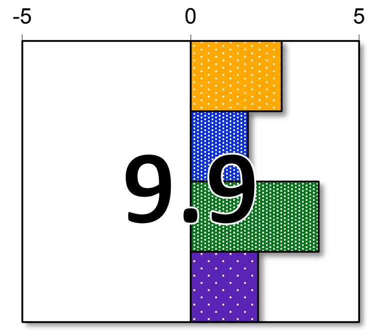
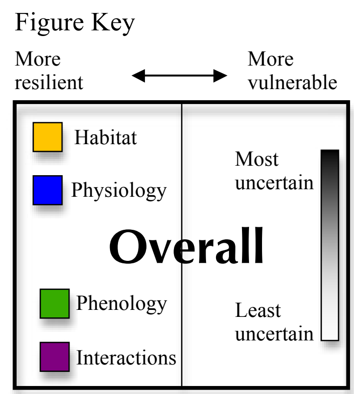
Southwestern Willow Flycatcher (*Empidonax trailii extimus*)



SUMMARY

The southwestern willow flycatcher is associated with riparian habitats, which have been largely degraded or lost in the Southwest. Climate change is expected to exacerbate the conditions associated with riparian area decline. Besides habitat use, we found vulnerability of willow flycatcher populations to decline was associated with timing of floods and insect emergence, thermal tolerances, and brood parasitism by brown-headed cowbirds. Management of water inputs for riparian habitats will be important along with control of exotic invasive plants, although any impacts originating from Fort Huachuca will be limited when considering the broad scope and scale of threats to this species.

VULNERABILITY	Score	Uncertainty
Habitat	**2.7**	29%
Physiology	**1.7**	50%
Phenology	**3.8**	50%
Interactions	**2.0**	20%
Overall	**9.9**	**36%**



Introduction

The southwestern willow flycatcher is one of four currently recognized subspecies and is classified as Federally endangered (USFWS 2003). Southwestern willow flycatchers do not occur on Fort Huachuca, but the nearby San Pedro River is designated critical habitat for the southwestern willow flycatcher.

Fort Huachuca Climate and Projections

- Annual increase in temperature 2.2 °C or 4 °F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell and others 2002)
- More droughts and intense storms (Seager and others 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager and others 2007)
- Riparian habitats decline (Stromberg and others 2006, Serrat-Capdevila and others 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Warmer temperatures and decreased soil moisture in Mexico (Liverman and O'Brien 1991)
- Decreased annual rainfall in Central America (Magrin and others 2007)
- Conversion of tropical forest to savannah in northern South America (Magrin and others 2007)

A detailed review of projections is in the "Projections of Climate, Disturbance, and Biotic Communities" section of the main document.

Other Threats and Interactions With Climate

Loss and degradation of dense riparian areas is generally cited as the main cause of population declines in the southwestern willow flycatcher (USFWS 2003). Degradation has been related to invasion by invasive non-native species, changing hydrology, water diversions, and livestock grazing (USFWS 2003). Regional climate change is likely to exacerbate a number of these conditions, including drying of riparian areas and invasion by non-native species, particularly salt cedar. Willow flycatchers will nest in riparian areas dominated by salt cedar. Riparian stands with >90% exotics are considered unsuitable (USFWS 2003). It is speculated that salt cedar reduces reproductive success in hotter climates because it provides poor shade compared to more broad-leafed plants. Depending on the strength of this mechanism, warming in the region may increase the more drought tolerant salt cedar while simultaneously increasing the threat of thermal limits on nesting. Changes in flood regimes also may impact this species depending on timing.

Research Needs

A wide variety of topics have been investigated for this species. Thermal aspects of their biology and habitat will become increasingly important and need more thorough study. In addition, impacts of control measures for exotic plants, such as introduced bio-control agents, on willow flycatchers are not well known.

Management Implications

The ability of management actions on Fort Huachuca to mitigate climate change threats to the willow flycatcher is limited. Willow flycatchers breed on the San Pedro River and likely seldom encounter habitats on Fort Huachuca. Activities that affect hydrology have the potential to impact habitats on the San Pedro River. Water conservation measures, many of which are already implemented, are important to protecting area water tables. Vegetation management can further affect run-off. In light of the multitude of threats to water, including increasing droughts, warmer temperatures, declining water tables, and expansion of exotic plants, riparian habitats will likely decline.

Habitat: Southwestern Willow Flycatcher (*Empidonax trailii extimus*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Often associated with shrubby and wet habitats (Sedgwick 2000). Nests in flooded areas with willow dominated areas but also with non-native saltcedar and Russian olive. Expected reductions in water availability due to high evaporative losses in the Southwest and increasing demands from growing human populations. Lower water tables will favor salt cedar over willow. Generally, does not occupy areas dominated by exotics (Sogge and Marshall 2000), but can successfully nest in some saltcedar-dominated habitats (Sogge and others 2006). Fire may increase shrubby habitats, but Paxton and others (1996) noted that fire destroyed habitat.	**1**
2. Area and distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Winters in southern Mexico, Central America, and northern South America (Sedgwick 2000). Wintering habitat dominated by shrubs in proximity to water. Occur mainly in lowland areas where agricultural and ranching activities occur (Lynn and others 2003). Drying in these regions will likely decrease habitat availability.	**1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Shrubs and small trees used for nesting substrates. Additionally, willow flycatchers will not nest if water is not flowing (Johnson and others 1999). Stream flows expected to be reduced, particularly later in the year when nesting occurs.	**1**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	None known.	**0**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Increased shrub cover associated with reproductive success (Bombay and others 2003). Low fecundity and starvation in nestlings associated with low snowpack and drying of marshes in Oregon (Sedgwick 2000). Flooding may be associated with reduced predation by mammalian predators (Cain and others 2003). Flooding may increase with warmer winter temperatures, but expected lower overall water output and advancement of flood pulse may shift pulse too early to benefit nesting. Salt cedar, while used for nesting, may be limiting for nesting in hotter climates because it does not provide needed shade (Hunter 1988). Decreased streamflow will likely drop water tables and favor salt cedar over willow, which will be detrimental to the extent that salt cedar decreases quality. This decrease seems likely because of the lack of microclimate advantage in salt cedar, which will be more critical as temperatures increase.	**1**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Highly mobile. Fairly high site fidelity to breeding grounds (Sedgwick 2000), but known cases of recolonization of habitats. Likely has a good capacity to shift with changes in habitat.	**-1**

Habitat: Southwestern Willow Flycatcher (*Empidonax trailii extimus*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Long-distant migrant through a variety of habitats.	**1**

Physiology: Southwestern Willow Flycatcher (*Empidonax trailii extimus*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Decline of willow flycatchers associated with spread of tamarisk, which may not have the thermal protection of broadleaf shrubs (Hunter 1988), although flycatchers nest successfully in tamarisk in many areas (Sogge and others 2006). Unknown if there are similar thermal limitations for adults. Moist and shady microclimates may be associated with relatively late nesting and accompanying hot temperatures (Sogge and Marshall 2000). It is likely that this species will be exposed to higher temperatures that will reduce nesting success.	**1**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g., severe storms, fires, floods) that affect survival or reproduction expected to change?	Not expected to be exposed to greater storms along the interior migration routes used by southwestern willow flycatcher. No extreme weather mortality recorded (except for nestlings—see Habitat Question 5).	**0**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	No known limits to diurnal activity. Activity may be somewhat buffered by occurrence in moist environments.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	No.	**1**
6. Metabolic rates	What is this species metabolic rate?	Moderate endothermic.	**0**

Phenology: Southwestern Willow Flycatcher (*Empidonax trailii extimus*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g., hibernation, migration, breeding)?	Photoperiod likely important for timing migration. No change in cue expected.	**0**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g., food, breeding sites) that are expected to change?	Short nesting season is thought to be limited by short duration of resource availability (Sedgwick 2000). Insects may emerge earlier or become more variable with more variable rainfall.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Potentially large difference in migration cues and insect emergence—not tightly related in space or time.	**1**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	Generally single brooded with a fairly short breeding season (Sedgwick 2000).	**1**

Biotic Interactions: Southwestern Willow Flycatcher (*Empidonax trailii extimus*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Willow flycatchers are primarily insectivorous (Sedgwick 2000). Years of low rainfall associated with reduced food supplies and lower reproductive success. Dry periods and rainfall variability both expected to increase.	**1**
2. Predators	Are important predator populations expected to change?	Various predators (Sedgwick 2000). No overall changes in predation rates expected.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	No symbionts.	**0**

Biotic Interactions: Southwestern Willow Flycatcher (*Empidonax trailii extimus*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Nests are parasitized by brown-headed cowbirds, which mostly cause failure of the genetic young. Currently, willow flycatcher reproduction occurs relatively late, which does not allow for breeding attempts too early from cowbird brood parasitism (Robinson and others 1995). The shorter migration distance in cowbirds will likely allow cowbirds to keep pace with any advancement in breeding by willow flycatchers. In addition, cowbirds possess a number of traits that will incur resilience to climate change.	**1**
5. Competitors	Are populations of important competing species expected to change?	None known.	**0**

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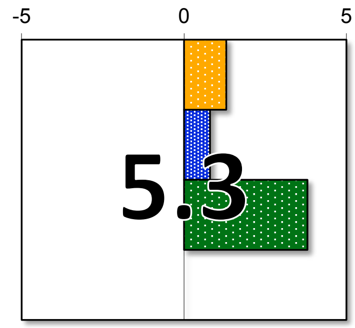
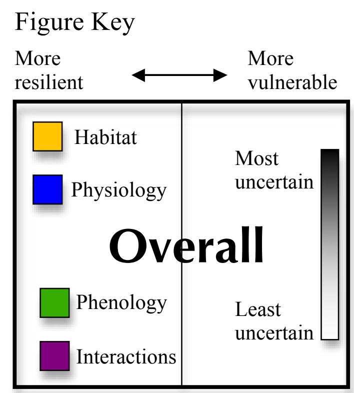
Northern Buff-breasted Flycatcher (*Empidonax fulvifrons pygmaeus*)



SUMMARY

The buff-breasted flycatcher was assessed as vulnerable to population declines associated with future climate change. Fire is an important factor in habitat suitability for this species; but climate-related fire parameters, such as intensity and frequency, make effective management actions difficult to identify albeit increasingly relevant. Management related to prescribed burning and post-fire rehabilitation will likely be important to sustaining populations of buff-breasted flycatcher.

VULNERABILITY	Score	Uncertainty
Habitat	**1.3**	29%
Physiology	**0.8**	50%
Phenology	**3.8**	25%
Interactions	**0.0**	60%
Overall	**5.3**	**41%**



Introduction

Northern buff-breasted flycatcher has retreated from formerly occupied habitats in Arizona (Bowers and Dunning 1994). It currently breeds at Fort Huachuca in the summer and is designated as Tier 1B in Arizona State Wildlife Action Plan or SWAP (AGFD 2006) as well as a species at risk (SWESA 2006). The rarity of this species in the United States also attracts birders to Fort Huachuca.

Fort Huachuca Climate and Projections

- Annual increase in temperature 2.2 °C or 4 °F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell and others 2002)
- More droughts and intense storms (Seager and others 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager and others 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir and others 2008)
- Reductions in Madrean woodlands (Rehfeldt and others 2006)
- Warmer temperatures and decreased soil moisture in Mexico (Liverman and O'Brien 1991)
- Decreased annual rainfall in Central America (Magrin and others 2007)
- Conversion of tropical forest to savannah in northern South America (Magrin and others 2007)

A detailed review of projections is in the "Projections of Climate, Disturbance, and Biotic Communities" section of the main document.

Other Threats and Interactions With Climate

Formerly, this species also occurred farther north in central Arizona (Bowers and Dunning 1994). Declines during the past century are thought to be due to fire suppression and overgrazing of mountain meadows (Bowers and Dunning 1994). Buff-breasted flycatchers have also been found in areas with evidence of high severity wildfires, suggesting that these types of fires may be needed to provide preferred habitat (Conway and Kirkpatrick 2007). Although cowbird populations could change in the future, brood parasitism may be rare because of nest placement in this species (Bowers and Dunning 1994). Overall population trends in the United States are unclear with declining trends in some survey areas (Conway and Kirkpatrick 2007) and increasing trends in some new or historic habitats (Bowers and Dunning 1994, Kirkpatrick and others 2007).

Research Needs

Despite being on the edge of the species' distribution, most studies are from Arizona. Studies within more central portions of the range in Mexico may provide better information on fitness components and habitat requirements. Interaction of habitats with fire is thought to be key to habitat suitability but is not well studied. Further study is needed to identify fire frequencies and intensities that are important to sustainable populations.

Management Implications

Foraging habitats are thought to improve with clearing of the understory such as by low severity fires (Martin and Morrison 1999). Other studies have suggested that more intense fires are needed to provide sustainable habitats (Conway and Kirkpatrick 2007). The degree of fire severity seems to be an important variable in habitat suitability, but time since fire may also play a role. It has been suggested that prescribed fires will be unable to improve habitat for this species, and fires of higher intensity may be needed (Conway and Kirkpatrick 2007). High intensity wildfires that will be encouraged by very hot conditions and variable rainfall, along with large areas of continuous fuels, are likely to result in high tree mortalities and loss of habitat; thus, the relationship between sustainable populations and fire seems to be a matter of degree. Prescribed fires or mechanical treatments may help prevent very large and intense wildfires that would almost certainly be detrimental. Forests that have regrown following burning may be important habitats, at least in the short term, thus post wildfire management and restoration are important management considerations.

Habitat: Northern Buff-breasted Flycatcher (*Empidonax fulvifrons pygmaeus*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Occupies open oak/pine woodlands and riparian areas at higher elevations (Bowers and Dunning 1994). In Arizona, often found in pine forests with a sparse oak understory (Martin and Morrisson 1999). Oak woodlands and riparian areas will likely be reduced by higher temperatures, upslope shifts, and increased fires.	**1**
2. Area and distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Migratory in northern part of its range, including Arizona. Winter habitats in Mexico similar, but may also move downslope into canyons and more low-lying riparian areas (Bowers and Dunning 1994). Wintering grounds in northern Sonora likely subject to the same threats.	**1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Arizona nests are usually in a conifer with a protective overhanging branch or piece of bark (Bowers and Dunning 1994). Not expected to change within suitable woodlands.	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	None known.	**0**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Reproductive success is higher farther from edges (Martin and Morrison 1999). Reduced understory vegetation may enhance foraging opportunities. Unclear how climate may influence landscape patchiness or understory vegetation.	**0**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Highly mobile.	**-1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Arizona populations are migratory through northern Mexico.	**1**

Physiology: Northern Buff-breasted Flycatcher (*Empidonax fulvifrons pygmaeus*)

Trait/Quality	Question	Background Info & Explanation of Score	Points
1. Physiological thresholds	Are limiting physiological conditions expected to change?	None known. Most of this species range is in Mexico and Central America.	**0**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g., severe storms, fires, floods) that affect survival or reproduction expected to change?	None known.	**0**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	None known.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	No.	**1**
6. Metabolic rates	What is this species metabolic rate?	Moderate endothermic.	**0**

Phenology: Northern Buff-breasted Flycatcher (*Empidonax fulvifrons pygmaeus*)

Trait/Quality	Question	Background Info & Explanation of Score	Points
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g., hibernation, migration, breeding)?	Not known, but likely a combination of internal and external signals.	**0**

Phenology: Northern Buff-breasted Flycatcher (*Empidonax fulvifrons pygmaeus*)

Trait/Quality	Question	Background Info & Explanation of Score	Points
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g., food, breeding sites) that are expected to change?	Nest during the (current) dry season in Arizona, May through June (Bowers and Dunning 1994), but no known consequences for reproduction. Availability of aerial insects is likely important to nesting, and emergence of these insects is related to temperature.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Migration timing and cues distant from breeding.	**1**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	One reproductive period.	**1**

Biotic Interactions: Northern Buff-breasted Flycatcher (*Empidonax fulvifrons pygmaeus*)

Trait/Quality	Question	Background Info & Explanation of Score	Points
1. Food resources	Are important food resources for this species expected to change?	Eats aerial insects but also ants, grasshoppers, and spiders (Bowers and Dunning 1994). No overall changes anticipated.	**0**
2. Predators	Are important predator populations expected to change?	Likely various. No overall change in predation levels.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	None	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	None known. Not prone to brood parasitism.	**0**
5. Competitors	Are populations of important competing species expected to change?	None known; possibly other flycatchers although those are likely similarly vulnerable to climate change.	**0**

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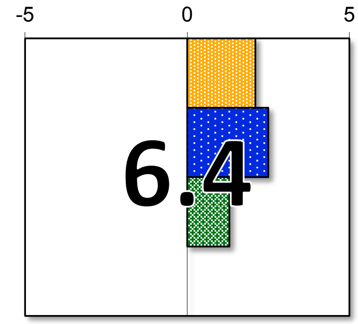
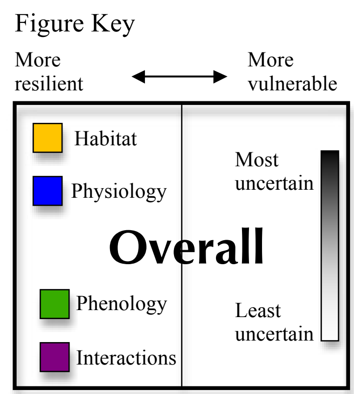
Arizona Shrew (*Sorex arizonae*)



SUMMARY

Arizona shrews were assessed as vulnerable to declines associated with projected changes in climate. Vulnerability is related both to predicted physiological effects and to the species' association with mesic environments, which are likely to dry with increasing temperatures. Preservation of riparian habitats and water tables will be key management areas. Many aspects of this species' response are uncertain, so further research efforts will be beneficial.

VULNERABILITY	Score	Uncertainty
Habitat	**2.1**	57%
Physiology	**2.5**	33%
Phenology	**1.3**	75%
Interactions	**0.0**	60%
Overall	**6.4**	**55%**



Introduction

The Arizona shrew is known to occur at Fort Huachuca. Little information is available on this species, but there is potential for it to occur in more locations than those currently identified. Currently, it is only known from a few mountain locales in southeast Arizona and southwest New Mexico and the Sierra Madre Occidental in Mexico. It is a USFWS species of concern (last reviewed in 1994) and a species at risk (SWESA 2006). The Arizona shrew is designated as Tier 1B in Arizona State Wildlife Action Plan or SWAP (AGFD 2006) and as sensitive by the USDA Forest Service.

Fort Huachuca Climate and Projections

- Annual increase in temperature 2.2 °C or 4 °F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell and others 2002)
- More droughts and intense storms (Seager and others 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager and others 2007)
- Riparian habitats decline (Stromberg and others 2006, Serrat-Capdevila and others 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir and others 2008)
- Reductions in Madrean woodlands (Rehfeldt and others 2006)

A detailed review of projections is in the "Projections of Climate, Disturbance, and Biotic Communities" section of the main document.

Other Threats and Interactions With Climate

Potential threats to this species include removal of downed woody debris through understory clearing and firewood collection, intense ground-burning fires that removes ground structure, livestock grazing, and development of recreation sites (NatureServe 2009). Threats to understory debris are expected to increase as more fires burn under warmer temperatures and more variable precipitation regimes. Increases in invasive grasses may also carry more fires from lower elevations.

Research Needs

Even basic life history traits are not well studied in this species. It is unknown how low severity fires may impact this species and its habitats. In addition, it is unknown how different fuel and fire management techniques, such as mastication or prescribed fire, affect this species, although they may be critical to reducing high severity fires, which remove key habitat elements.

Management Implications

Activities that disturb or remove ground cover, especially in canyons or riparian areas, are likely to negatively impact this species, but are generally well regulated because of the concentration of biodiversity in these areas. Protection of water sources and water tables will be important. Riparian areas may be particularly prone to drying with warmer temperatures and increased high severity wildfires. Activities that increase fire occurrence from surrounding areas could contribute to fire incidence. Management efforts to reduce forest fuels and manipulate fire severity, although increasing resiliency of some forest elements, may also reduce downed woody debris that this species is dependent on. Even low severity fires could remove important forest debris although patchy burning patterns may leave enough habitat intact. On the other hand, fire suppression efforts will eventually increase the risk of higher severity fires that will reduce availability of unburned patches and potential refugia for this species when fires inevitably occur. Management plans should include post-fire actions that can rehabilitate or protect shrew habitat.

Habitat: Arizona Shrew (*Sorex arizonae*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Occurs in mesic environments, such as riparian edges, in dense oak woodlands or conifer forest; although may also be adjacent to dry environments that support agave and cactus (BISON-M). Also associated with boulders and logs. One study in Garden Canyon, Arizona, found this species in riparian habitats above 1500 m (Simons and others 1990). Generally found in canyon bottoms and often near springs or along dry creek beds. Riparian edges, dense woodlands are likely reduced by warming and increased fires.	**1**
2. Area and distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Same as above.	**1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Desert shrews (*Notiosorex crawfordi*) build nests of bark and leaves in protected locations for reproduction and torpor (NatureServe 2009). Specificity of materials for this species is unknown, thus effects are unknown.	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	None known.	**0**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Forage in and under litter (BISON-M), but no known relationship between litter quantity and foraging success. Litter should remain unchanged in suitable habitats.	**0**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Male shrews of other species may wander widely (Hawes 1977), but dispersal in this species unknown and potentially limited by mesic environments. Small *Sorex* generally have high dispersal abilities and colonization rates (Taylor 1998). Limited information. Dispersal is possibly sex biased and limited by patchiness of mesic habitats.	**1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	No.	**0**

Physiology: Arizona Shrew (*Sorex arizonae*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Soricines (Soricidae) are thought to have low tolerance for high ambient temperatures (Taylor 1998). Shrews generally have high body temperatures and low critical thresholds. Likely to be exceeded in these habitats where temperatures are already high.	**1**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g., severe storms, fires, floods) that affect survival or reproduction expected to change?	None known.	**0**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Desert shrew uses torpor to escape physiological extremes, but torpor is unknown for this species and generally not seen in Soricidae. Buffered from extremes to some extent by use of mesic and fossorial habitats.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	Desert shrew stores paralyzed insects in food caches, but only in the short term (BISON-M). No flexible strategies.	**1**
6. Metabolic rates	What is this species metabolic rate?	Very high metabolic requirements.	**1**

Phenology: Arizona Shrew (*Sorex arizonae*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g., hibernation, migration, breeding)?	None known.	**0**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g., food, breeding sites) that are expected to change?	Breeds in the spring, but unknown resource peaks.	**0**

Phenology: Arizona Shrew (*Sorex arizonae*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Active throughout the year (NatureServe 2009). No large separation between events and cues.	**0**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	No information, but likely to have one breeding event per year.	**1**

Biotic Interactions: Arizona Shrew (*Sorex arizonae*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Shrews eat insects, spiders, and other invertebrates (BISON-M). No overall changes in invertebrates are expected.	**0**
2. Predators	Are important predator populations expected to change?	Likely various. No overall changes in predation levels are anticipated.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	None.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	None known.	**0**
5. Competitors	Are populations of important competing species expected to change?	None known.	**0**

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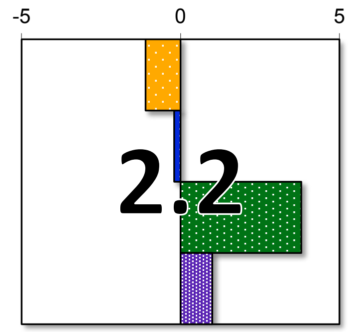
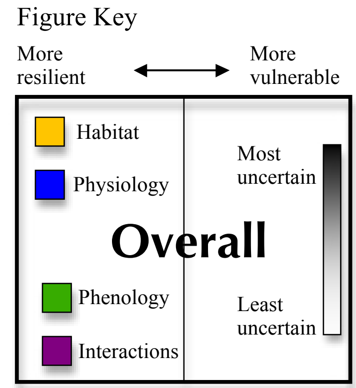
Cave Myotis (*Myotis velifer*)



SUMMARY

Vulnerability of this species to declining populations is increased by expected effects of climate change. This species both migrates and hibernates, two activities associated with timing changes that may lead to mis-matches with other events such as insect emergence or suitable breeding conditions. Timing relationships are complex, so eventual outcome in the future is unknown and periodic monitoring is recommended. Roosts and open water sources are important elements for this species that could be affected and should be considered in management planning.

VULNERABILITY	Score	Uncertainty
Habitat	**-1.1**	14%
Physiology	**-0.2**	33%
Phenology	**3.8**	25%
Interactions	**1.0**	60%
Overall	**2.2**	**32%**



Introduction

Cave myotis is a Federal species of concern (since 1994) and a species at risk (SWESA 2006) that occurs on Fort Huachuca. The USDA Forest Service also identifies it as sensitive. Despite being widespread, this species is threatened locally, particularly in western portions of its range.

Fort Huachuca Climate and Projections

- Annual increase in temperature 2.2 °C or 4 °F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell and others 2002)
- More droughts and intense storms (Seager and others 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager and others 2007)
- Riparian habitats decline (Stromberg and others 2006, Serrat-Capdevila and others 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir and others 2008)
- Reductions in Madrean woodlands (Rehfeldt and others 2006)
- Warmer temperatures and decreased soil moisture in Mexico (Liverman and O'Brien 1991)

A detailed review of projections is in the "Projections of Climate, Disturbance, and Biotic Communities" section of the main document.

Other Threats and Interactions With Climate

Patchy distribution of this species may be due to its reliance on caves, which are geographically limited. Recent population declines in cave myotis are thought to be related to local habitat loss (BISON-M). Additionally, cave myotis, like many other bats, is vulnerable to disturbance at roosts, especially maternity roosts.

Research Needs

More information on suitable roost sites at a local level is needed as these features affect species' presence. The threat of white-nosed fungus for Arizona bats will be important to the species overall, but this disease has, thus far, not been detected in Arizona. This disease is associated with cool temperatures and may threaten higher elevation sites on Fort Huachuca, but almost all aspects of this disease need more study. Importance of various foraging habitats is not well known, thus critical habitat elements are difficult to assess. Response of populations to drought conditions will be critical to predicting climate change effects and have not been studied in this species.

Management Implications

Most cave myotis winter outside of Arizona, and their affinity for cool, moist hibernacula is unlikely to increase winter presence at Fort Huachuca in the future. Maternity roosts may become more limited and suitability of current roosts may be altered over time. Potential roost sites should be checked periodically for species presence. Some monitoring of populations is warranted, as identified phenological vulnerability will have an uncertain outcome on populations because interactions of bats with critical resources are more complex than can be evaluated here. Flexibility in migratory behaviors will likely help this species cope with changes on a broad scale but will increase likelihood of population changes on Fort Huachuca and other parts of Arizona.

Habitat: Cave Myotis (*Myotis velifer*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Occurs in various desert grassland habitats, but has also been found in pinyon-juniper woodland (BISON-M). Grasslands may increase with warmer temperatures.	**-1**
2. Area and distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	May move to southwestern Mexico for winter (BISON-M). Assume similar habitats to breeding.	**-1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Roosts in caves and mines, occasionally buildings or bridges. Often found near the entrance (BISON-M). Caves and mines will not change with climate.	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	Prefers moist caves for hibernation (NatureServe 2009). In Arizona, winter roosts are in moist caves above 6000 ft. Cave availability not expected to change (but see Physiology Question 1).	**0**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	In Arizona, often in vicinity of water sources (Hoffmeister 1986). It is likely that these features are important for successful foraging and likely to decline with warmer temperatures.	**1**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Highly mobile.	**-1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Mostly migratory in Arizona although migratory behavior seems somewhat flexible (NatureServe 2009).	**1**

Physiology: Cave Myotis (*Myotis velifer*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Ranges from the southwestern and central United States into Central America. Preferred hibernaculum temperature is 8 to 9° C (Hoffmeister 1986). Most bats in Arizona migrate to hibernate, but those that remain seek out moist, cool habitats (Hoffmeister 1986). Not known if warmer, drier conditions will exceed thresholds, but they may. Rely on moist, cool caves for hibernation, which will warm and lose moisture with increasing temperatures.	**1**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g., severe storms, fires, floods) that affect survival or reproduction expected to change?	None known. Buffered from extremes in hibernaculum.	**0**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Nocturnal. No expected changes in activity.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	Sperm is stored over winter, which may maintain breeding with population and resource fluctuations. In addition, migratory behavior may be flexible (NatureServe 2009)	**-1**
6. Metabolic rates	What is this species metabolic rate?	Moderate endothermic.	**0**

Phenology: Cave Myotis (*Myotis velifer*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g., hibernation, migration, breeding)?	Emergence from roosts is later after sunset in summer than spring (NatureServe 2009) and is apparently signaled by exterior light levels (Hoffmeister 1986).	**0**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g., food, breeding sites) that are expected to change?	Young born mid to late June in Arizona and females leave maternity colonies in August (NatureServe 2009). Favorable weather conditions and insect peaks are likely to change timing.	**1**

Phenology: Cave Myotis (*Myotis velifer*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Bats in Mexico moved to higher elevation caves to hibernate (NatureServe 2009), perhaps to take advantage of colder conditions. Emergence from hibernation and migration occurs far from insect emergence and feeding of young.	**1**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	One reproductive event per year.	**1**

Biotic Interactions: Cave Myotis (*Myotis velifer*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Insectivorous and likely opportunistic (NatureServe 2009). Overall prey levels not expected to change.	**0**
2. Predators	Are important predator populations expected to change?	Likely various. No overall changes in predation expected.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	Hibernates in large clusters and occupies roosts with other species (NatureServe 2009). May have thermal advantages, but no known changes in clusters.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Single bat found in May 2010 with white-nose syndrome from western Oklahoma was from this species (USFWS news release: 19 May 2010). This is the first reported occurrence of the disease in this species and the first from west of the Mississippi although no associated mortality was reported. Transmission may increase if individuals are restricted to fewer suitable roosts.	**1**
5. Competitors	Are populations of important competing species expected to change?	*Myotis lucifugus occultus* may exclude this species from suitable habitat (BISON-M). No known changes in this species, although likely to be vulnerable similarly to cave myotis.	**0**

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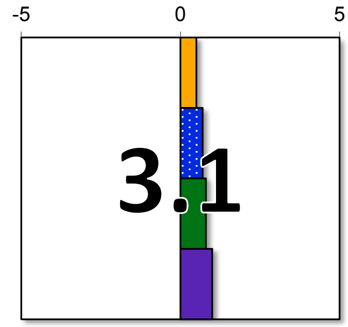
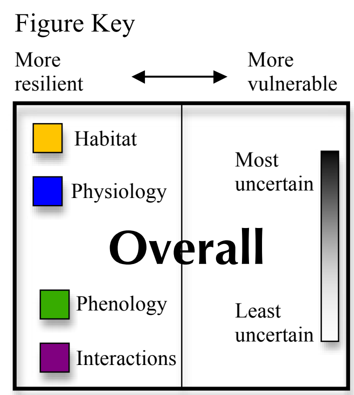
Lesser Long-nosed Bat
(*Leptonycteris yerbabuenae*)



SUMMARY

Lesser long-nosed bats were assessed to have moderate vulnerability to declines related to global climate change. Vulnerability is increased by their reliance on quantity and timing of flowering of a limited number of plant species, while resilience is incurred by flexible migratory behaviors and probable resilience of forage plant populations to increasing temperatures. Unfortunately, changes in climate are expected to exacerbate current threats, making conservation of this species more challenging. Current critical threats of roost disturbance and loss of foraging habitats may increase through growing international border activity and the interactive effects of fire occurrence and non-native invasive grasses. Additionally, changes in the timing of bat presence on Fort Huachuca should be anticipated and integrated into planning.

VULNERABILITY	Score	Uncertainty
Habitat	**0.5**	0%
Physiology	**0.7**	33%
Phenology	**0.8**	0%
Interactions	**1.0**	0%
Overall	**3.1**	**9%**



Introduction

Lesser long-nosed bats were listed in 1988 as endangered under the subspecies *Leptonycteris curasoae yerbabuenae*. Originally, they were listed as *Leptonycteris sanborni* (Sanborn's bat) but were also sometimes identified as *Leptonycteris curasoae*. Lesser long-nosed bats inhabit the desert scrub habitats in Arizona and northwestern Mexico and are nectarivorous, closely associated with paniculate agaves and columnar cactus. Agaves on Fort Huachuca are primarily Palmer's agave (*Agave palmeri*) with some Parry's agave (*Agave parryi*).

Numbers of lesser long-nosed bats have increased in recent years or may not have been as low as reported when first listed. Only three maternity roosts and approximately 40 roosts overall are known in the United States (USFWS 2005).

The five-year review by the USFWS suggested downlisting the status to threatened because current populations appear to be stable or increasing, but the review also acknowledged that threats still exist, particularly for roosts, impacts in Mexico, and vulnerability of foraging plants to fire and invasive species (USFWS 2005). Populations are migratory from Mexico where there are also resident populations of this species. Occurrence of two female demes complicates population dynamics and species requirements (USFWS 2005). In this account, we focus on the migratory group that lives from Arizona south to southern Sonora.

Lesser long-nosed bats arrive in late summer at Fort Huachuca, Arizona, after giving birth and before continuing their migration south. Bats in this region may arrive from maternity roosts in western Arizona and/or travel north from the Sierra Madre Occidental (Fleming and Nassar 2001). Over the past 10 years, lesser long-nosed bats have increased on Fort Huachuca from a few hundred to more than 14,000 (USFWS 2005). While some increases in numbers have been attributed to counting methodologies and newly discovered roosts, increases at the Fort are thought to represent population increases or at least increased use of known roosts on the Fort (USFWS 2005).

Fort Huachuca Climate and Projections

- Annual increase in temperature 2.2 °C or 4 °F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell and others 2002)
- More droughts and intense storms (Seager and others 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager and others 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Upward shifts of montane plants (Kelly and Goulden 2008, Lenoir and others 2008)
- Reductions in Madrean woodlands (Rehfeldt and others 2006)
- Warmer temperatures and decreased soil moisture in Mexico (Liverman and O'Brien 1991)
- CAM plants (succulents, cacti) will be resilient to increasing temperatures (Smith and others 1984)

A detailed review of projections is in the "Projections of Climate, Disturbance, and Biotic Communities" section of the main document.

Other Threats and Interactions With Climate

There are many known threats to this species. Suitable concentrations of food plants and day roosts are considered critical (Fleming 1995). The USFWS five-year review identified illegal border activity, fire, and drought as important threats to roosts or foraging habitats (USFWS 2005). The review further noted that grazing, tequila harvesting, and prescribed fire are probably not substantial threats (USFWS 2005). Urban development, wind farms, and changing fire regimes are additional threats that have yet to be addressed as part of recovery planning. Climate change impacts were not specifically addressed in the five-year review (USFWS 2005).

Roost protection is complicated by disturbance at roost sites. There are also issues with gating cave and mine entrances, including gate vandalism and bat avoidance after gating (USFWS 2005). Lesser long-nosed bats may be sensitive to gate construction and configuration. Climate change will also potentially increase roost disturbance by illegal immigrants. Increased droughts predicted under future climate scenarios will result in failure of agricultural crops and put stress on growing human populations. Buffering of climate impacts varies with factors such as irrigation and Government programs, both of which predict that drought impacts will be less severe in the United States as compared to Mexico (Vásquez-León and others 2003). In the absence of alterations to immigration policies, increased illegal traffic at the international border is expected and, subsequently, an increase in threats to roosts.

Lesser long-nosed bats use clumped concentrations of agaves rather than isolated individuals (Ober and Steidl 2004). Changing climate may allow expansion of agaves into new areas, although it is not expected that increasing temperatures will reduce current agave populations as they are well suited to survival under dry and hot conditions. Nectar availability, however, may be affected. The greatest threat to bat foraging areas at a landscape level is the likely expansion of invasive grasses and the concurrent increase in fire occurrence followed by subsequent reduction in agaves and cacti. Buffelgrass (*Pennisetum ciliare*), in addition to the already common Lehmann's lovegrass (*Eragrostis lehmanniana*), is rapidly expanding and increasingly problematic in the Sonoran Desert (Burquez-Montijo and others 2002). It was, and continues to be, introduced in the Sonoran desert to enhance livestock grazing with almost the entire Sonoran desert ecosystem prone to buffelgrass invasion (Arriaga and others 2004). The invasion of African grasses and accompanying alteration of fire regimes will be exacerbated by climate change. African grasses will likely not be limited by climate changes in this region and any increase in fire and other disturbances will favor further conversion to grasslands.

Climate change has the potential to create timing mismatches between species and resources. A number of observations and studies have found there is currently not close synchrony between lesser long-nosed bat arrival in Arizona and New Mexico with the peak of agave flowering (Fleming and others 2001, Scott 2004). Bat arrival late in agave blooming may allow flexibility for earlier bat arrival, although advancement of blooming may be problematic if bat migration cannot advance equally (see Table A1). Observations of bat arrival and flowering timing, however, are limited and generally only over short time periods, so it is reasonable to assume annual variability in arrival, flowering, and, therefore, synchrony of these events. Elevational variation at the Fort may lengthen availability of blooming agave so the Fort may be a relatively small but important foraging site (ENRD 2006). Timing and the extent of synchronicity in flowering of forage species along migratory routes will affect population sizes and arrival dates in Arizona—at least as observed from a single location such as Fort Huachuca. Migratory and non-migratory demes probably make the species more resilient as a whole to flowering variability. More critical to populations is failure of flowering, particularly if synchronous across range. In one study, monsoons were found to be generally asynchronous between northern Mexico and the Southwest (Comrie and Glenn 1998), thus adequate flowering resources should be available within some part of the range. Monsoon behavior under current climate projections, however, is unpredictable at this point and past patterns may not extend into the future. Interestingly, there is some evidence that seed set of agaves was higher in the past (Howell and Roth 1981). It is also possible that there was greater synchronicity between bats and flowering in the past.

Part of the U.S. strategy to combat increasing CO_2 levels is to promote alternative energy sources. Wind farms are increasingly being proposed in many areas including the Southwest. Wind turbines are known to kill bats (Arnett and others 2008), but to date, there has been no documented mortality for lesser long-nosed bats. Potential for impacts will be, at least in part, related to wind farm locations and their proximity to bat roosts, migratory routes, or foraging areas.

Research Needs

Several areas of deficient information on lesser long-nosed bats were identified in the five-year review (USFWS 2005). These include bat response to gates and other methods aimed at preventing roost disturbance, wind farm impacts, overall population size, and long-term effects of fire on foraging resources.

This assessment of vulnerability to climate change indicates additional research needs. Of particular interest is how fluctuations in flowering timing alter bat migratory behavior and timing of arrival throughout the U.S. range and, in particular, Fort Huachuca. In addition, little is known about how climate variability may affect flowering variability particularly across latitudes where the bat occurs and how flowering variables relate to survival. Studies of the interaction of warming climate, fire, and expansion of invasive grasses would help identify effective management actions. Information is also needed on bat mortality and wind turbines. Research on management options that reduce populations of African grasses and probability of spread is needed.

Management Implications

Because lesser long-nosed bats only spend a portion of the year on Fort Huachuca, factors that affect populations occur largely in other regions, including Mexico, and effects from military activities will be limited. Fort Huachuca has already undertaken important steps to protect roosting and foraging resources. The Fort Huachuca Agave Management Plan includes established areas for agave management and a monitoring program. Agave management should include a range of elevations to incur greater resiliency of flowering resources under climate change. The potential for increasing impacts from invasive African grasses and increasing fires warrants consideration in management planning and implementation of preventative actions. Management related to post-fire rehabilitation should also include actions that encourage agaves.

Current activity restrictions to protect bats are in place from July 1 to October 31 (ENRD 2006). To protect bats, the Fort also has seasonal closing of mines and caves. Although this time period includes a buffer to known dates of bat presence, Fort Huachuca needs to anticipate timing changes in bat arrival and reevaluate time restrictions on activities that may disturb bats in the future.

Habitat: Lesser Long-nosed Bat (*Leptonycteris yerbabuenae*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Lesser long-nosed bats primarily occupy desert scrub habitats (primarily Sonoran, but also Chihuahuan) along with a variety of woodlands, grasslands, and shrublands where food resources are available. Climate projections indicate possible expansion of the Sonoran desert northward as temperatures warm (Weiss and Overpeck 2005). Accordingly, expansion of available habitat for lesser long-nosed bat might be inferred, but there are other important issues to be considered. Expansion will be limited by projected increases in fire frequency and increases in invasive grass species that will both be favored by a warming climate. Some evidence for expansion of suitable areas, but other factors such as fire, invasives, and human developments likely to limit expansion and threaten current range.	**1**
2. Area and distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Non-breeding areas will likely be reduced with decreases in Sonoran desert habitats to the south in Mexico predicted by temperature and precipitation projections in addition to the interacting effects of invasive grasses and fire occurrence. Sonoran desert is projected to decline in the southern portions of the range (Weiss and Overpeck 2005). Active conversion of Sonoran desert to grasslands and projected increases in fires make further loss of habitat area likely.	**1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Several types of roosts are used: day roosts, maternity roosts, bachelor roosts, and temporary night roosts. Roosts are often in caves or abandoned mines. Individuals require multiple roost types at different locations. A large maternity roost is located approximately 240 km (150 miles) from the Fort in Organ Pipe Cactus National Monument (ENRD 2006). Maternity roosts do not occur on Fort Huachuca. Use roosts of variable types and microclimates. Climate unlikely to affect availability of suitable roosts.	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	Roosts are often in caves or abandoned mines. Individuals require multiple roost types at different locations. Important day and night roosts have been identified on Fort Huachuca, although there are likely unknown roost sites as well (ENRD 2006). Thought to use roosts with a variety of microclimates, so it is unlikely that warmer temperatures will decrease roost availability.	**0**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Warmer maternity caves associated with better development of young (Arends and others 1995). May benefit from rising temperatures.	**-1**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Migratory and highly mobile moving over large areas to feed.	**-1**

Habitat: Lesser Long-nosed Bat (*Leptonycteris yerbabuenae*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	For Arizona, this species is a long-distance migrant. Some populations remain resident in Mexico. Migratory behavior is thought to take advantage of periodic resources (USFWS 1995). Individuals follow progressive flowering of columnar cactus and paniculate agaves. Although highly mobile, they avoid crossing high density urban housing (USFWS 2005).	**1**

Physiology: Lesser Long-nosed Bat (*Leptonycteris yerbabuenae*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Lesser long-nosed bats have a lower critical temperature of 30.5 °C and generally seek warm conditions (Fleming and others 1998). They often roost colonially in caves that trap metabolic heat, but have been found in a variety of different roost conditions (USFWS 1995). Migratory females give birth in Arizona and warmer maternity roosts may increase growth rates of the young (Arends and others 1995). Leave the United States because of cold winter conditions and seem well suited to desert conditions with a fairly high lower critical temperature. While projected changes are not expected to exceed physiological thresholds, they may instead reduce cold periods, which are unsuitable.	**-1**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g., severe storms, fires, floods) that affect survival or reproduction expected to change?	Heavy rainfall events, which are expected to increase, are associated with mortality in some species- documented at Carlsbad Caverns. Flood risk at Fort Huachuca roosts is unknown.	**1**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	They can fly long distances between roosts and foraging sites (from 50-100 km, USFWS 1995). Although distance from roosts to foraging areas is considered an important component of energy expenditure, lesser long-nosed bats have also been found to be efficient fliers and well adapted to performing long daily commutes (Horner and others 1998). Active at night. Rest part of the night in night roosts, but no information on limitations to foraging on hot nights. Although distance between roost sites and foraging locations may be affected, there is no anticipated effect because individuals apparently do not need to expend large amounts of energy to forage at distant locations.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across	Migratory behavior seems to be variable with both migratory and sedentary strategies that may be an adaptation to highly variable flowering resources (Rojas-Martinez and others 1999). Occurrence of migratory and	**1**

Physiology: Lesser Long-nosed Bat (*Leptonycteris yerbabuenae*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
	multiple years?	non-migratory demes related to resource availability and likely helpful with fluctuating resources. All individuals at Fort Huachuca, however, are migratory, so these populations do not possess this alternative and plasticity in behavior within demes is unknown.	
6. Metabolic rates	What is this species metabolic rate?	Moderate endothermic.	**0**

Phenology: Lesser Long-nosed Bat (*Leptonycteris yerbabuenae*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g., hibernation, migration, breeding)?	Do not hibernate. Probably initiates migration based on flowering resources, but may also be related to progress of pregnancy in females. No direct moisture or temperature cues known.	**0**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g., food, breeding sites) that are expected to change?	Migratory females arrive in Arizona pregnant and give birth to 1 young that can fly at about 4 weeks. Birth is not highly synchronous among individuals at the same maternity cave, with pregnant females co-occurring with females with young that are ready to fly (USFWS 1995). Females that do not migrate give birth in winter in Mexico (USFWS 2005). Migration and breeding is tied to flowering timing, which is likely to be altered by changes in temperature and precipitation.	**1**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Lesser long-nosed bats are present April to November in Arizona, although this seems to vary by year. Movements coincide with blooming (cactus in the spring, agave in the summer). Likely that this species' movements are directly related to presence of nectar resources, thus has the potential to respond quickly to changes.	**-1**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	One reproductive event per year.	**1**

Biotic Interactions: Lesser Long-nosed Bat (*Leptonycteris yerbabuenae*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Lesser long-nosed bats are adapted to feed on nectar and pollen of various columnar cactus and paniculate agave species. They are able to switch between various cactus and agave species when flowering of one species fails and also may eat insects, fruits, and have been observed to use hummingbird feeders (USFWS 2005). Northern migrants eat almost exclusively CAM plants (agaves and cactus). Because of their ability to open their stomates at night, CAM plants are well adapted to dry conditions. In Mexico, lesser long-nosed bats are known to feed on C_3 plants (most shrubs and forbs) as well (Fleming and others 1993). Agaves on Fort Huachuca are primarily Palmer's agave (*Agave palmeri*) with some Parry's agave (*Agave parryi*). Mostly dependent on agave at Fort Huachuca. These CAM plants are resilient to dry conditions, but flowering and, thus, nectar availability generally decreases under dry conditions. In addition, more variable rainfall may increase variability in flowering.	**1**
2. Predators	Are important predator populations expected to change?	Few incidences of predation have been documented and predators were various. No avoidance of activity during full moons suggests predation pressure while foraging is not strong (USFWS 1995). Potentially large impacts of single predators at small roosts, but overall, probably has little impact on populations.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	They are an important, but not exclusive, pollinator and seed disperser for these plants. Some researchers cite close association and bat adaptations in paniculate agaves and columnar cactus as evidence for a tight mutualistic relationship, but others have noted that this relationship is likely not as strong in the southwestern United States and northwest Mexico as in areas where nectar-feeding bats occur year-round (Fleming and others 2001). Foraging plant populations expected to survive warmer temperatures and reduced rainfall.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Rabies has been found in this species in Mexico, and, while it can result in bat mortality, rabies is not common and generally not considered to be a significant threat to bat populations (Gillette and Kimbrough 1970). Another emerging bat disease is white nose syndrome, which has been killing large numbers of roosting bats in northeastern North America. So far, it appears this disease only threatens hibernating species and is associated with cold conditions (Blehert and others 2008). Lesser long-nosed bats have neither of these risk factors.	**0**
5. Competitors	Are populations of important competing species expected to change?	Lesser long-nosed bats roost with a variety of other bats in Mexico (Arita 1993) and do not appear to segregate from other bat species at roosts. Other nocturnal nectarivores that exploit these nectar resources are much	**0**

Biotic Interactions: Lesser Long-nosed Bat (*Leptonycteris yerbabuenae*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
		smaller (e.g., moths, birds) so probably little competition. Could be competition with other nectarivorous bats, but Mexican long-tongued bats probably exploits additional flower resources with its longer tongue. Expected to be similarly affected by climate change.	

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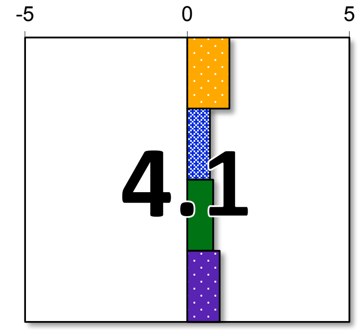
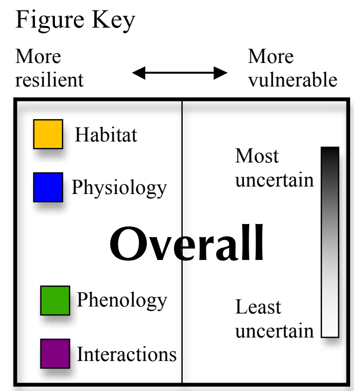
Mexican Long-tongued Bat (*Choeronycteris mexicana*)



SUMMARY

Populations of Mexican long-tongued bats that currently occur in Arizona are females migrating to maternity colonies. Like the lesser-long nosed bat, this species is expected to be vulnerable to changes in temperatures that will affect habitats and, in particular, flowering cacti and agave. Conversely, warmer winters will make conditions more favorable to year-round presence in the future. Fire, fuels, and invasive grass species management will be critical to this species.

VULNERABILITY	Score	Uncertainty
Habitat	**1.3**	14%
Physiology	**0.7**	67%
Phenology	**0.8**	0%
Interactions	**1.0**	20%
Overall	**4.1**	**27%**



Introduction

Mexican long-tongued bat is a USFWS species of concern, Forest Service sensitive species, and a species of greatest conservation need, Tier 1C, in Arizona SWAP (2010). It is also designated as a species at risk (SWESA 2006). Many aspects of this species' biology are not well known, but populations may be declining in Arizona (BISON-M). Individuals recorded in Arizona have been mostly females, but there are a few records of males in the United States as well (Balin 2009). These populations are largely maternal roosting colonies, although it is rare to see more than 25 individuals together (Joaquín and others 1987). Similar in ecology to the lesser long-nosed bat, this species is nectivarous and migrates from U.S. locations to Mexico where it is generally resident year-round. This species is present at Fort Huachuca.

Fort Huachuca Climate and Projections

- Annual increase in temperature 2.5-4.5 °F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell and others 2002)
- More droughts and intense storms (Seager and others 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager and others 2007)
- Riparian habitats decline (Stromberg and others 2006, Serrat-Capdevila and others 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- Reductions in Madrean woodlands (Rehfeldt and others 2006)
- Warmer temperatures and decreased soil moisture in Mexico (Liverman and O'Brien 1991)
- Decreased annual rainfall in Central America (Magrin and others 2007)

- CAM plants (succulents, cacti) will be resilient to increasing temperatures (Smith and others 1984)

A detailed review of projections is in the “Projections of Climate, Disturbance, and Biotic Communities” section of the main document.

Other Threats and Interactions With Climate

Many historic locations for this species remain occupied in Arizona, including various locations in the Huachuca Mountains (Cryan and Bogan 2003). Thus, although rare, populations in Arizona may be relatively stable. Mexican long-tongued bats, however, are threatened by a number of factors that we expect to be exacerbated by future climate change.

Like most bats, Mexican long-tongued bats are vulnerable to roost disturbance (NatureServe 2009). Roost protection is complicated by disturbance at roost sites. It is unknown if they are sensitive to gate construction like lesser long-nosed bats. Climate change will potentially increase roost disturbance by illegal immigrants. Increased droughts predicted under future climate scenarios will result in failure of agricultural crops and put stress on growing human populations. Buffering of climate impacts varies with factors such as irrigation and government programs, both of which predict that drought impacts will be less severe in the United States as compared to Mexico (Vásquez-León and others 2003). In the absence of alterations to immigration policies, increased illegal traffic at the international border is expected and, subsequently, an increase in threats to roosts.

The greatest threat to bat foraging areas at a landscape level is the likely expansion of invasive grasses and the concurrent increase in fire occurrence with subsequent reduction in agaves and cacti. Buffelgrass (*Pennisetum ciliare*), in addition to the already common Lehmann’s lovegrass (*Eragrostis lehmanniana*), is rapidly expanding and is becoming increasingly problematic in the Sonoran Desert. It was, and continues to be, introduced in the Sonoran desert to enhance livestock grazing with almost the entire Sonoran desert ecosystem prone to buffelgrass invasion (Arriaga and others 2004). Fires occur more frequently in the dry biomass created, and burning encourages more buffelgrass. The invasion of African grasses and accompanying alteration of fire regimes will be exacerbated by climate change. African grasses will likely not be limited by climate changes in this region and any increase in fire and other disturbances will favor grasses at the expense of species prone to fire mortality such as cacti and agaves.

Research Needs

Critical resource requirements are not well known in this species, making effective management difficult. We found little information on the specific requirements for roosting locations, which will be important to identifying critical roost resources. Important foraging plants are also not well known in this species, although it is assumed that this species may use a broader selection than lesser long-nosed bats. More study is needed to understand flexible migratory behaviors in this species. Depending on how this flexibility occurs in populations or individuals, changes in migration might be expected to occur regularly resulting in observed population fluctuations at isolated locations.

Management Implications

The potential for increasing impacts from invasive African grasses and increasing fires warrants consideration in management planning and implementation of preventative actions. Management related to post-fire rehabilitation should also include actions that encourage agaves and cacti in suitable areas.

Fort Huachuca has taken a number of measures to protect bats, including protecting agave in Agave Management Areas and seasonal closure of mines and caves. Although these primarily target the endangered lesser long-nosed bat, the Mexican long-tongued bat also benefits. Timing changes in bat arrival and presence at Fort Huachuca related to climate change indicate a need to reevaluate time restrictions on activities that may disturb bats. In addition, identification and monitoring of suitable caves or mines is warranted as conditions become more favorable for these bats.

Habitat: Mexican Long-tongued Bat (*Choeronycteris mexicana*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	In the United States, Mexican long-tongued bats breed along the border region with Mexico. In Arizona, this species to inhabit primarily the oak-pine belt at elevations ranging from 4000–6000 ft as well as saguaro-paloverde desertscrub (BISON-M). Additionally, they are often associated with Madrean evergreen woodlands and semidesert grasslands with agave species in this region (Cryan and Bogan 2003). Increasing fires and invasive grasses will likely reduce pine-oak habitats along with upward elevational shifts.	**1**
2. Area and distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Individuals that breed in the United States are mostly, if not all, females and, after breeding, migrate to Mexico for the winter (Joaquín and others 1987, BISON-M). Central Mexico vegetation associations include desert scrub and mixed pine-oak forest (NatureServe 2009). Also expected to be exposed to increased fires and invasive grasses.	**1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Maternity roosts are required and are usually in caves or abandoned mines (NatureServe 2009). Availability not expected to change.	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	Day and night roosts are also required for non-breeding individuals (BISON-M 2009). Roosts include buildings, rock fissures, and caves (NatureServe 2009). Availability not expected to change.	**0**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	None known.	**0**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Highly mobile, although males and females have different dispersal patterns.	**-1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	Populations in Arizona are migratory.	**1**

Physiology: Mexican Long-tongued Bat (*Choeronycteris mexicana*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Range extends from southern California, Arizona, and southwestern New Mexico southward into central Mexico and into Central America (Joaquín and others 1987). This species is limited in occupation of Arizona habitats because of cold limitations. Warmer temperatures may create more favorable conditions.	**-1**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g., severe storms, fires, floods) that affect survival or reproduction expected to change?	Fire or other extreme weather is unlikely to result in direct mortality. Roosts are somewhat protected from disturbance though there have been incidences of flooding of roosts and bat mortality in some species. Heavy rainfall events, which are expected to increase, are associated with mortality in some species and have been documented at Carlsbad Caverns. Flood risk at Fort Huachuca roosts is unknown.	**1**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Active at night. No information on limitations to foraging on hot nights. Rest part of the night in night roosts. Activity periods will probably not be reduced or increased.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	Seems to have somewhat flexible migration. Not known if this flexibility is possessed within individuals or within certain populations. All bats in Arizona are currently migratory and it is not known if they would not migrate should flowering fail. Possible, but too little information.	**1**
6. Metabolic rates	What is this species metabolic rate?	Moderate endothermic.	**0**

Phenology: Mexican Long-tongued Bat (*Choeronycteris mexicana*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g., hibernation, migration, breeding)?	Cues are likely a combination of internal and external signals. Do not hibernate.	**0**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g., food, breeding sites) that are expected to change?	Births in Arizona occur between mid-June and early July (BISON-M) and may be timed to peak flowering. Earlier flowering has been documented in many Sonoran desert plant species including columnar cacti and agave (Bustamante and Búrquez 2008).	**1**

Phenology: Mexican Long-tongued Bat (*Choeronycteris mexicana*)

Trait/Quality	Question	Background Info & Explanation of Score	Points
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	These bats follow the sequential flowering of agave, saguaro, ocotillo, palo verde, and prickly pear cactus (Fleming 1988). Migrations are described as following the sequential flowering of various cacti species (Fleming 1988).	**-1**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	One reproductive event per year.	**1**

Biotic Interactions: Mexican Long-tongued Bat (*Choeronycteris mexicana*)

Trait/Quality	Question	Background Info & Explanation of Score	Points
1. Food resources	Are important food resources for this species expected to change?	Consume nectar and pollen from flowering plants, such as agaves and saguaro, and may supplement their diet with cactus fruit and insects (BISON-M 2009). Mexican long-tongued bats may be able to feed on a greater variety of flowers than lesser long-nosed bats because of their longer tongues (BISON-M 2009). In Arizona, large numbers of bats are thought to rely on hummingbird feeders before and after agave flowering season (BISON-M 2009). Flowering and thus nectar availability generally decreases under dry conditions. In addition, more variable rainfall may increase variability in flowering.	**1**
2. Predators	Are important predator populations expected to change?	Limited information on predators, but known to be preyed upon by owls (Joaquín and others, 1987). Predation rates not expected to change.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	No symbionts.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Rabies has been found in this species in Mexico, but, while it can result in bat mortality, rabies is not common and generally not considered to be a significant threat to bat populations (Gillette and Kimbrough 1970). Another emerging bat disease is white nose syndrome, which has been killing large numbers of roosting bats in northeastern North America. So far, it appears this disease only threatens hibernating species and is associated with cold conditions (Blehert and others 2008). Mexican long-tongued bats have neither of these risk factors.	**0**
5. Competitors	Are populations of important competing species expected to change?	Other nocturnal nectarivores that exploit these nectar resources are much smaller (e.g., moths, birds), so probably little competition. Could be competition with other bats, but Mexican long-tongued bat probably exploits additional flower resources with its longer tongue. Expected to be similarly affected by climate change.	**0**

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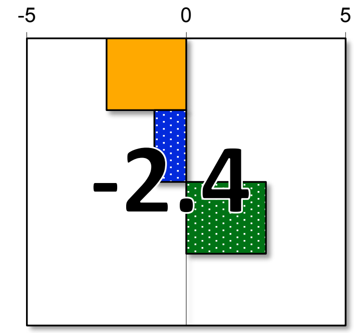
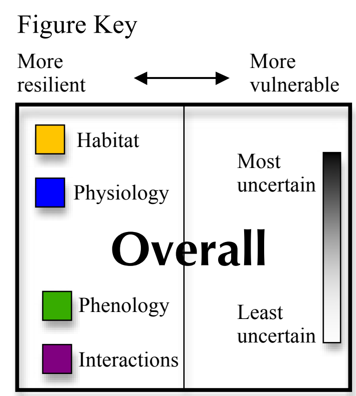
Black-tailed Prairie Dog (*Cynomys ludovicianus*)



SUMMARY

Potential habitat exists on Fort Huachuca for this keystone species. Plague is considered to be the greatest current impact, and plague prevalence will likely be altered by climate change, but ultimate outcome for mortality rate in prairie dogs is unclear. Based on a broad suite of traits, we predict that prairie dog response to climate change will be somewhat resilient overall, thus population dynamics will largely depend on other factors. Potential for dispersal to Fort Huachuca should be evaluated.

VULNERABILITY	Score	Uncertainty
Habitat	**-2.5**	0%
Physiology	**-1.0**	33%
Phenology	**2.5**	25%
Interactions	**0.0**	40%
Overall	**-2.4**	**23%**



Introduction

USFWS found that listing of the black-tailed prairie dog as threatened or endangered was unwarranted and that the proposed Arizona black-tailed prairie dog (*Cynomys ludovicianus arizonensis*) is not a distinct population or subspecies (Dec. 2009). Other analyses identified the *arizonenis* populations as a unique subspecies (BISON-M 2009). In 1960, the black-tailed prairie dog was considered extirpated in Arizona (ENRD 2006), but it was reintroduced to Arizona in 2008 via translocations. Reintroductions in and adjacent to Las Cienegas National Conservation Area began in 2008. USFWS included climate change as a potential threat when considering listing status and concluded that climate change does not threaten the species with extinction in the foreseeable future. Black-tailed prairie dogs are a species of greatest conservation need, Tier 1A, in Arizona SWAP (AGFD 2006) and a species at risk (SWESA 2006). Fort Huachuca has potential habitat for this species (ENRD 2006).

Fort Huachuca Climate and Projections

- Annual increase in temperature 2.2 °C or 4 °F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell and others 2002)
- More droughts and intense storms (Seager and others 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager and others 2007)
- Riparian habitats decline (Stromberg and others 2006, Serrat-Capdevila and others 2007)
- Grasses favored over shrubs (Esser 1992)
- Increases in invasive grasses and fires (Esser 1992, Williams and Baruch 2000)
- CAM plants (succulents, cacti) will be resilient to increasing temperatures (Smith and others 1984)

A detailed review of projections is in the "Projections of Climate, Disturbance, and Biotic Communities" section of the main document.

Other Threats and Interactions With Climate

Prairie dogs have been widely poisoned and shot for interference with livestock, but sylvatic plague is considered to be the most important current impact (USFWS 2009). Spread of plague could be exacerbated by climate change (USFWS 2009). Plague is enhanced by cooler summer temperatures and by increased precipitation. Consequently, the extent to which plague may shift due to climate change versus expand or contract is unclear (USFWS 2009). Extinction of colonies generally follows ENSO events, but colony metapopulation dynamics are complex (Stapp and others 2004). Warmer and wetter winters may contribute to flea vector populations and also winter survival in prairie dogs, thus increasing the chances of transmission (Stapp and others 2004). In the Southwest, human plague outbreaks are higher during periods of higher rainfall but decrease with high summer temperatures (Parmenter and others 1999).

Population declines in the Southwest have partly been attributed to the conversion of grasslands to shrublands (USFWS 2009). Climate change will have important interactions with grass and shrub species and may favor grasses in the Southwest. Incidence of fires and current vegetation will also be influential in future vegetation projections.

Research Needs

More complex analysis is needed to evaluate how plague and climate change interact with particular attention to regional differences. Plague interactions in Arizona may be quite different from those in the Midwest. In general, most studies on this species are from cooler climates; therefore, more specific information on habitat and population dynamics for the Southwest are needed.

Management Implications

Black-tailed prairie dog is not of current management concern for Fort Huachuca. We expect that climate change will not greatly impact this species. If other impacts are low enough to allow reintroduced populations to increase, there could be expansion of prairie dog towns. Dispersal onto Fort Huachuca will depend on a number of factors including dispersal barriers and land ownership. An evaluation of this potential would be useful in determining if prairie dogs need to be included in future planning documents.

Habitat: Black-tailed Prairie Dog (*Cynomys ludovicianus*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Area and distribution: *breeding*	Is the area or location of the associated vegetation type used for breeding activities by this species expected to change?	Occurs in grasslands with flat or gently sloped topography (USWFS 2009). In Arizona, occupies desert grasslands (BISON-M 2009). Desert grasslands in southwestern United States are probably encouraged by warmer temperatures and increasing fires.	**-1**
2. Area and distribution: *non-breeding*	Is the area or location of the associated vegetation type used for non-breeding activities by this species expected to change?	Same as above.	**-1**
3. Habitat components: *breeding*	Are specific habitat components required for breeding expected to change within associated vegetation type?	Burrows are required and created by prairie dogs. No change in suitable soils for burrowing.	**0**
4. Habitat components: *non-breeding*	Are other specific habitat components required for survival during non-breeding periods expected to change within associated vegetation type?	Same as above.	**0**
5. Habitat quality	Within habitats occupied, are features of the habitat associated with better reproductive success or survival expected to change?	Shorter and less dense vegetation is generally associated with greater predator avoidance in prairie dogs. Although vegetation height will be more variable with increasing variability in rainfall, prairie dogs also actively clip vegetation. No effect anticipated.	**0**
6. Ability to colonize new areas	What is the potential for this species to disperse?	Known to disperse long distances to establish new colonies although most dispersal is between colonies. Dispersal rates are considered generally low and may contribute to interpopulation genetic variation (Chesser 1983). May expand foraging area during drought (USFWS 2009). Dispersal abilities can likely keep up with habitat shifts.	**-1**
7. Migratory or transitional habitats	Does this species require additional habitats during migration that are separated from breeding and non-breeding habitats?	No.	**0**

Physiology: Black-tailed Prairie Dog (*Cynomys ludovicianus*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Physiological thresholds	Are limiting physiological conditions expected to change?	Tolerant of a wide variety of conditions including hot daytime temperatures.	**0**
2. Sex ratio	Is sex ratio determined by temperature?	No.	**0**
3. Exposure to weather-related disturbance	Are disturbance events (e.g., severe storms, fires, floods) that affect survival or reproduction expected to change?	None known and generally avoid areas prone to flooding. Fires probably do not result in direct mortality. Drought not thought to be a limiting factor (USFWS 2009).	**0**
4. Limitations to daily activity period	Are projected temperature or precipitation regimes that influence activity period of species expected to change?	Less active in summer than winter (Tileston and Lechleitner 1966), but no known effect on fitness. Although this species may avoid the hottest parts of the day in burrows, no information that activity periods are limited.	**0**
5. Survival during resource fluctuation	Does this species have flexible strategies to cope with variation in resources across multiple years?	Facultative torpor has been observed in this species and was associated with sudden drops in ambient temperatures but not precipitation (Lehmer and others 2001). Colonial habits and flexibility may help populations cope with resource fluctuations.	**-1**
6. Metabolic rates	What is this species metabolic rate?	Moderate endothermic.	**0**

Phenology: Black-tailed Prairie Dog (*Cynomys ludovicianus*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Cues	Does this species use temperature or moisture cues to initiate activities related to fecundity or survival (e.g., hibernation, migration, breeding)?	Cues are likely a combination of internal and external factors. Arizona populations do not go through hibernation.	**0**
2. Breeding timing	Are activities related to species' fecundity or survival tied to discrete resource peaks (e.g., food, breeding sites) that are expected to change?	In Colorado, young were born in late March through early April (Tileston and Lechleitner 1966). Breeding in the spring may be timed with new growth of vegetation. Timing of new growth is likely to change.	**1**

Phenology: Black-tailed Prairie Dog (*Cynomys ludovicianus*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
3. Mismatch potential	What is the separation in time or space between cues that initiate activities related to survival or fecundity and discrete events that provide critical resources?	Cues not distant from resources.	**0**
4. Resilience to timing mismatches during breeding	Is reproduction in this species more likely to co-occur with important events?	One litter per year.	**1**

Biotic Interactions: Black-tailed Prairie Dog (*Cynomys ludovicianus*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Food resources	Are important food resources for this species expected to change?	Eats grasses and forbs. Also consumes roots (Tileston and Lechleitner 1966). Prefers grass species in desert grasslands (BISON-M 2009). Food preferences vary with phenology and diet is considered specialized opportunist (USFWS 1989). Seeds, woody stems, and cactus are eaten in winter (USFWS 1989). Variety will likely result in no overall change in quantity.	**0**
2. Predators	Are important predator populations expected to change?	Large number of predator species. Major predators in Arizona are not known. Unlikely to change overall.	**0**
3. Symbionts	Are populations of symbiotic species expected to change?	Considered a keystone species but is not dependent on presence of other species. Interactions with other prairie dogs also important. Colonial behavior aids predator detection, rearing of young, and parasite removal (see Physiology Question 5). No changes in colony size predicted. No dependence on other species.	**0**
4. Disease	Is prevalence of diseases known to cause widespread mortality or reproductive failure in this species expected to change?	Plague is a major source of mortality and can also be transmitted through fleas during grooming and other contact. Complex interactions with climate and metapopulations. Could increase with warmer wetter winters, but precipitation is not expected to increase on average and hot summers are associated with decreased incidence of plague. Needs more complex analysis. No change projected.	**0**
5. Competitors	Are populations of important competing species expected to change?	Domestic livestock are popularly considered competitors, but livestock grazing may also favor prairie dogs by reducing vegetation height and increasing predator detection (USFWS 2009). Grazing interactions with domestic or native species is limited on Fort Huachuca.	**0**

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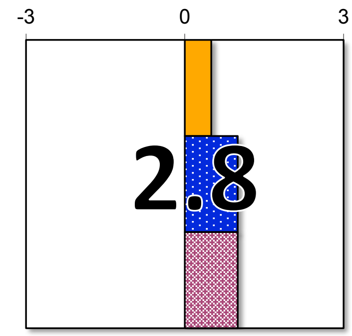
Huachuca Water Umbel
(*Lilaeopsis schaffneriana* var. *recurva*)

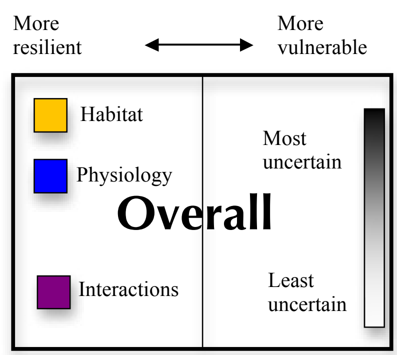


SUMMARY

The Huachuca water umbel is present only at locations that remain wet year round, thus is prone to future population declines as evaporation increases and precipitation patterns are altered. Flooding is important for dispersal, but also can threaten established populations. Similarly, fires can increase sedimentation but can also open canopy and increase surface water through run-off. Some intermediate level of disturbance is likely optimal for this species, although optimal levels may change as disturbance regimes are altered. Management related to hydrology and fire will be important with the biggest challenge being the retention of water in occupied wetlands.

VULNERABILITY	Score	Uncertainty
Habitat	**0.5**	0%
Physiology	**1.0**	33%
Interactions	**1.0**	66%
Overall	**2.8**	**30%**

Figure Key



Introduction

The Huachuca water umbel is a Federally endangered plant that has also been known as *Lilaeopsis recurva*. It is designated as sensitive by the USDA Forest Service and highly safeguarded under Arizona Native Plant Law (ENRD 2006). Huachuca water umbel occupies Garden Canyon and tributaries (ENRD 2006). Portions of this habitat are designated as critical (USFWS 1999). Some of these populations were identified after 1995 along with several populations outside of Fort Huachuca (ENRD 2006). It also occurs outside of the United States in northern Sonora, Mexico.

Fort Huachuca Climate Projections Used for Assessment

- Annual increase in temperature 2.2 °C or 4 °F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell and others 2002)
- More droughts and intense storms (Seager and others 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager and others 2007)

A detailed review of projections is in the "Projections of Climate, Disturbance, and Biotic Communities" section of the main document.

Other Threats and Interactions With Climate Change

The primary threat to the Huachuca water umbel is loss of water and degradation of wetlands (USFWS 1999). This threat will be intensified under warmer temperatures regardless of precipitation changes. High severity wildfires, which are projected to increase, are likely to increase sedimentation, which negatively impacts habitat. Other sources of erosion such as recreation and flooding are also considered detrimental (ENRD 2006). Flooding, however, is important for dispersal, thus the best habitats include locations that are both prone to floods and those that are refugia from floods (USFWS 1999). Irregular flood events may be beneficial to sustaining populations, although this will depend on a number of factors, including topography and flood intensity. This species should be resilient to changes in timing of floods.

Flowering may be reduced where cover of competing species is high, possibly from reduced light levels (Titus and Titus 2008). More open habitats, however, can dry out faster (Titus and Titus 2008) and dispersal seems to mostly be associated with flooding.

Various activities are considered potentially detrimental to populations. The most important are those that reduce water for wetland habitats or otherwise alter or degrade wetland habitats or hydrology. Channelization also encourages unfavorable flooding (Titus and Titus 2008). Other potential threats include catastrophic fires, livestock grazing, logging, military activities, and recreation. Low to moderate severity fires may maintain suitable habitats by reducing competing canopy (Titus and Titus 2008), but, as previously noted, can also increase sedimentation. Fires may be additionally beneficial as run-off increases water inputs from burned upland areas, at least in the short term. The favorable environmental conditions of a more closed canopy will likely increase in importance with climate change.

Research Needs

An assessment of future flood risk and potential impacts for Fort Huachuca would aid management of this species because it is associated with specific hydrological conditions and dispersal depends on flooding.

Management Implications

Response to climate change in this species is difficult to project because of its complex relationship with flooding and other processes that remove vegetation, such as fire. Some balance of these disturbances is likely optimal, but detailed projections of fire and flooding are unavailable and depend on many factors. Management that affects hydrology and fire regimes will need to consider both the positive and negative influence of these activities. Planning should be in place for locations that are expected to dry to the point they are no longer suitable for this species. Inclusion of translocation options in planning may be warranted.

Habitat: Huachuca Water Umbel (*Lilaeopsis schaffneriana* var. *recurva*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Increased droughts and warming.	Is this species associated with wetlands, riparian areas, or other mesic environments expected to decline?	Occupies cienegas in a variety of arid habitats including grasslands, desert scrub, oak woodlands, and coniferous forests (ENRD). Locations of occurrence have permanent surface water or are seasonally saturated and are not prone to flooding (USFWS 1999). Current elevational limits are 855–2100 m (2800–7000 ft) (Titus and Titus 2008).	**1**
2. Habitat elements	Does this species require specialized microsites?	Also needs refugia from flooding that are also not prone to drying and a moderately open canopy (USFWS 1999). Flooding will likely be more irregular and intense while fires will become more frequent. In addition, wetland areas are limited in the region.	**1**
3 Ability to colonize new areas	What is this species dispersal ability?	Perennial species with creeping rhizomes. Reproduction can be sexual through flowers, but most is through asexual through spread of rhizomes (USFWS 1999). Dispersal can also occur through rooting of dislodged clumps that are swept downstream (USFWS 1999). Seeds are buoyant and likely dispersed by water (Titus and Titus 2008).	**-1**
5. Seedling conditions	Do seedlings require different conditions from mature individuals (shade, moisture, fires, nurse plants, etc.)?	Seedling conditions similar to mature plants	**0**

Physiology: Huachuca Water Umbel (*Lilaeopsis schaffneriana* var. *recurva*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Exposure to disturbance	Are disturbance events that result in direct mortality or reproductive failure expected to change?	Wildfires are likely to increase sedimentation and negatively impact habitat although an open canopy may increase light levels. Other sources of erosion such as recreation and flooding are also considered detrimental (ENRD). Locations of occurrence have permanent surface water or are seasonally saturated and where not prone to flooding (USFWS 1999). Flooding can, however, aid dispersal. Overall, increases in drought, flooding, and wildfires will have at least some detrimental impacts.	**1**
2. Adaptations to survive water limitations	Does this species possess adaptations to increase survival during droughts (i.e., waxy leaves, water storage, cavitation, drought deciduous)?	Leaves may not grow from rhizomes during droughts, saving energy and exposure. In addition, seeds have some ability to survive droughts (Titus and Titus 2008).	**-1**
3. Photosynthetic pathway	Which photosynthetic pathway does this species use?	C3.	**1**

Interactions: Huachuca Water Umbel (*Lilaeopsis schaffneriana* var. *recurva*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Pollination	What is the pollination vector?	Insect.	**1**
2. Disease	Any known diseases/parasites that result in mass mortality related to temperature or precipitation?	No.	**0**
3. Competitors	Are populations of important competing species expected to change?	Non-native plants can limit occurrences (USFWS 1999), although no information on problematic species. Interaction is subject to changes dependent on species and disturbance regimes. Flowering may be reduced where cover of competing species is high, possibly from reduced light levels (Titus and Titus 2008). No predictable change based on various species and interactions.	**0**

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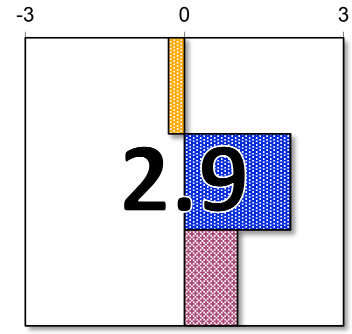
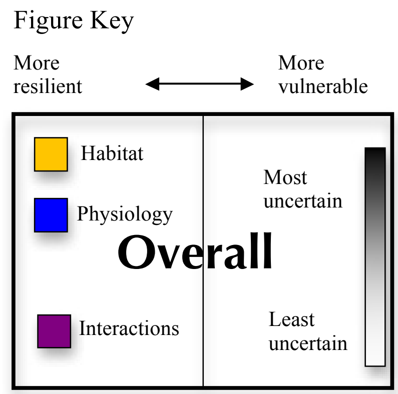
Lemmon Fleabane (*Erigeron lemmonii*)



SUMMARY

Additional vulnerability to population declines is predicted for this species with future climate change, but this is based on limited species information. Its presence in a single location alone is enough to increase vulnerability to any impact. Recruitment in particular may be vulnerable to changes in precipitation. Identification of other populations will be important and any translocation needs to consider future conditions of potential sites.



VULNERABILITY	Score	Uncertainty
Habitat	**-0.3**	50%
Physiology	**2.0**	66%
Interactions	**1.0**	66%
Overall	**2.9**	**60%**

Introduction

Lemmon fleabane is a candidate for listing as a Federally endangered or threatened species. The only known location for this species is Scheelite Canyon on Fort Huachuca (USFWS 2001).

Fort Huachuca climate projections used for assessment

- Annual increase in temperature 2.2 °C or 4 °F by 2050 (www.climatewizard.org, A2 emissions, ensemble GCM) and greater evaporation
- No change in average rainfall by 2050 (www.climatewizard.org, A2 emissions, ensembled GCM)
- Summer monsoon changes unknown (Mitchell and others 2002)
- More droughts and intense storms (Seager and others 2007)
- Earlier and more intense flooding (Garfin and Lenart 2007, Seager and others 2007)

A detailed review of projections is in the "Projections of Climate, Disturbance, and Biotic Communities" section of the main document.

Other Threats and Interactions With Climate Change

Lemmon fleabane is highly prone to extinction as it is only known to occur at one location. The current location is relatively invulnerable to human impacts but is exposed to other impacts that may or may not be related to climate change. Its specialized habits, however, may help protect it from disturbance. Occurrence in shady habitats may reduce exposure to higher temperatures to some extent, but physiological tolerances are not known. Hairy leaves will likely help protect plants from increased solar radiation. Flowering occurs in August and October and thus may depend on summer rainfall (USFWS 2001). Flowering and recruitment are likely vulnerable to projected increases in rainfall variability and reduction in water availability.

Research Needs

Research needs cover almost all aspects of this species' biology. Little published information on any topic was found on this species making assessment and management difficult.

Management Implications

Potential habitats should be evaluated and surveys should be conducted to identify additional populations of this species. Possible threats to the current known population should be evaluated, including erosion and flooding. This species may be a good candidate for transplantation or propagation, but future climate will need to be considered for any transplant locations. Monitoring will be important and should examine recruitment to assure sustainable populations.

Habitat: Lemmon Fleabane (*Erigeron lemmonii*)

Trait/Quality	Question	Background Info & Explanation of Score	Points
1. Increased droughts and warming.	Is this species associated with wetlands, riparian areas, or other mesic environments expected to decline?	Grows on vertical cliffs at 1900–2200 m (USFWS 2001). Not mesic.	**0**
2. Habitat elements	Does this species require specialized microsites?	Grows in crevices on vertical faces of boulders (USFWS 2001).	**1**
3 Ability to colonize new areas	What is this species dispersal ability?	Wind dispersal of seeds assumed.	**-1**
5. Seedling conditions	Do seedlings require different conditions from mature individuals (shade, moisture, fires, nurse plants, etc.)?	Not known.	**0**

Physiology: Lemmon Fleabane (*Erigeron lemmonii*)

Trait/Quality	Question	Background Info & Explanation of Score	Points
1. Exposure to disturbance	Are disturbance events that result in direct mortality or reproductive failure expected to change?	No known response to disturbance. Presumably protected from fires on vertical cliffs. May be prone to erosion following intense rainfall, but may also be minimal in crevices of rocky cliffs of Scheelite Canyon. Rock slides are not expected to change with climate.	**0**
2. Adaptations to survive water limitations	Does this species possess adaptations to increase survival during droughts (i.e., waxy leaves, water storage, cavitation, drought deciduous)?	None known.	**1**
3. Photosynthetic pathway	Which photosynthetic pathway does this species use?	C3.	**1**

Interactions: Lemmon Fleabane (*Erigeron lemmonii*)			
Trait/Quality	**Question**	**Background Info & Explanation of Score**	**Points**
1. Pollination	What is the pollination vector?	Presumably insect pollinated.	**1**
2. Disease	Any known diseases/parasites that result in mass mortality related to temperature or precipitation?	None known.	**0**
3. Competitors	Are populations of important competing species expected to change?	None known but likely limited in specialized habitats.	**0**

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Garfin, G. and M. Lenart. 2007. Climate change effects on Southwest water resources. Southwest Hydrology 6:16–17.

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