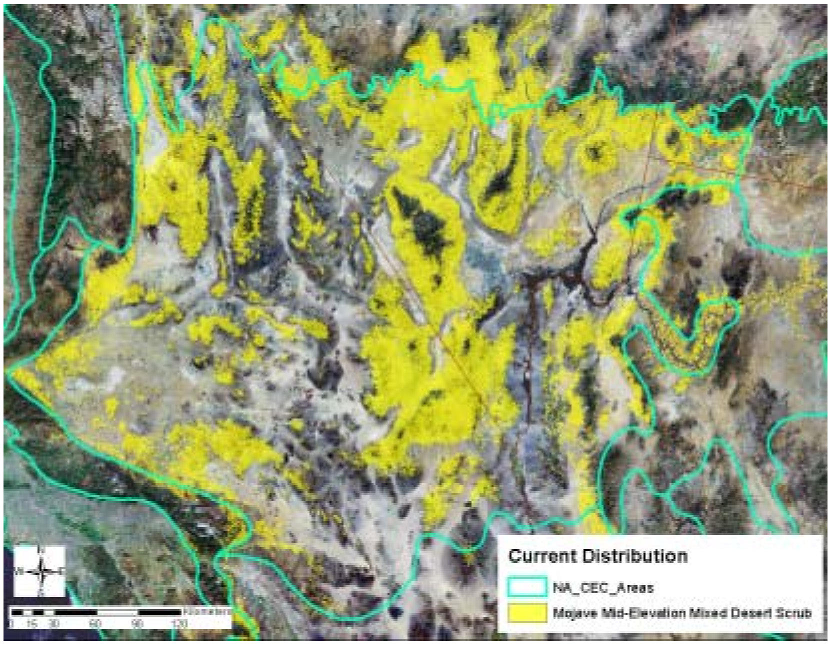
Appendix 3

Type Summaries: Climate Change Vulnerability Assessments for selected Mojave and Sonoran Desert Upland, Riparian, and Aquatic Communities

Contents

Mojave Desert - Mojave Mid-Elevation (Joshua Tree-Blackbrush) Desert Scrub

CONCEPT



This ecological system represents the extensive desert scrub in the transition zone above Creosote-Bursage desert scrub and below the lower montane woodlands (700-1800 m elevations) that occur in the eastern and central Mojave Desert. It is also common on lower piedmont slopes in the transition zone into the southern Great Basin. The vegetation in this ecological system is quite variable. Codominants and diagnostic species include *Coleogyne ramosissima, Eriogonum fasciculatum, Ephedra nevadensis, Grayia spinosa, Lycium* spp., *Menodora spinescens, Nolina* spp., *Opuntia acanthocarpa, Salazaria mexicana, Viguiera parishii, Yucca brevifolia,* or *Yucca schidigera*. Less common are stands with scattered Joshua trees and a saltbush short-shrub layer dominated by *Atriplex canescens, Atriplex confertifolia*, or *Atriplex polycarpa*, or occasionally *Hymenoclea salsola*. In some areas in the western Mojave, *Juniperus californica* is common with the yuccas. Desert grasses, including *Achnatherum hymenoides, Achnatherum speciosum, Muhlenbergia porteri, Pleuraphis jamesii, Pleuraphis rigida,* or *Poa secunda*, may form an herbaceous layer. Scattered *Juniperus osteosperma* or desert scrub species may also be present.

Overall Climate Change Vulnerability Score: High

DIRECTS EFFECTS

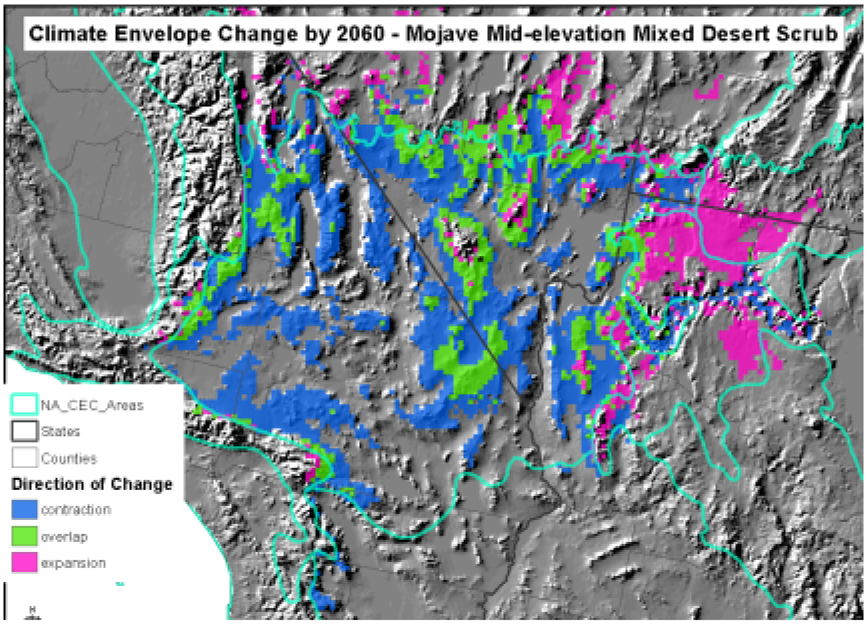
Forecasted Climate Stress Index Result 0.**35 High Sensitivity**

For the distribution of this community type within the Mojave Desert, maximum temperatures in the months of July-September define this stress, with forecasted increases reaching 9 degrees F. Climate models indicate that the Mean Maximum (daytime) Temperatures for July-August and Mean Minimum (night-time) Temperatures for June-September will increase by ~6 degrees F) for the majority of the Mojave Desert. The increased aridity from additional evapo-transpiration will likely cause decline in vegetation cover especially at the lower, hotter elevation sites. The model results also indicate a 0.9 inch (0.3-3.0 inch) increase in mean precipitation in August for the Spring Mountains and other nearby ranges.

The stress of increased mid-summer temperatures could take several forms. While many plants are already dormant, there may be interacting effects from wildlife if isolated springs dry up sooner. If additional moisture does occur in August, it could locally favor pinyon-juniper woodlands and other higher elevation communities commonly located adjacent to this desert scrub. There could also effects on cryptobiotic soil crusts, which are vulnerable to wetting without time to recover carbohydrate losses.

They are adapted to arid summers and can get killed by multiple wetting. They are stabilizing our soils and form a **key functional group of species** for soil stabilization.

Forecasted Climate Envelope Shift Index Result **0.12 High Sensitivity**
This indicates that a dramatic shift from the current climate envelope which suggests potential movement of species from this community into the higher elevation pinyon-juniper woodlands and invasion from lower elevation stands of creosotebush desert scrub. This lower elevation conversion could be composed of shorter-lived, faster colonizing species such as *Ambrosia dumosa*, and years later, *Larrea tridentata*.



Dynamic Process Forecast
Fire Regime Departure Index 2060: Result **0.44 High Sensitivity**
This indicates that currently this community is significantly departed from natural conditions, largely by increase fire frequency resulting from invasion of non-native annual grasses. Condition is predicted to become more departed in 2060.

INDIRECT EFFECTS

Landscape Condition 1960: Result **0.70 High Resilience**
In 1960, the ecological impacts of urbanization (conversion) had begun. Impacts from the transportation system (fragmentation) consisted of a several highways and railroad lines and a sparse network of unimproved roads. Major economic activities with ecological impacts were mining (high intensity localized disturbance), cattle grazing (variable intensity, concentrated in areas), and military training and development near Las Vegas. Intensive cattle grazing dates back to the 1920s, with many Mojave yuccas pulled or otherwise impacted.

Landscape Condition 2010: Result **0.60 Medium Resilience**
Current urbanization (conversion) has increased since 1960. Current ecological impacts from transportation (fragmentation), mining (high intensity localized disturbance), and recreation use (ORVs) has also increased. Grazing has changed since 1960. Increase in off highway vehicles and urbanization and less grazing has occurred since 1990 due to protection of tortoise. Overall though, this type is the most heavily used system type for cattle grazing in the Mojave Desert (Keeler-Wolf 2007).

Invasive Species Effects 1960: Result **0.7 High Resilience**
Invasive, non-native plant species such as annual grasses *Bromus rubens* and *Schismus barbatus* invaded much of the Mojave Desert largely introduced from historic cattle grazing. This community is one of the most heavily used for cattle grazing in the Mojave Desert.

Invasive Species Effects 2010: Result **0.45 Low Resilience**
Model suggests a massive expansion of introduced, non-native plant species since 1960. Invasion of non-native grasses have increased fire frequency and led to destruction of fire sensitive desert scrub (Sawyer et al. 2009).

Dynamic Process Alteration
Fire Regime Departure Index 2010: Result **0.7 High Resilience**
Introduction of fine fuels have an increasing effect on this types throughout many portions of the Mojave Desert.

ADAPTIVE CAPACITY

Diversity within Plant/Animal Functional Groups: Result **0.9 High Resilience**
The key species functional group is species that are tolerant to severe drought (severity and length). The diversity of characteristic dominant species is high (33 species). Additional consideration should be given for treatment of cryptobiotic soil crusts within this category.

Keystone Species Vulnerability: Result **0.78 High Resilience**
Species were tentatively identified as those that could likely have cascading ecological impacts on community function. Selection criteria included dominant plant species and pollinators for Yucca. Once selected a climate change vulnerability index was scored for their distribution within the ecoregion. Categorical scores were transformed to a 0.0 – 1.0 scale and averaged together for an overall index score.

Blackbrush (*Coleogyne ramosissima*): (0.7 Medium)
This species might be moderately vulnerable (with high confidence) to climate change effects in the region, despite its high genetic variation and reliance on a variety of methods for seed dispersal. The increased vulnerability may be the result of proposed changes in the moisture availability within the assessment area and land use changes by humans in response to climate change.

Black-throated Sparrow (*Amphispiza bilineata*): (1.0 High):
This bird may not be vulnerable to climate change in the region. Although it may be negatively affected by possible land use changes resulting from human responses to climate change and could experience detrimental effects from projected changes in moisture availability, it is a good disperser and ecologically versatile.

Yucca moth (*Tegeticula synthetic*) (West Mojave): (0.7 Medium)
Although this species may be a fairly good disperser and is associated with common geological features or derivatives, it may be negatively affected by projected changes in moisture availability. It is dependent on just one plant species (Joshua tree) for habitat and food, and that plant may be highly vulnerable to climate change within the assessment region. It could be negatively affected by land use changes resulting from human responses to climate change. Overall, it may be moderately vulnerable to climate change.

Yucca moth (*Tegeticula altiplanella*): (East Mojave) (0.7 Medium)
Although this species may be a fairly good disperser and is associated with common geological features or derivatives, it may be negatively affected by projected changes in moisture availability. It could be negatively affected by land use changes resulting from human responses to climate change. It is dependent on just one plant genus (*Yucca*) for habitat and food (in this assessment, yuccas were assumed to be at least somewhat vulnerable to climate change within the assessment region). Overall, the moth may be moderately vulnerable to climate change.

Bioclimate Variability Result **0.7 High Resilience**
This type occurs in a moderately high number of isobioclimates (14/20) which is expected for a widespread type.

Elevation Range: Result **0.5 Medium Resilience**
Number of 500’ (152 m) elevation belts that encompass the type distribution is 6 of 12.

Expert Workshop: Ecosystem Stressor Worksheet – Non-Climate Stressors

Non-Climate Stressor	**Current Scope**	**Current Severity**	**2060 Climate Scenario**	**Description**	**Mgmt Opportunity**
Altered fire regime, invasive plants Rank 1	High	moderate	Increased summer temp, possible summer moisture through storms		Same as creosote-bursage
N deposition, ozone Rank 2					low
Livestock grazing Rank 3	High – mod locally	High-mod locally			High
Military training Rank 3	L	L			Same as above

Ecosystem Stressor Worksheet – Climate Stressors

Climate Stressor	**Current Scope**	**Current Severity**	**2060 Climate Scenario**	**Description**	**Mgmt Opportunity**
Summer precipitation effects on crytobiotic soil crusts	low	low	Increased summer temp, possible summer moisture through storms		Mod. protections from all forms of surface disturbance

Potential Climate Change Adaptation Strategies

Agency Management Goals for communities:

FWS: keep intact for desert tortoise and plant recovery, water development for game species
USFS: Recreation opportunities

“No-regrets” actions to take within the next 5 years:

- Invest resources into minimizing effects of fire using strategic planning – reduce response time to fires in year after high rains in Nov/Dec
- Soil stabilization
- Control of off road vehicles

- Restore hydrological function e.g., improve culverts, restore flows, remove diversions, prevent soil compaction, maintain natural litter fall, restore natural channels where altered, ensure herbicide application allows biomass to remain
- Closer management of grazing intensity
- Fine fuel reduction
- Prevention and control of invasive plants
- Reduce drought stress through thinning in PJ
- Reduce drought stress by preventing soil compaction in salt desert and creosote and blackbrush

Anticipated actions over the coming 5-15 years:

- Consider water developments where springs are drying up.
- Consider earthwork modifications that increase residence time of water in an area (check dams, low long berms)
- Encourage discussions among botanists, entomologists, etc. to develop indicators of ecosystem health and use these to guide adaptive management of all these habitats.
- Develop decision support system and adaptive management for when not to intervene and how to intervene

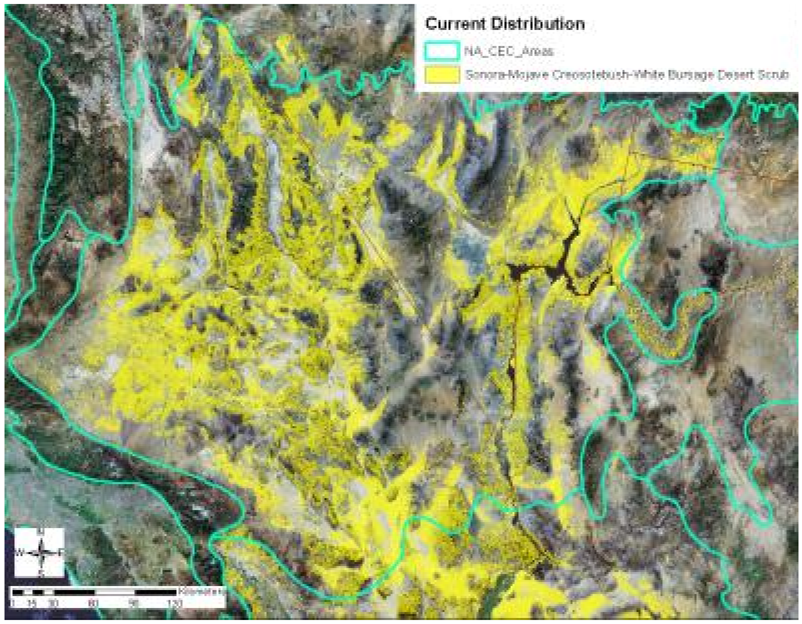
"Wait and watch" actions: Potential actions to anticipate over the 15-30 timeframe, with indicators to monitor and inform that future decision

- #1 Land Fire improvement: complete field verification of existing map and model outputs and monitor with aim to evaluate their predictions
- #2 Downscaling CC modeling to a useful scale; need to determine what scales are useful for which purposes.
- #3 How successful are re-vegetation efforts and mitigations that have been used?
- #4 Soil crust impacts, succession, function, under changes in rainfall pattern

Research and Monitoring priorities:

- Monitor effectiveness of mitigations for renewable energy impacts
- Research how to use mitigations to alleviate climate change – opportunistic, open ended
- Impacts of retiring grazing allotments – not only to protect desert tortoise, contrast where still in effect, and controlled livestock in vegetation near conservation areas.
- Monitor extent of nitrogen and ozone deposition and impacts to vegetation, cycling
- Large scale fuel reduction strategies for adjacent creosote scrub, and use of additional pathogens.
- Invertebrates key to ecosystem services and processes – monitor
- Research – focus on plant pollinator relations (rare plants)
- Pollutant/toxic impacts under climate change
- Synthesis of existing knowledge
- We talk about what we are losing, but not about what we are gaining. May want to manage for the changes. Is it all going to become desert pavement? What do we want to facilitate that provides the ecological services?
- Do we have our monitoring set up to pick up the shifts in functional groups?

Mojave Desert - Sonora-Mojave Creosotebush-White Bursage Desert Scrub



CONCEPT

This ecological system forms the vegetation matrix in broad valleys, lower bajadas, plains and low hills in the Mojave and lower Sonoran deserts. Elevation ranges from -75 to 1200 m. Substrates are typically well-drained, sandy soils derived from colluvium or alluvium, and are often calcareous.

This desert scrub is characterized by a sparse to moderately dense layer (2-50% cover) of xeromorphic microphyllous and broad-leaved shrubs. *Larrea tridentata* and *Ambrosia dumosa* are typically dominants, but many different shrubs, dwarf-shrubs, and cacti may codominate or form typically sparse understories. Associated species may include *Atriplex canescens*, *Atriplex hymenelytra*, *Encelia farinosa*, *Ephedra nevadensis*, *Fouquieria splendens*, *Lycium andersonii*, and *Opuntia basilaris*. The herbaceous layer is typically sparse, but may be seasonally abundant with ephemerals. Herbaceous species such as *Chamaesyce* spp., *Eriogonum inflatum*, *Dasyochloa pulchella*, *Aristida* spp., *Cryptantha* spp., *Nama* spp., and *Phacelia* spp. are common. This system can often appear as very open sparse vegetation, with the mostly barren ground surface being the predominant feature.

Overall Climate Change Vulnerability Score: Moderate

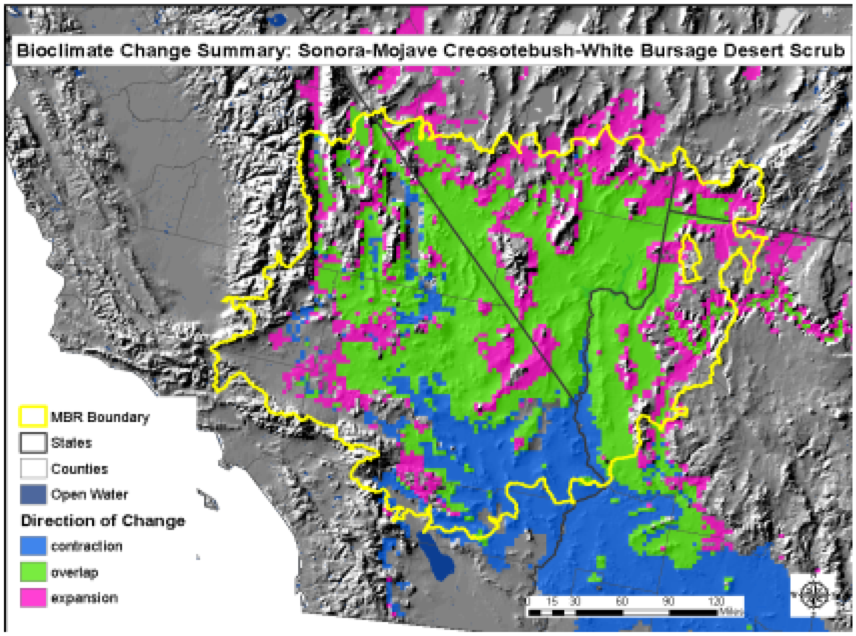
DIRECTS EFFECTS

Forecasted Climate Stress Index: Result **0.35 High Sensitivity**

For the distribution of this community type within the Mojave Desert, maximum temperatures in the months of July-September define this stress, with forecasted increases reaching 9 degrees F. The model results indicate that the Mean Maximum (daytime) Temperatures for July-August and Mean Minimum (night-time) Temperatures for June-September will increase by ~6 degrees F) for the majority of the Mojave Desert. The increased aridity from additional evapo-transpiration will likely cause decline in vegetation cover especially at the lower, hotter elevation sites. However, this effect could be minimized if this primarily occurs when plants have already gone dormant.

The Sonoran Desert may warm by, on average, 2-4 degrees F. Precipitation is less predictable. Given the higher probability of warming, the stress on component species is high for drought and heat intolerant species. With the higher uncertainty on how precipitation may change, it is difficult to rate the stress this may have on this ecosystem. Cryptobiotic crusts are adapted to surviving summers with no rain and may be vulnerable to wetting without time to recuperate carbohydrate losses. They provide a critical role with soil stabilization.

Forecasted Climate Envelope Shift Index: Result **0.8 Low Sensitivity**
This indicates that a moderate shift in the current climate envelope which suggests moderate potential movement of species from this community into the higher elevation mid-elevation desert scrub and decline and possible loss of lower-elevation creosotebush-bursage desert scrub stands to desert pavement.



Dynamic Process Forecast
Fire Regime Departure Index 2060: Result **0.56 Medium Sensitivity**
This indicates that community is currently significantly departed from natural conditions (introduced invasive species, fire regime, uncharacteristic states), but is predicted to be slightly less departed in 2060.

INDIRECT EFFECTS

Landscape Condition 1960: Result **0.8 High Resilience**
In 1960, the ecological impacts of urbanization (conversion) had begun. Impacts from the transportation system (fragmentation) consisted of a several highways and railroad lines and a sparse network of unimproved roads. Major economic activities with ecological impacts were mining (high intensity localized disturbance), cattle ranching (low intensity, widespread disturbance), and military training and development near Las Vegas.

Landscape Condition 2010: Result **0.73 High Resilience**
Current urbanization (conversion) has in the increased dramatically since 1960. Current ecological impacts from transportation (fragmentation), mining (high intensity localized disturbance), cattle ranching (low intensity, widespread disturbance), and recreation use (ORVs) has also increased.

Invasive Species Effects 1960: Result **0.8 High Resilience**
Invasive, non-native plant species such as annual grasses *Bromus rubens* and *Schismus barbatus* were invading much of the Mojave Desert largely introduced from historic cattle grazing.

Invasive Species Effects 2010: Result **0.59 Medium Resilience**

Model suggests a massive expansion of introduced, non-native plant species since 1960. Invasion of non-native grasses have also increased fire frequency and led to destruction of fire sensitive desert scrub (Sawyer et al. 2009).

Dynamic Process Alteration
Fire Regime Departure Index 2010: Result **0.1 Low Resilience**
This indicates that community is currently significantly departed from natural conditions (introduced invasive species, fire regime, uncharacteristic states).

ADAPTIVE CAPACITY

Diversity within Plant/Animal Functional Groups: Result **0.7 High Resilience**
The key species functional group is the extended drought tolerance species functional group. Although there are relatively low number of characteristic dominant species in this group, *Larrea tridentata* has extreme resistance to high temperature and low tissue water potential caused by extended drought (Yang 1967). This species is also very long-lived with clones living over 10, 000 years and so indicates remarkable robust species. It has deep roots that utilized winter precipitation (Munson et al. 2011). The codominant species, *Ambrosia dumosa* is short-lived low shrub with shallow roots that quickly colonizes open areas and is common on disturbed sites.

Diversity of characteristic dominant species in the extended drought tolerance vegetation functional group is relatively low at (mostly two species), however these species, especially *Larrea tridentata,* are very robust species that tolerate this extremely hot, dry, drought prone environment for millennia.

Keystone Species Vulnerability: Result **0.6 Medium Resilience**

Creosotebush (*Larrea tridentata*): (0.5 Medium)
This species might be vulnerable to climate change effects, mainly due to its dependence on seasonal rainfall for successful germination and potential effects of climate change on plant pollinators. Also, land use changes in response to climate change will increase vulnerability as well. The species may expand its range within the assessment area, potentially because proposed hydrological changes do not deviate as extremely in this particular assessment area. It is the characteristic dominant species of this desert scrub community that provides habitat or food for most other species.

Creosotebush grasshopper (Bootettix argentatus): (0.5 Low)
This species may be highly to moderately vulnerable to climate change in the region, based on effects of projected changes in moisture availability, possible land use changes resulting from human responses to climate change, and consequences of the species' high degree of dietary and habitat specialization on creosotebush.

Agassizi's Desert Tortoise (*Gopherus agassizii*): (0.7 Medium)
This species may be moderately vulnerable to climate change in the region, due primarily to effects of projected changes in moisture availability, the species' dependence on plants that are affected by seasonal precipitation patterns, possible land use changes resulting from human responses to climate change, and climate-change-induced habitat degradation (increases in invasive species and fire frequency). Published studies show major reductions in desert tortoise suitable habitat and range in the Mojave Desert with projected climate change.

Bioclimate Variability: Result**: 0.7 High Resilience**
This type occurs in a moderately high number of isobioclimates (14/20) which is expected for a widespread type.

Elevation Range: Result **0.6 Medium Resilience**
Number of 500' (152 m) elevation belts that encompass the type distribution is 7 of12.

Ecosystem Stressor Worksheet: - Creosote – Bursage - Non-Climate Stressors

Non-Climate Stressor	**Current Scope**	**Current Severity**	**2060 Climate Scenario**	**Description**	**Mgmt Opportunity**
Wind solar development Ranked 1	high	high	Increased summer temp, possible summer moisture through storms	Uncertain at present – little empirical data are available	Same as above
Urban expansion	high	high			Low for Land disposal planning
Altered fire regime, invasive plants Ranked 2	high				High for herbicide, mechanical, and pathogen fuel treatments
Livestock grazing Ranked 3	High, locally moderate	High, moderate locally		Cc will move grazing effect up hill	High More intensive management
OHV, dust Ranked 3	Locally high	High-medium locally		Cc reduces resilience to soil crust disturbance from OHV and T/E plants albedo	
Toxics and ground disturbance from mining	L	H		Reveg and heat degrade habitat, species health Cc may cause more intense flooding dispersing toxics more rapidly.	High for accelerate rate of closures and mediation of mine sites
Military training ranked 3	L	L		Cc reduces resilience to impacts of disturbance from military training	High for working with military
N deposition, ozone					
Transmission lines, roads					See renewable energy, High for corridor design.

Potential Climate Change Adaptation Strategies

Management Goals for communities:
FWS: keep intact for desert tortoise and plant recovery, water development for game species

"No-regrets" actions to take within the next 5 years:

- Fine fuel reduction (exotic annual grass control) and fire suppression in this fire sensitive system.
- Closer management of grazing intensity
- Planning to maintain contiguous natural blocks
- Aggressive prevention and control of invasive plant species
- Invest resources into minimizing effects of fire using strategic planning – reduce response time to fires in year after high rains in Nov/Dec
- Soil stabilization
- Control of off road vehicles
- Restore hydrological function e.g. improve culverts, restore flows, remove diversions, prevent soil compaction, maintain natural litter fall, restore natural channels where altered, ensure herbicide application allows biomass to remain,
- Reduce drought stress by preventing soil compaction

Anticipated actions over the coming 5-15 years:

- Aggressive management of wildland fire
- Consider water developments where springs are drying up.
- Consider earthwork modifications that increase residence time of water in an area (check dams, low long berms)
- Develop decision support system and adaptive management for when not to intervene and how to intervene

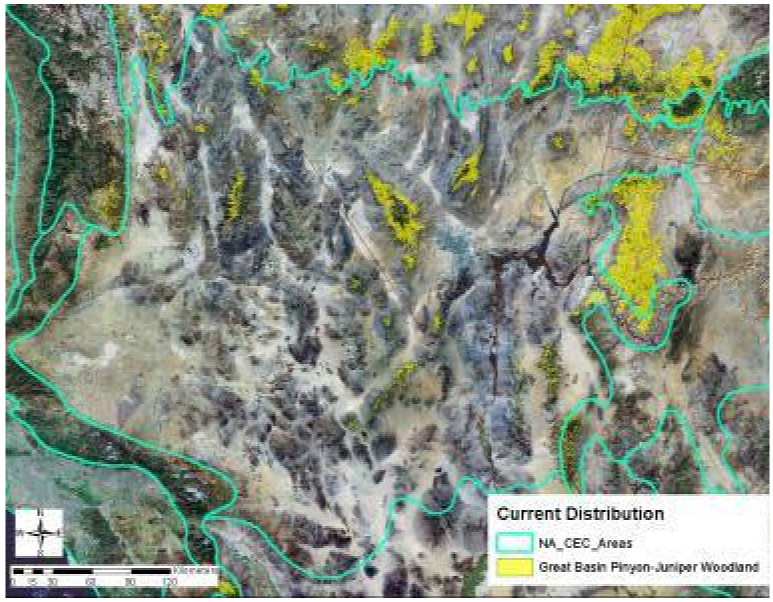
"Wait and watch" actions: Potential actions to anticipate over the 15-30 timeframe, with indicators to monitor and inform that future decision

- Encourage discussions among botanists, entomologists, etc to develop indicators of ecosystem health and use these to guide adaptive management of all these habitats
- Increasing fire ignition with drought years, and expanding fire patch size
- Increased densities of invasive plant populations at higher elevations.
- Decreasing vegetation density and erosion with transformation into desert pavement.

Research and Monitoring needs –
Monitor Recruitment of key species
#1 LandFire data improvement; field check succession class maps
#2 Downscaling CC modeling to a useful scale (*scale not specified*)
#3 How successful are re-veg efforts and mitigations that have been used?
#4 Soil crust impacts, succession, function, under changes in rainfall pattern

- Monitor effectiveness of mitigations for renewable energy impacts
- Research how to use mitigations to alleviate climate change – opportunistic, open ended
- Research and monitor impacts of retiring grazing allotments – not only to protect desert tortoise, contrast where still in effect, and controlled livestock in vegetation near conservation areas.
- Monitor extent of nitrogen and ozone deposition and impacts to vegetation, cycling
- Large scale fuel reduction strategies for creosote scrub, and use of additional pathogens.
- Monitor invertebrates - key to ecosystem services and processes
- Research – focus on plant pollinator relations (start with rare plants)
- Pollutant/toxic impacts under climate change

Mojave Desert - Great Basin Pinyon-Juniper Woodland



CONCEPT

This ecological system occurs on dry mountain ranges of the Great Basin region and eastern foothills of the Sierra Nevada south in scattered locations in the Mojave Desert in southern California. It is typically found at lower elevations ranging from 1600-2600 m. These woodlands occur on warm, dry sites on mountain slopes, mesas, plateaus and ridges. Severe climatic events occurring during the growing season, such as frosts and drought, are thought to limit the distribution of pinyon-juniper woodlands to relatively narrow altitudinal belts on mountainsides. Woodlands dominated by a mix of *Pinus monophylla* and *Juniperus osteosperma*, pure or nearly pure occurrences of *P. monophylla*, or woodlands dominated solely by *J. osteosperma* comprise this system, but in some regions of southern California, *J. osteosperma* is replaced by *J. californica*. *Cercocarpus ledifolius* is a common associate. Understory layers are variable. Associated species include shrubs such as *Arctostaphylos patula, Artemisia arbuscula, A. nova, A. tridentata, Cercocarpus ledifolius, C. intricatus, Coleogyne ramosissima, Yucca brevifolia, Quercus gambelii, Q. turbinella, Q. john-tuckeri, Q. chrysolepis, Juniperus californica*, and bunch grasses *Hesperostipa comata, Festuca idahoensis, Pseudoroegneria spicata, Leymus cinereus (= Elymus cinereus),* and *Poa fendleriana*.

Overall Climate Change Vulnerability Score: Moderate

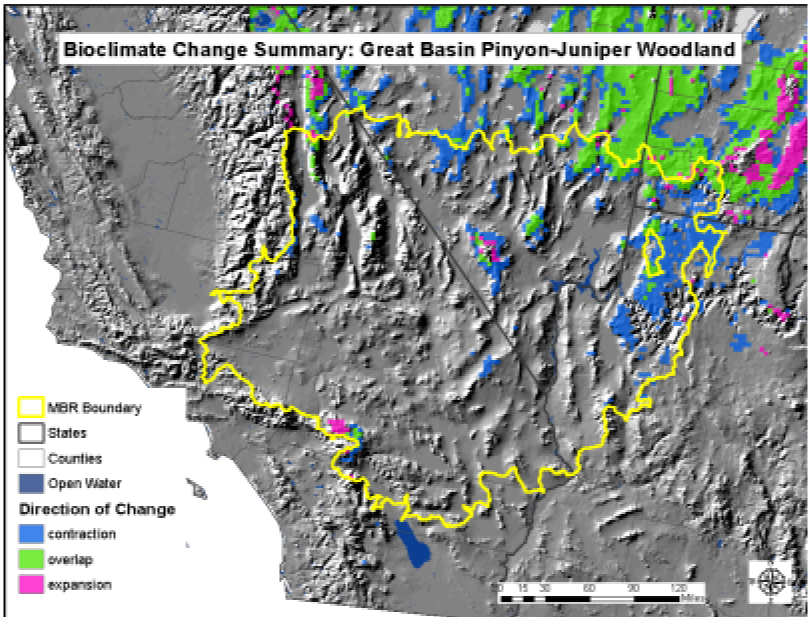
DIRECTS EFFECTS

Forecasted Climate Stress Index: Result **0.35 High Sensitivity**

For the distribution of this community type within the Mojave Desert, maximum temperatures in the months of July-September define this stress, with forecasted increases reaching 9 degrees F. The model results indicate that the Mean Maximum (daytime) Temperatures for July-August and Mean Minimum (night-time) Temperatures for June-September will increase by ~6 degrees F) for the majority of the Mojave Desert. The model results also indicate a 0.9 inch (0.3-3.0) increase in mean precipitation in August for the Spring Mountains and other nearby ranges. This additional monsoonal moisture, if it occurs, will locally favor pinyon-juniper woodlands and other higher elevation communities.

Forecasted Climate Envelope Shift Index: Result **0.17 High Sensitivity**

This indicates that a limited shift in the current climate envelope which suggests potential movement of species from pinyon-juniper woodland into higher elevation montane woodlands and potential invasion of species from Mojave mid-elevation desert scrub into current PJ stands.



Dynamic Process Forecast
Fire Regime Departure Index 2060: Result **0.49 High Sensitivity**
Currently, the fire regime of this community is significantly departed from natural conditions (e.g., from introduced invasive species, uncharacteristic successional states), but is predicted to be slightly less departed in 2060 within this ecoregion.

INDIRECT EFFECTS

Landscape Condition 1960: Result **0.9 High Resilience**
In 1960, the ecological impacts of urbanization (conversion) had begun. Impacts from the transportation system (fragmentation) consisted of a several highways and railroad lines and a sparse network of unimproved roads. Major economic activities with ecological impacts were mining (high intensity localized disturbance), and cattle ranching (low intensity, widespread disturbance).

Landscape Condition 2010: Result **0.76 High Resilience**
For the Mojave Desert, a 90m spatial grid with 0.0 -1.0 scores of landscape-level effects of land conversion (intensity and distance from impact) was overlain on the current distribution of the community; the average per-pixel score provides a relative index. Current ecological impacts from transportation (fragmentation), mining (high intensity localized disturbance), cattle ranching (low intensity, widespread disturbance), and recreation use (ORVs) has also increased.

Invasive Species Effects 1960: Result **0.8 High Resilience**
Building upon spatial model results for current conditions, a review of literature and historical maps supported a relative expert estimate. Invasive, non-native plant species such as annual red brome grass (*Bromus rubens*) was invading much of the Mojave Desert largely introduced from historic cattle grazing. Lower elevation occurrences of PJ woodlands would likely have been affected.

Invasive Species Effects 2010: Result **0.65 Medium Resilience**
The spatial model suggests a massive expansion of introduced, non-native plant species since 1960, now effecting as much as 35% of the current distribution; primarily at its lower elevations.

Dynamic Process Alteration
Fire Regime Departure Index 2010: Result: **0.35 Low Resilience**

Currently, the fire regime of this community is significantly departed from natural conditions (e.g., from introduced invasive species, uncharacteristic successional states), but is predicted to be slightly less departed in 2060 within this ecoregion.

ADAPTIVE CAPACITY

Diversity within Plant/Animal Functional Group: Result **0.5 Moderate Resilience**
Additional work is needed to specify functional groups for pinyon-juniper woodlands, especially as they occur within the Mojave Desert. A moderate rating should be viewed as preliminary (low confidence).

Keystone Species Vulnerability: Species were tentatively identified as those that could likely have cascading ecological impacts on community function. Once selected a climate change vulnerability index was scored for their distribution within the ecoregion. Categorical scores were transformed to a 0.0 – 1.0 scale and averaged together for an overall index score. Result **0.9 High Resilience**

Singleleaf Pinyon (*Pinus monophylla*) (0.7 Medium)
This species might be moderately vulnerable (with moderate confidence) to climate change in the region, mainly due to proposed changes in moisture availability, land use changes by humans in response to climate change, and potential effects of climate change on seed dispersers. The species may expand its range within the assessment area, potentially because proposed hydrological changes do not deviate as extremely in this particular assessment area.

Utah juniper (*Juniperus osteosperma*) (1.0 High)
This species might be potentially stable (with high confidence) despite climate change effects, although land use changes by humans in response to climate change may increase vulnerability. The potential stability may result from the high genetic variation in populations and the dependence for seed dispersal less on bird species and more on mammals potentially less affected by climate change.

Pinyon mouse (*Peromyscus truei*) (0.7 Medium)
This species may be moderately vulnerable to climate change in the assessment region, due primarily to effects of projected changes in moisture availability and the species' high degree of dependence on one or two plant species that likely are vulnerable to climate change in the assessment region.

Pinyon jay (*Gymnorhinus cyanocephalus*) (1.0 High)
Although this species is a good disperser and associated with common geological features or derivatives, it is highly dependent on just one plant species (pinyon pine) for habitat and food, and that plant may be highly vulnerable to climate change within the assessment region.

Bioclimate Variability: Result **0.9 High Resilience**
This type occurs in a high number of isobioclimates (18/20) which is expected for a widespread type.

Elevation Belts: Result **0.5 Moderate Resilience**
Number of 500' (152 m) elevation belts that encompass the type distribution is 6 of12).

Ecosystem Stressor Worksheet: Pinyon - Juniper- Non-Climate Stressors

Non-Climate Stressor	Current Scope	Current Severity	2060 Climate Scenario	Description	Mgmt Opportunity
Altered fire regime Rank 1	high	med	Increased summer temp, possible summer moisture		High for prescribed fire or mechanical treatments

Non-Climate Stressor	Current Scope	Current Severity	2060 Climate Scenario	Description	Mgmt Opportunity
			through storms		
Deforestation (cutting) Rank 3	med	med		CC may increase conversion to grassland	
Livestock grazing Rank 5	high	med			Same as above
Invasive annual grasses Rank 2	high	high			Same as above
N deposition, ozone Rank 4					
Insects, disease Rank 3				Cc affects stand density from drought stress	High for Thinning or pheromone work based on research

Ecosystem Stressor Worksheet: Pinyon - Juniper- Climate Stressors

Climate Stressor	Current Scope	Current Severity	2060 Climate Scenario	Description	Mgmt Opportunity
Local lower production of fine fuels in extremely hot areas			Increased summer temp, possible summer moisture through storms	In extreme areas carbon sequestration may increase	
Increased lightning strikes from more August storms					

Management Goals for communities:
NPS: fire management to maintain natural system,
FWS: maintain pinyon jay habitat, water development for game species
USFS: Recreation opportunities
BLM: maintain healthy vegetation communities, properly functioning in all habitats

Potential Climate Change Adaptation Strategies

"No-regrets" actions to take within the next 5 years:

- Fine fuel reduction (exotic annual grass control) and fire suppression in this fire sensitive system.

- Planning to maintain contiguous natural blocks
- Aggressive prevention and control of invasive plant species

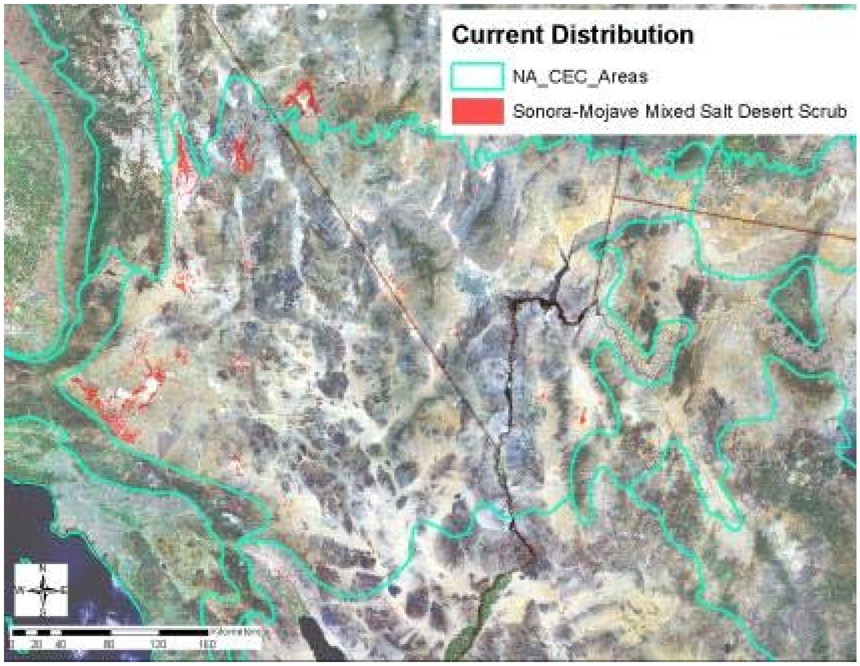
Anticipated actions over the coming 5-15 years:

- Aggressive management of wildland fire
- Substantial die-off from drought and/or interacting pest infestation

"Wait and watch" actions: Potential actions to anticipate over the 15-30 timeframe, with indicators to monitor and inform that future decision

- Increasing fire ignition with drought years, and expanding fire patch size
- Increased densities of invasive plant populations at higher elevations.
- Plant species invasion from mid-elevation desert scrub
- Expansion of PJ species into adjacent, higher elevation shrublands

Mojave Desert - Sonora-Mojave Mixed Salt Desert Scrub



CONCEPT

This ecological system includes extensive open-canopied shrublands of typically saline basins in the Mojave and Sonoran deserts; typically up to 2400m elevation. Stands most often occur around playas and in valley bottoms or basins where evapo-transpiration results in saline soils. Soils are generally fine-textured. Vegetation is typically composed of facultatively deciduous xeromophic shrubs, typically composed of one or more *Atriplex* species, such as *Atriplex canescens* or *Atriplex polycarpa, or Kraschenninnikovia lanata*., such as *Atriplex polycarpa*. *Opuntia* cacti may also be common. Species of *Allenrolfea, Salicornia, Suaeda, Kraschenninnikovia lanata*, or other halophytic plants are often present to codominant. A sparse to moderately dense graminoid layer may include *Sporobolus airoides* or *Distichlis spicata* at varying densities. Forb cover is generally sparse, but annual forbs may be abundant in wet years. Conversion to agriculture and/or grazing have been among the most significant stressors on salt desert scrub.

Overall Climate Change Vulnerability Score: Moderate

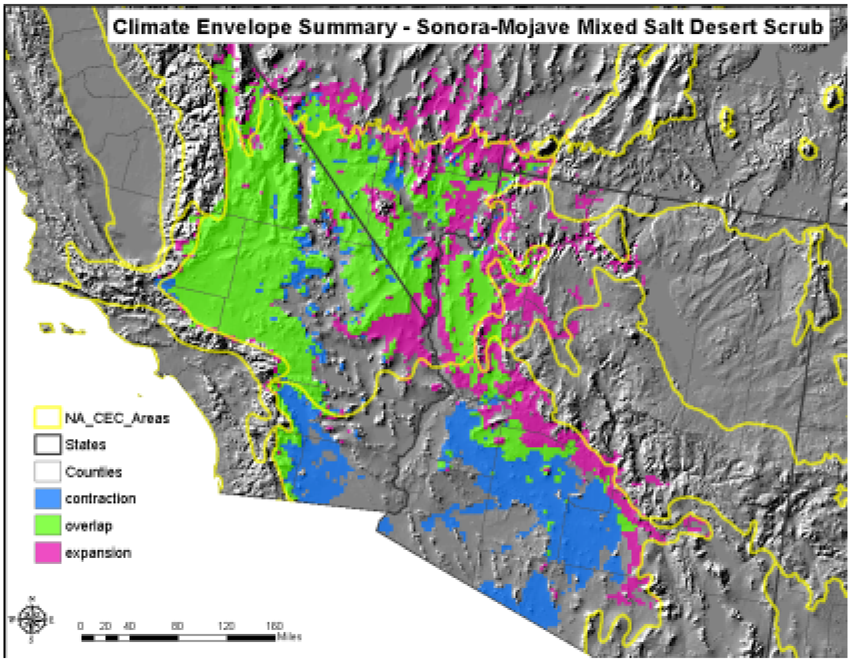
DIRECTS EFFECTS

Forecasted Climate Stress Index: Result **0.35 High Sensitivity**

For the distribution of this community type within the Mojave Desert, maximum temperatures in the months of July-September define this stress, with forecasted increases reaching 9 degrees F. The model results indicate that the Mean Maximum (daytime) Temperatures for July-August and Mean Minimum (night-time) Temperatures for June-September will increase by ~6 degrees F) for the majority of the Mojave Desert. The increased aridity from additional evapo-transpiration will likely cause decline in vegetation cover especially at the lower, hotter elevation sites. There is potential for increased precipitation in August. Cryptobiotic crusts are vulnerable to wetting without time to recuperate carbohydrate losses.

Forecasted Climate Envelope Shift Index: Result **0.91 Low Sensitivity**

This indicates that a limited shift in the current climate envelope which suggests minor potential movement of species from this community into the adjacent desert scrub communities such as creosotebush dominated desert scrub. However, most saltbush desert scrub is limited to fine-textured, saline substrates, so likely the density of saltbush in more arid stands will decline rather that significant conversion to other types.



Fire Regime Departure Index 2060: Result **0.48 Moderate Sensitivity**
This indicates that community is currently significantly departed from natural condition (introduced invasive species, fire regime), but is predicted to be less departed in 2060.

INDIRECT EFFECTS

Landscape Condition 1960: Result **0.9 High Resilience**
In 1960, the ecological impacts of urbanization (conversion) had begun. Impacts from the transportation system (fragmentation) consisted of a several highways and railroad lines and a sparse network of unimproved roads. Major economic activities with ecological impacts were mining (high intensity localized disturbance), cattle ranching (low intensity, widespread disturbance), and military training and development near Las Vegas.

Landscape Condition 2010: Result **0.72 High Resilience**
Current urbanization (conversion) has in the increased dramatically since 1960. Current ecological impacts from transportation (fragmentation), mining (high intensity localized disturbance), cattle ranching (low intensity, widespread disturbance), and recreation use (ORVs) has also increased.

Invasive Species Effects 1960: Result **0.8 High Resilience**
Invasive, non-native plant species such as annual grasses *Bromus rubens* and *Schismus barbatus* were invading much of the Mojave Desert largely introduced from historic cattle grazing.

Invasive Species Effects 2010: Result **0.54 Moderate Resilience**
Model suggests a massive expansion of introduced, non-native plant species since 1960. Invasion of non-native grasses have also increased fire frequency and led to destruction of fire sensitive desert scrub.

Fire Regime Departure Index 2010: Result: **0.26 Low Resilience**
This indicates that community is currently significantly departed from natural condition (introduced invasive species, fire regime), but is predicted to be less departed in 2060.

ADAPTIVE CAPACITY

Diversity within Plant/Animal Functional Groups: Result **0.7 High Resilience**
The key functional group is characteristic dominant species that are tolerant to high salinity. The diversity of species is low to moderately at 6-10 species.

Keystone Species Vulnerability: Result: **1.0 High Resilience**
Allscale (*Atriplex polycarpa*): (1.0 High)
This species might not be vulnerable (with high confidence) to climate change effects in the region. This species has the widest range of salt tolerance of saltbush in the Mojave Desert and occurs across many geographic and elevational gradients.

Fourwing saltbush (*Atriplex canescens var angustifolia*): (1.0 High)
This species might not be vulnerable (with high confidence) to climate change effects in the region. This species has been called the most adaptable shrub in North America and is salt, cold, and drought resistant, and shows extreme genetic diversity across geographic and elevational gradients.

Bioclimate Variability Result **0.7 High Resilience**
Mojave Desert scrub is dependent on highly variable winter precipitation. This type occurs in a moderate number of isobioclimates (13/20), which is expected for a substrate defined type.

Elevation Range: Result **0.8 High Resilience**
This salt desert scrub occurs in a relatively high number of elevation belts. The number of 500ft (152m) elevation belts that encompass the type distribution is 9 of 12. **NOTE:** Current maps may be overestimating the extent of salt desert scrub.

Ecosystem Stressor Worksheet: Saltbush - Non-Climate Stressors

Non-Climate Stressor	Current Scope	Current Severity	2060 Climate Scenario	Description	Mgmt Opportunity
Renewable energy ranked 1	M	H	Increased summer temp, possible summer moisture through storms	Possibly CC will increase renewable energy depending upon public policy? Unknown outcomes as technology, policy choices, etc., may change unpredictably. Reduced water flow and redirected hydrology might produce locally more or less vegetation outside of installations. Microclimate changes may result from large-scale installation (increased shading, greater reflectance).	High for developing specific mitigations for each project.
grazing ranked 2	M	H		CC might decrease grazing after a short increase. Initial increase from moderate increase	High for closer manageme

Non-Climate Stressor	Current Scope	Current Severity	2060 Climate Scenario	Description	Mgmt Opportunity
				of precip will push for higher stocking rates. Cc might make recovery from grazing slower.	nt of intensity.
OHV Ranked 3	M	H		No CC interaction (see also dunes)	
Nitrogen deposition, ozone Ranked 4	M	H		Not easy to predict, policy dependent. What happens with rainfall will determine effects of cc on N deposition. Increased rainfall might spike N-induced fertility that favors invasive weeds; reduced rainfall (esp. early winter) might suppress benefits of N-induced fertility that would otherwise promote invasive weeds.	Low
ozone ranked 5				Warmer air temperatures may accelerate ozone reactions and lengthening the time of impact (season) on plant tissues, thus reducing plant growth, seed set, etc.	

Ecosystem Stressor Worksheet: Climate Stressors

Climate Stressor	Current Scope	Current Severity	2060 Climate Scenario	Description	Mgmt Opportunity
salinization	low			Salinity levels could get so high as to decrease vegetation. Reduced rainfall would create greater soil evaporation depositing more salts in upper soil layers that reduced rainfall would not be able subsequently to transport salts deeper into	low

				the soil. Salinity might increase so that species shifts to the most salt-tolerant chenopod species (e.g., *Allenrolfea* – reducing the species diversity of plants in salt desert scrub)	
El nino , la nina monsoon	med			May increase production of weedy species in intensified El Nino winters (e.g., 2005) that in turn increase fine fuels in this habitat (native saltgrass, non-native grasses).	Moderate for planning weed suppression after high rain season
Invasion into other veg types	low			This type may invade other veg types because these plants can live in high salinity soils under moderate salinization – assuming that salinity will increase in vegetation types adjacent to mixed salt desert scrub	Protect connectivity to facilitate species movement

Management Goals for communities:
FWS: protect ash meadows species (all trust resources)

Potential Climate Change Adaptation Strategies

"No-regrets" actions to take within the next 5 years:

- Manage/control all impacts of groundwater use – specific to salt desert scrub, dries out causing PM10 dust from playas
- Fine fuel reduction (exotic annual grass control) and fire suppression in this fire sensitive system.
- Closer management of grazing intensity
- Planning and restoration to build larger, contiguous natural blocks
- Aggressive prevention and control of invasive plant species

Anticipated actions over the coming 5-15 years:

- Aggressive management of wildland fire

"Wait and watch" actions: Potential actions to anticipate over the 15-30 timeframe, with indicators to monitor and inform that future decision

- Increasing fire ignition with drought years, and expanding fire patch size
- Increased densities of invasive plant populations at higher elevations.
- Decreasing vegetation density and transformation into desert pavement.

Mojave Desert - North American Warm Desert Active and Stabilized Dune

CONCEPT

This ecological system occurs across the warm deserts of North America and is composed of unvegetated to sparsely vegetated (generally <10% plant cover) active dunes and sandsheets and small patches of vegetation on stabilized dunes and sandsheets. The system is defined by the presence of migrating dunes or, where the dunes are entirely anchored or stabilized, evidence that the substrate is eolian and not residual and that the substrate is likely to become actively migrating again with disturbance or increased aridity. There are also smaller, active and partially vegetated dunes along some of the larger washes and on sides of playas and basins (where sand is blown out of a wash or basin and forms dunes) and some larger dunes, but many of the larger dunes were formed during the Pleistocene when sand was blown from large drying lake basins into dunes. Within a dunefield some dune species are typical of active sand, such as *Croton wigginsii, Eriogonum deserticola, Palafoxia arida var. gigantea, Panicum urvilleanum*, and *Petalonyx thurberi*, while others are common on stabilized dunes, such as *Pleuraphis rigida, Psorothamnus emoryi, Tiquilia palmeri*, and scattered *Larrea tridentata*. Dune "blowouts" and subsequent stabilization through succession are characteristic processes.

Overall Climate Change Vulnerability Score: Moderate

DIRECTS EFFECTS

Forecasted Climate Stress Index: Result **0.35 High Sensitivity**

For the distribution of this community type within the Mojave Desert, maximum temperatures in the months of July-September define this stress, with forecasted increases reaching 9 degrees F. The model results indicate that the Mean Maximum (daytime) Temperatures for July-August and Mean Minimum (night-time) Temperatures for June-September will increase by ~6 degrees F) for the majority of the Mojave Desert. The increased aridity from additional evapo-transpiration will likely cause decline in vegetation cover especially at the lower, hotter elevation sites, such as in all desert dunes.

INDIRECT EFFECTS

Landscape Condition 1960: Result **0.9 High Resilience**

In 1960, the ecological impacts of urbanization (conversion) had begun. Impacts from the transportation system (fragmentation) consisted of a several highways and railroad lines and a sparse network of unimproved roads. Major economic activities with ecological impacts were mining (high intensity localized disturbance), cattle ranching (low intensity, widespread disturbance), and military training and development near Las Vegas.

Landscape Condition 2010: Result **0.77 High Resilience**
Current urbanization (conversion) has in the increased dramatically since 1960. Current ecological impacts from transportation (fragmentation), mining (high intensity localized disturbance), cattle ranching (low intensity, widespread disturbance), and recreation use (ORVs) has also increased dramatically.

Invasive Species Effects 1960: Result **1.0 High Resilience**
Invasive, non-native plant species such as annual grasses *Bromus rubens* and *Schismus barbatus* were invading much of the Mojave Desert largely introduced from historic cattle grazing, but were of very limited significance in these communities at that time.

Invasive Species Effects 2010 : Result **0.54 Medium Resilience**
Model results suggest a massive expansion of introduced, non-native plant species since 1960.

ADAPTIVE CAPACITY

Diversity within Plant/Animal Functional Groups: Result **0.9 High Resilience**
In this system the key processes are dune stabilization and nitrogen fixation. Stabilizing dunes is critical to providing habitats for sand loving plants and animals. Destabilization of vegetated dunes has been linked to periods of extended drought (Foreman et al. 2006). Early seral dune stabilization species in Mojave desert include taxa that are typically stoloniferous grasses (*Panicum urvilleanum*, *Swallenia alexandrae*) or annuals such as *Abronia villosa*, *Argemone corymbosa*, *Astragalus lentiginosus, Camissonia claviformis, Chamaesyce ocellata, Cleome sparsifolia, Crytantha angustifolia, Dicorea canescens, Eriogonum inflatum, Gilia latifolia var. latifolia, Heliotropium convolvulaceum, Lupinus shockleyi, Oenothera deltoides, and Palafoxia arida* (Keeler-Wolf 2007). Later seral species help maintain stabilized condition, many are dune endemics with adaptions to burial and excavation, but may include wider ranging species such as *Atriplex canescens*, *Larrea tridentata*, *Pleuraphis rigida*, and *Prosopis glandulosa*, especially on the outer perimeters of dunefields (Bowers 1984, Keeler-Wolf 2007). Introduced annual, *Salsola tragus* is prominent in some dune systems.

Diversity of annual and early seral species in the dune stabilization functional group is variable, but is generally high for most Mojave dune systems. Estimates of 39 characteristic taxa are listed in Bowers (1984) for Kelso and Eureka Dunes. Diversity of characteristic dominant species in the dune stabilization functional group is moderately high = 0.9.

Many of these species form symbiotic relationships with nitrogen-fixing bacteria, which is an important ecological process in this N deficient system. These species include *Achnatherum hymenoides* , *Aristida purpurea, Astragalus lentiginosus, Hesperostipa comata, Lupinus arboreus, Psoralidium lanceolatum,* and *Psorothamnus polydenius* (Bowers 1982). Diversity of species in nitrogen-fixing functional group is variable, but is generally moderate for most Mojave dune systems.
Estimates 7 nitrogen-fixing species listed from Bowers (1982) is moderately high = 0.9.

Keystone Species Vulnerability: Result **0.75 High Resilience**
Desert kangaroo rat (Dipodomys deserti) (0.7 Medium)

This species may be moderately vulnerable to climate change in the region, due primarily to effects of projected changes in moisture availability, possible land use changes resulting from human responses to climate change, and the species' dietary and substrate specializations.

Desert panicgrass (Panicum urvilleanum) (0.8 High)
This species does not appear to be vulnerable to climate change in the region. It forms a sparse cover and begins to stabilize open dunes and sand deposits. Aeolian processes disturb it rather than fire. It diminishes under drought conditions.

Bioclimate Variability Result **0.4 Low Resilience**
This type occurs in a lower number of isobioclimates (8/20).

Elevation Range: Result **0.3 Low Resilience**
Number of 500ft (152m) elevation belts that encompass the type distribution is 4 of 12.

Ecosystem Stressor Worksheet: Dunes - Non-Climate Stressors

Non-Climate Stressor	**Current Scope**	**Current Severity**	**2060 Climate Scenario**	**Description**	**Mgmt Opportunity**
ATVs All same rank	low	high		Neutral: ATV recreation will depend on fuel prices and people's discretionary income (related to employment level of ATV/OHV) riders. Riders frequently ride at night in hyper arid/hot areas such as the Imperial Sand Dunes (Sonoran Desert) and are often undeterred by heat. New technology may be available that avoids impacts to the natural environment and reduces consumption of fossil fuels.	Low for management intervention, High for law enforcement
Stabilization by invasive annual grasses All same rank	low	high		Will increase if increased precip in winter Increased dune stabilization will be a disadvantage to Mojave Fringe-toed Lizard and endemic dune invertebrates. If winter precip decreases, bromes may decline. If summer precip increases with high temps, C4 grasses including fountain grass	High for identifying places to protect in future.

Non-Climate Stressor	Current Scope	Current Severity	2060 Climate Scenario	Description	Mgmt Opportunity
				may increase in the Mojave Desert. Native C4 grasses may benefit if grazing is reduced.	
Changes in accretion due to river diversion/development and sand transport issues All same rank	low	med		Sand transport in desert rivers may decline as rains and stream flows are reduced. Inputs to mobile dunes will decline; thus degrade Mojave Fringe-toed Lizard habitat.	Moderate for manipulated river systems. Low for Aeolian dunes.

Ecosystem Stressor Worksheet: Tree - Dunes- Climate Stressors

Climate Stressor	Current Scope	Current Severity	Description	Mgmt Opportunity
Water flow (low lake level)	M	M	Groundwater under dunes may drop as recharge from the Mojave River declines. Mesquite coppice stands in dunes will have less access to water; their growth will decline; suitable habitat for Lucy's Warblers. Groundwater under dune ecosystems near solar energy installation (e.g., Palen Dunes in the Chuckwalla Valley CA) will drop as water is diverted for solar installation maintenance.	Water flow (low lake level)
Mobility – air transport of sand – impacts communities			If temps increase and precip decreases, veg will grow less quickly, impacts of herbivory will be more severe. Veg cover will decline. Dunes will become more mobile (good for Fringe-toed Lizards) but not so good for quality of life in communities near dunes as sandstorms may become more frequent and severe.	Mobility – air transport of sand – impacts communities

Management Goals for communities:
NPS: maintain natural system, minimal development, not impair resource, active T&E and rare species management, reduce carbon footprint, same for all ecosystems, low impact recreation is provided for in all habitats
FWS: overall goal is to conserve species and natural functioning, avoid impacts in wilderness, esp. dune endemics, work with land management agencies in partnership for all habitats
BLM: maintain healthy vegetation communities, properly functioning, sustainable motorized recreation in CA, renewable energy in salt desert scrub and creosote. Multiple-objective management in national landscape conservation system.
Military lands: military goals often trump conservation goals.

Potential Climate Change Adaptation Strategies

"No-regrets" actions to take within the next 5 years:

- Closer management of ORV usage and grazing intensity in surrounding landscapes
- Planning and restoration to build larger, contiguous natural blocks of natural vegetation surrounding current dune fields
- Aggressive prevention and control of invasive plant species into dune fields

Anticipated actions over the coming 5-15 years:

- Aggressive management of wildland fire

"Wait and watch" actions: Potential actions to anticipate over the 15-30 timeframe, with indicators to monitor and inform that future decision

- Decreasing vegetation density, expansion of dune blowout size and frequency, and transformation into greater proportional area of active dunes.

North American Warm Desert Riparian Woodland, Shrubland and Stream

CONCEPT

This ecological system consists of low-elevation (<1200 m) riparian corridors along medium to large perennial streams throughout canyons and desert valleys of the southwestern United States and adjacent Mexico. Major rivers include the lower Colorado (into the Grand Canyon), Gila, Santa Cruz, Salt, lower Rio Grande, and the lower Pecos.The vegetation is a mix of riparian woodlands and shrublands. Dominant trees include *Acer negundo, Fraxinus velutina, Populus fremontii, Salix gooddingii, Salix lasiolepis, Celtis laevigata var. reticulata, Platanus racemosa*, and *Juglans major*. Shrub dominants include *Salix geyeriana, Shepherdia argentea*, and *Salix exigua*. Woody vegetation is relatively dense, especially when compared to drier washes, and phreatophytes draw alluvial groundwater from below the streambed elevation when surface flows stop. Alluvial groundwater levels depend on seasonal precipitation and runoff, and on basin-scale hydrogeology including connections between the alluvial aquifer and surrounding basin-fill and bedrock aquifers. Vegetation depends for growth and reproduction upon annual or periodic flooding and associated sediment scour and/or on annual rise in the water table, with this rise driven by precipitation. The system thus depends on both surface and groundwater regimes, and is sensitive to changes in both.

Overall Climate Change Vulnerability Score: High (Mojave Desert)
Overall Climate Change Vulnerability Score: High (Sonoran Desert)

DIRECTS EFFECTS

Forecasted Climate Stress Index: Mojave Desert Result **0.35 High Sensitivity**
Sonoran Desert Result **0.45 High Sensitivity**

Sonoran Desert may warm by, on average, 2-4 degrees F; whereas the Mojave Desert is predicted to have a 4-9 degree F increase. Precipitation is less predictable. If precipitation increases significantly, this may change the timing or magnitude of peak and low stream flows which may be beneficial to some species and detrimental to others. Given the higher probability of warming, the stress on component species is high for drought and heat intolerant species. With the higher uncertainty on how precipitation may change, it is difficult to rate the stress this may have on this ecosystem. The direct effect on the hydrologic regime is considered separately.

Dynamic Process Forecast
Hydrologic and Fire Regime Change 2060: Mojave Desert Result **0.3 High Sensitivity**
Sonoran Desert Result **0.3 High Sensitivity**

Current and forecasted trends—Both deserts have potential for moderate increases in precipitation in July and August months; although some models show a decrease or no change in the amount of moisture. The latter could result in:

- **higher evapo-transpiration rates** leading to an earlier, more rapid seasonal drying-down of stream/riparian communities;
- **increased water stress** in nearby basin-floor phreatophyte communities (e.g., Mesquite Bosque), and later, less frequent, briefer wetting of nearby playas;
- **shrinkage of areas of perennial flow/open water**, coupled with higher water temperatures at locations/times when water temperatures are not controlled by groundwater discharges or snowmelt;
- **persistence of these hydrologic conditions later** into the fall or early winter; and
- **reduced groundwater recharge** in the mountains and reduced recharge to basin-fill deposits along the mountain-front/basin-fill interface.

→ Where <u>increases</u> in precipitation, especially in July and Aug, might occur this may result in:

- Increased soil erosion from increased surface flows, which may negatively impact water quality
- Increased stream flow magnitude in summer time
- No change as these results from Sonoran are not compared to historic variation in precipitation

Increased fire frequency and intensity in the watersheds of these systems will have enormous post-fire effects on riparian systems.

- *Increased* winter precipitation causes increased fire in low/mid elevation shrublands, which causes decreased short-term evapotransporation. This leads to increased groundwater recharge, which increases post-fire runoff, changing riparian geomorphology and water chemistry.
- Long-term *decreased* precipitation (e.g., drought) causes increased fire in woodlands and forests, which causes decreased evapotransporation. This leads to increased groundwater recharge, which increases post-fire runoff, changing riparian geomorphology and water chemistry.
- Example 1: Mogollon Rim. Decreased precipitation caused increased fire intensity/size/frequency, which led to increased post fire watershed effects to downstream riparian and spring systems.
- Example 2: Increased August precipitation in high-elevation woodlands caused increased intensity post-fire watershed events following June fires.

Fires also have direct effects on these systems, changing water chemistry, increasing invasive spp. spread, and increasing inflammability.

Primary concerns include:

- **Increased flammability** due to tamarisk and fountain grass causes increased fire frequency and fuel continuity, which results in changes in species composition and structure.
- Many of the hydrological regime changes could be exacerbated by fire.
- Compounding effects of in situ climate change on **post-fire regeneration of dominant species** (e.g., mesquite regeneration by seed germination).

<u>INDIRECT EFFECTS</u>

Landscape Condition 1960: Mojave Desert Result **0.6 Medium Resilience**
Sonoran Desert Result **0.6 Medium Resilience**

Ample evidence suggests Native American impacts in the Salt/Gila basin from their own irrigation systems. Ranching and farming have been drawing groundwater and diverting surface water from the relevant streams/rivers since the late 1800s. Maps of the extent of perennial flow in Arizona, for example, show a drastic decline that started in the late 1800s, due to diversions and groundwater withdrawals. Physical collapse of basin-fill aquifers due to the groundwater removal, date to the mid-1900s; along with the effects of domestic livestock grazing. This would have significantly altered the distribution of this community type, greatly reducing its extent.

Landscape Condition 2010: Mojave Desert Result **0.4 Low Resilience**
Sonoran Desert Result **0.4 Low Resilience**

The Sonoran Desert has a very similar footprint to the Mojave Desert with several large urban and agricultural areas along with many relatively unfragmented watersheds. Long-distance canals and impoundments feed water to urban areas and cause impacts from a great distance. There are also cumulative effects of groundwater withdrawals from ranches and numerous small towns. Intensive farming along the riparian corridors impact and fragment floodplains and remove riparian habitats. Riparian corridor areas are impacted by domestic livestock grazing that reduces bank stability and causes high soil erosion, channel widening and increased in-channel water temperatures. In addition there are watershed-scale impacts of domestic livestock grazing, including soil compaction and removal of runoff-retaining vegetation.

Invasive Species Effects 1960: Mojave Desert Result **0.5 Medium Resilience**
Sonoran Desert Result **0.7 High Resilience**

Historic cattle grazing introduced invasive plant spp. Late-19th -early 20th century. Deliberate introductions of tamarisk, Russian olive, and annual grasses in residential areas and grazing lands brought these species into riparian corridors.

Invasive Species Effects 2010: Mojave Desert Result **0.4 Low Resilience**
Sonoran Desert Result **0.5 Medium Resilience**

Current footprint of the extent of exotic species is incompletely mapped, however models of areas within the Unites States likely to contain significant amounts of tamarisk, Russian olive, and annual grasses indicate >50% of the riparian areas are affected. In addition, there are aquatic invasive species such as mollusks, non-native fish, bullfrogs and crayfish, which could completely change the aquatic food chain dynamics and eliminate native aquatic species.

Dynamic Process Alteration
Hydrologic Change 2010: Mojave Desert Result **0.4 Low Resilience**
Sonoran Desert Result **0.4 Low Resilience**

Agricultural and residential/urban use has dropped groundwater levels significantly, already reducing or eliminating many gaining reaches. This began in the late 1800s, and the effects were coupled with a climate-change episode and/or impacts of cattle grazing on watershed runoff (the debate is ongoing) that resulted in a period of significant channel downcutting during the 1930s across the Sonoran region. This resulted in the death of large riparian woodlands on what became hydrologically stranded elevated terraces, and re-establishment of the system on new lower terraces that the entrenched streams carved out.

ADAPTIVE CAPACITY

Diversity within Plant/Animal Functional Groups: Mojave Desert Result **0.8 High Resilience**
Sonoran Desert Result **1.0 High Resilience**

These communities include a variety of plant and animal life, from woody phreatophytes to warm season grasses, and freshwater and alkaline tolerant species. Within each functional group there are a moderate number of species such as several warm season grasses that are alkaline tolerant, several broad-leaf woody tree and shrub species although none are nitrogen fixers, and multiple nutritious forb species.

Keystone Species Vulnerability: Mojave Desert Result **1.0 High Resilience**

Sonoran Desert Result **0.85 High Resilience**

American Beaver (*Castor canadensis*) (*tbd, likely high***)**
This species plays an obvious 'keystone' role in stream and riparian ecosystems where they occur. They would only be expected to occur in the largest portions of this system along the eastern margins of the Sonoran Desert. Evaluation of their relative vulnerability to climate change within this ecoregion has yet to be completed.

The following two species were selected for their relative structural contributions to these communities, with cottonwoods forming primary tree canopy constituents, and indicative of functioning hydrodynamics. Gilded flicker was chosen due to its cavity-nesting behavior and related influence on other species habitat requirements.

Fremont's cottonwood (*Populus fremontii*) (1.0 High)
This species might be potentially stable (with high confidence) in the region despite climate change effects. This may be a result of high genetic variation in Fremont cottonwood that affects whole-tree physiological processes which help adapt a tree to its environment including whole-tree water use and also net primary productivity**.**

Gilded flicker (*Colaptes chrysoides*) (1.0 High)
This species exhibits characteristics that both increase and decrease its vulnerability to climate change, but overall it may not be vulnerable to climate change and might actually expand its range in the region. It relies heavily on a small number of species that are critical in providing suitable habitat, and land use changes resulting from human responses to climate change could affect it, but these may be overcome by the bird's good dispersal abilities and other aspects of its ecological versatility.

Bioclimate Variability:
Mojave Desert Result **0.8 High Resilience**
Sonoran Desert Result **0.8 High Resilience**
This community could occur throughout all local climate regimes that characterize the Mojave, Sonoran, and Chihuahuan deserts. This type occurs in a high number of isobioclimates (16/20).

Elevation Range:
Mojave Desert Result **0.6 Medium Resilience**
Sonoran Desert Result **0.6 Medium Resilience**
Type is limited to elevations <1200 m (3950 ft). This community occurs within a relatively narrow elevation range. Number of 500ft (152m) elevation belts that encompass the type distribution is 8 of 12.

Expert Workshop: Ecosystem Stressor Worksheet – Non-Climate Stressors

Non-Climate Stressor	Current Scope	Current Severity	2060 Climate Scenario	Description	Mgmt Opport unity
Human overpopulation -Recreation	H	H	Y	Hotter temps means that people will aggregate more in cool, wet places. Warming temps will make riparian areas more restricted, so recreation will be more concentrated.	M
-Land use change (development, energy, agriculture)			Y	Solar panels require lots of water for washing.	
-Surface water withdrawal			Y	Less water will remain in perennial streams due to increased evapotransportion.	
-Groundwater depletion			Y		
Non-native herbivorous ungulates	M	H	Y	Will concentrate more around water. Legal cattle grazing may decrease because increased temps may make the activity no longer economically viable.	M/L US/Mex
Fire and post-fire watershed effects	L /but increasing	H	Y	Increasing variability in precipitation will increase fire frequency.	M
Invasive species -plants -animals (includes honey bees)	H	H	Y	Dry conditions can promote the growth of invasives.	Variable (site and sp specific)
Water flow control (dams, aqueducts) – Mainstem (includes trans-basin transport of water, e.g., Col. Riv. water going to LA)	H	H	Y	Climate change will influence the activities and maintenance of dams, which will have an influence on downstream riparian communities.	L
Water flow control (dams, aqueducts) - Tributaries	H	H	Y	Same as for mainstem dams, but severity of the impact is greater.	M
Resource extraction (logging, mining)	L	H	N		H
Contamination/water quality	H	H	Y	Extreme storm events will wash more contaminants from urban areas and	H

Non-Climate Stressor	Current Scope	Current Severity	2060 Climate Scenario	Description	Mgmt Opportunity
				upper water sheds into riparian areas. Increased evapotransporation will lead to lower water levels and therefore greater concentrations of contaminants.	
Air Pollution/nitrate deposition & acid rain	M	L-M	Y	Higher temps can lead to greater dust deposition.	

Ecosystem Stressor Worksheet: Climate Stressors

Climate Stressor	Current Scope	Current Severity	2060 Climate Scenario	Description
Increased Water Temperature				Can be greater than physiological tolerances and therefore cause distributional shifts or contractions. Increase in metabolism and decrease in dissolved oxygen.
Increased in mean and maximum air temperature				Can be greater than physiological tolerances and therefore cause distributional shifts or contractions. Increase in metabolism. Increased evaporation and evapotransporation. Increase in stress to plants and therefore lower vigor. Can cause de-synchronization of interspecific events. Some springs/seeps may go dry.
Shift in timing of precipitation events.				Plant regeneration could be threatened if there are no spring rains.
Shift in intensity of precipitation events.				Runoff, plant response and insect hatches are all related to rain intensity.
Shift in amount of precipitation.				Influences hydrogeology that maintains these systems. Can cause increased sp-specific mortality. Some springs/seeps may go dry.
Increase in extreme events (freezes, floods, heat waves, droughts, wind, and combinations of these)				Can cause shift in species composition and structure of habitat. Can exacerbate other nonclimate stressors (such fire, invasives).
All Climate Stressors				climate events in watersheds beyond where these systems occur has a major influence on this system.

Context				These systems have many migratory species that are subject to climate and nonclimate stressors during other stages of their life cycle that take place beyond the watersheds addressed here.

Potential Climate Change Adaptation Strategies

Generalized strategies and notes:

-Protect and enhance riparian areas and the listed species that depend on them
-Create and manage 5 acres of riparian habitat for 17 species
-Preservation of remnant riparian areas to support migratory birds
-Protect upper watershed
-Reduce invasives
-Maintain biodiversity and processes (such as flooding)
-Maintain and enhance connectivity for fish
-Preserve scenery, water-based natural and cultural resources for public enjoyment
-Identify information needs of land managers, conduct research, and provide information
***expert work group had no fish advocate so didn't identify any fish-specific strategies, although we do suggest ways to restore riparian habitat that will in turn benefit fish.

"No-regrets" actions to take within the next 5 years:

- Water flow controls on tributaries
- Fully exercise water rights pertaining to protected lands (various legal mechanisms)
- Work with tribes to fully exercise water rights for mutual benefits.
- Work with agricultural water users to adjust timing and use of diverted water to benefit stream inflows.
- Explore management options for existing dams to maintain downstream riparian processes (e.g., controlled floods)
- Explore opportunities to manage return flows (e.g., stormwater, irrigation return, wastewater effluent) to benefit riparian resources and/or processes (geomorphology)
- Comprehensive aquifer mapping to better understand temporal and spatial connectivity between surface and groundwaters.
- Improve engineering practices for diverting/allocating flows to maintain more instream flow.
- Monitor surface flows and losses.
- Fix laws to better maintain instream flows.

Fire and invasives

- Increase resistance to fire by removing/controlling fire-tolerant invasive plants (e.g., buffle grass, tamarisk)
- Selectively transition riparian forest species composition to meet target conservation species while reducing fire hazard (eg, planting willow/cottonwood pockets to increase after tam beetle)
- Increase and maintain availability of plant propagules for restoration after fire/invasive species treatment (willow, cottonwood, grasses, others)
- Research drought and temperature tolerant genotypes for restoration.

- Education and management to prevent unplanned human ignitions in riparian and adjacent uplands
- Pre-plan post-fire response to minimize impacts of water impacts of watershed effects (EG debris flows, floatable debris, ask, etc) (site specific)
- Pre-plan for invasive species control and post treatment restoration (in general)
- Explore/research restoration techniques
- Monitor – ecological monitoring and treatment effectiveness to define baselines and implement adaptive management

Actions to anticipate over the coming 5-15 years:

- Manage water control structures at the system level to meet multiple demands (including instream flows).

"Wait and watch" actions: Potential actions to anticipate over the 15-30 timeframe, with indicators to monitor and inform that future decision:

Research and Monitoring Needs *(numbers refer to number of votes by participants indicating priorities)*

A. Invasives and restoration

-Modeling of spread through regions of greatest risk (with projected new climates)
-Invasive effects of system? (2)
-Feral animal impacts on systems
-Synergies, such as cattle/livestock grazing and bufflegrass and fountain grass invasions
-Identification of spring/seep species best for propagation and reintroduction
-Monitor treatment effectiveness (1)
-Monitor past disturbance restoration
-early invasion
-establishment of natives
-Research drought and temperature tolerant genotypes and species (1)
-Research restoration techniques to improve efficiency and effectiveness (6)
-How to improve restoration of agricultural lands to mesquite bosques
-Ecological monitoring to define baselines (1)

B. Hydrology

-Need for spatial information linking recharge zones with springs and riparian systems (3)
-Where are the aquifers and which springs are dependent on which aquifers (1)
-How does recharge effect aquifer levels (2)
-What makes particular springs or riparian areas more vulnerable to climate change
-Better groundwater monitoring
-Better general understanding of hydrological regimes (7)
-Explore management options for existing dams to maintain riparian processes
-Explore opportunities to manage return flows (e.g, stormwater, irrigation return, wastewater effluent) to benefit riparian resources and/or processes (geomorphology)
- Monitor surface flows and losses.
-Monitor flows, seasonality and temperature and water chemistry in springs. (1)
-How do we establish buffers around recharge areas?
-Inventory ephemeral drainages in mesquite systems (1)

C. Species traits

- Which species have the genetic diversity that make them better candidates for restoration in the context of climate change?

-What is the vulnerability of species at critical stages (e.g., seedlings) with increased climate variability? (5)
-Need more information about physiological temperature tolerances of key species. (3)
-Identify the species at risk that are especially vulnerable to climate change. (3)

D. Fire

-More information about the natural history of fire in all three systems

E. Keystone species

-Quantitative selection of keystone species? (5)
-Algae as keystone species for species and seeps?
-Need more thought on which keystone species to select.

F. Synchrony

-How precipitation and temperature influence phenology (identifying problem species) (3)

G. Identifying sensitive species

-Establish and maintain long-term monitoring of multi-species and community level variables so we will learn which species are sensitive and what the baseline normal variance is. (2)

North American Warm Desert Mesquite Bosque

CONCEPT

This ecological system consists of low-elevation (<1100 m) riparian corridors along perennial and intermittent streams in valleys of the warm desert regions of the southwestern U.S. and adjacent Mexico. Major U.S. river basins include the lower Colorado (within and downstream of the Grand Canyon), Gila, Santa Cruz, Salt, lower Rio Grande, Pecos, and their tributaries that occur in the desert portions of their range. More extensive examples occur throughout the Plains of Sonora, Mexico. Dominant trees include *Prosopis glandulosa*, *Prosopis pubescens*, and *Prosopis velutina*. Shrub dominants include *Baccharis salicifolia, Pluchea sericea*, and *Salix exigua*. Woody vegetation is relatively dense, especially when compared to drier washes. Vegetation, especially the mesquites, draw alluvial groundwater from below the streambed elevation when surface flows stop. Alluvial groundwater levels depend on seasonal precipitation and runoff, and on basin-scale hydrogeology including connections between the alluvial aquifer and surrounding basin-fill and bedrock aquifers. Vegetation depends upon annual rise in the water table for growth and reproduction, with this rise driven by precipitation. The system thus depends on both surface and groundwater regimes, and is sensitive to changes in both.

Overall Climate Change Vulnerability Score: High

DIRECTS EFFECTS

Forecasted Climate Stress Index: Mojave Desert Results **0.35 High Sensitivity**
Sonoran Desert Results **0.45 High Sensitivity**

Climate forecasts from an ensemble of downscaled global climate models are summarized for the period around 2050-2060. These forecasts indicate the relative degree of forecasted climate stress, using (in the Mojave Desert) a comparison of forecasts to 1900-1980 baseline conditions, or in the Sonoran Desert, forecasted change in temperature and precipitation between current and 2060. The Sonoran Desert may warm by, on average, 2-4 degrees F, whereas the Mojave Desert is predicted to have a 4-9 degree F increase. Sonoran species are already adapted to very high temps and even rapid changes in temperatures. Mojave species are also heat adapted, but not to the extreme temperatures that Sonoran species can tolerate. As a result, there may be different response in the northern part of the range, and species composition may shift as a result. Precipitation is less predictable. If precipitation increases significantly, this may change the timing or magnitude of peak and low stream flows which may be beneficial to some species and detrimental to others. Given the higher probability of warming, the *in situ* stress on component species is high for a drought and heat intolerant species. With the higher uncertainty on how precipitation may change, it is difficult to rate the *in situ* stress this may have on this ecosystem. The direct effect on the hydrologic regime is considered separately.

Dynamic Process Forecast
Hydrologic Regime Change

Hydrologic Regime Change 2060: Mojave Desert Result **0.3 High Sensitivity**
Sonoran Desert Result **0.3 High Sensitivity**

Current and forecasted trends—Both ecoregions have potential for moderate increases in precipitation in July and August months; although some models show a decrease or no change in the amount of moisture. The latter could result in:

- **higher evapotranspiration rates,** leading to an earlier, more rapid seasonal drawing-down of stream/riparian surface flows associated with an earlier, more rapid seasonal drawing-down in alluvial water table elevations – except along reaches where perennial flow is supported by deeper groundwater flow paths being forced to the surface by bedrock constrictions;
- **increased water stress** due to the combination of higher temperatures and lower water availability;
- **shrinkage of areas of perennial flow/open water**, leading also to higher water temperatures at locations/times when water temperatures are not controlled by groundwater discharges or snowmelt;
- **persistence of these hydrologic conditions later** into the Fall or early Winter;
- **reduced groundwater recharge** in the mountains and reduced recharge to basin-fill deposits along the mountain-front/basin-fill interface; and
- **possibly episodes of channel erosion and entrenchment associated with more intense monsoonal storms**, leading to stranding of bosque vegetation on higher terraces and their re-establishment at newer, lower terraces as the erosion cycle stabilizes.

→ Where <u>increases</u> in precipitation, especially in July and Aug, might occur, this may result in:

- Increased soil erosion from increase surface flows, which may negatively impact water quality
- Increased stream flow magnitude in summer time

Whether the predicted changes in precipitation are significant decreases or significant increases, either will likely cause significant change to hydrologic regimes, with increased water stress or changes in timing and magnitude of stream flows and groundwater rise and fall. For those reaches where deeper groundwater sustains the system, alterations to aquifer recharge on a basin scale will result in changes in perennial water availability that will become evident over time scales of decades to centuries.

Comments on how climate change interacts with fire regimes to influence riparian systems.

A. Fire in adjacent upland systems.

1) *Increased* winter precipitation causes increased fire in low/mid elevation shrublands, which causes decreased short-term evapotransporation. This leads to increased groundwater recharge, which increases post-fire runoff, changing riparian geomorphology and water chemistry.
2) Long-term *decreased* precipitation (e.g., drought) causes increased fire in woodlands and forests, which causes decreased evapotransporation. This leads to increased groundwater recharge, which increases post-fire runoff, changing riparian geomorphology and water chemistry.
3) Example 1: Mogollan Rim. Decreased precipitation caused increased fire intensity/size/frequency, which led to increased post fire watershed effects to downstream riparian and spring systems.
4) Example 2: Increased August precipitation in high-elevation woodlands caused increased intensity post-fire watershed events following June fires.

B. Fire in riparian areas and springs.

1) Increased flammability due to tamarisk and fountain grass causes increased fire frequency and fuel continuity, which results in changes in species composition and structure.

2) Many of the hydrological regime changes could be exacerbated by fire.
3) Compounding effects of in situ climate change on post-fire regeneration of dominant species (e.g., mesquite regeneration by seed germination).

INDIRECT EFFECTS

Landscape Condition 1960: Mojave Desert Result **0.7 High Resilience**
Sonoran Desert Result **0.7 High Resilience**

Ranching and farming have been drawing groundwater and diverting surface water from the relevant streams/rivers since the late 1800s. Maps of the extent of perennial flow in Arizona, for example, show a drastic decline that started in the late 1800s, due to all these diversions and groundwater withdrawals; and physical collapse of basin-fill aquifers due to the removal of so much groundwater date to the mid-1900s. Effects of intensive grazing have likely impacted these communities throughout the State of Sonora. All of this would have drastically altered the distribution of this ecological system, greatly reducing its extent.

Landscape Condition 2010: Mojave Desert Result **0.6 Medium Resilience**
Sonoran Desert Result **0.6 Medium Resilience**

The Sonoran Desert has very similar footprint with a of couple large urban and agricultural areas with many unfragmented watersheds. In addition, long-distance canals and impoundments feed the urban areas and cause extensive impacts from a great distance. There are cumulative effects of groundwater withdrawals from ranches and numerous small towns, and of farming along the riparian corridors, reducing floodplain habitat. Mesquite trees are logged for building lumber and for charcoal.

Invasive Species Effects 1960: Mojave Desert Result **0.5 Medium Resilience**
Sonoran Desert Result **0.7 High Resilience**

Historic cattle grazing introduced invasive plant spp. in the late-19th -early 20th century. Deliberate introductions of tamarisk, Russian Olive, fountain grass, and annual grasses in residential areas and grazing lands brought these species.

Invasive Species Effects 2010: Mojave Desert Result **0.5 Medium Resilience**
Sonoran Desert Result **0.5 Medium Resilience**

Current footprint of the extent of exotic species is poorly mapped, however models of areas likely to contain significant amounts of tamarisk, Russian olive, and annual grasses indicate >50% of the riparian areas are affected. Horse, burrow, and pig spread invasive plants spread invasive plants and compact soil, although cattle grazing can help control buffelgrass. In addition there are aquatic invasive species such as mollusks, bullfrogs, crayfish, and non-native fish that can completely change the aquatic food chain dynamics and eliminate native aquatic species.

Dynamic Process Alteration
Hydrologic Regime Change 2010: Mojave Desert Result **0.5 Medium Resilience**
Sonoran Desert Result **0.5 Medium Resilience**

Agricultural and residential/urban use has dropped groundwater levels significantly, already reducing or eliminating many gaining reaches. This began in the late 1800s, and the effects were coupled with a climate-change episode and/or impacts of cattle grazing on watershed runoff (the debate is ongoing) that resulted in a period of significant channel downcutting during the 1930s across the Sonoran region. This resulted in the death of large riparian woodlands on what became hydrologically stranded elevated terraces, and re-establishment of the system on new lower terraces that the entrenched streams carved out.

ADAPTIVE CAPACITY

Diversity within Plant/Animal Functional Group: Mojave Desert Result **0.6 Medium Resilience**
Sonoran Desert Result **0.6 Medium Resilience**

Mesquite Bosque has much lower plant species diversity, and fewer functional groups than the North American Warm Desert Riparian ecosystem. Several species are nitrogen fixers, and several species are broad leaved shrubs, but few species form the upper tree canopy.

Keystone Species Vulnerability: Mojave Desert Result **0.85 High Resilience**
Sonoran Desert Result **0.85 High Resilience**

Species were tentatively identified as those that could likely have cascading ecological impacts on community function. Once selected a climate change vulnerability index was scored for their distribution within the ecoregion. Categorical scores were transformed to a 0.0 – 1.0 scale and averaged together for an overall index score. *Note that screwbean mesquite (not treated here) is potentially the most vulnerable mesquite species because its root system extends only 1/3 as deep as the other mesquite species. Also note that some of the mesquites hybridize.*

Honey mesquite (*Prosopis glandulosa*): (1.0 High)
This species might be potentially stable (with high confidence) in the region despite climate change effects. This possible stability may result because this species is an aggressive spreader within its range and elevated carbon dioxide is expected to support further expansion.

Banner-tailed Kangaroo Rat (*Dipodomys spectabilis*): (0.7 High)
This species may be moderately vulnerable to climate change in the region, due primarily to effects of projected changes in moisture availability, possible land use changes resulting from human responses to climate change, the species' dietary specialization, and the existence of natural barriers that could limit the species' ability to shift its range with changing climate.

Bioclimate Variability: Mojave Desert Result **0.7 High Resilience**
Sonoran Desert Result **0.7 High Resilience**

This type is much more abundant in the southern portion of its range in Sonora MX than in Mojave Desert. This type occurs in a relatively high number of isobioclimates (14/20).

Elevation Range: Mojave Desert Result **0.7 High Resilience**
Sonoran Desert Result **0.7 High Resilience**

Type is limited to elevations <1100 m (3600 ft). But the number of 500ft (152m) elevation belts that encompass the type distribution is 6 of 12.

Ecosystem Stressor Worksheet: Mesquite Bosque - Non-Climate Stressors

Non-Climate Stressor	**Current Scope**	**Current Severity**	**2060 Climate Scenario**	**Description**	**Mgmt Oppor tunity**
Human Overpopulation -Recreation (not as important as for Riparian)	L	L	N (low)		H
Groundwater depletion	H	H	Y (high)	Continued or increased water withdrawal	M (-L)
Land use change (development, energy, ag)	Hi	H	Y (high)	Increased demand on water, conversion to agriculture; fragmentation reduces adaptability and other uses	M
Large non-native herbivores	H	H	Y (medium)	Concentration at more limited areas. Increased browsing and plant tolerance to browsing, increased variability in high ______	H
Fire and postfire watershed effects	H	M	Y (high)	Cause drying and changes in species composition within bisques. Also causes changes in species composition in upland communities. Regeneration after fire is affected by water availability.	M
Invasive species -plants -animals	M	M	Y (medium)	Buffle grass interacts with livestock. Honey bees can help spread diseases and compete with native bees.	M
Resource extraction (logging, mining)	H	H	Y(high)	Increased fragmentation, causing decreased adaptability.	H

Ecosystem Stressor Worksheet: Mesquite Bosque - Climate Stressors

Climate Stressor	Current Scope	Current Severity	2060 Climate Scenario	Description
Increased Water Temperature				Can be greater than physiological tolerances and therefore cause distributional shifts or contractions. Increase in metabolism and decrease in dissolved oxygen.
Increased in mean and maximum air temperature				Can be greater than physiological tolerances and therefore cause distributional shifts or contractions. Increase in metabolism. Increased evaporation and evapotransporation. Increase in stress to plants and therefore lower vigor. Can cause de-synchronization of interspecific events. Some springs/seeps may go dry.
Shift in timing of precipitation events.				Plant regeneration could be threatened if there are no spring rains.
Shift in intensity of precipitation events.				Runoff, plant response and insect hatches are all related to rain intensity.
Shift in amount of precipitation.				Influences hydrogeology that maintains these systems. Can cause increased sp-specific mortality. Some springs/seeps may go dry.
Increase in extreme events (freezes, floods, heat waves, droughts, wind, and combinations of these)				Can cause shift in species composition and structure of habitat. Can exacerbate other nonclimate stressors (such fire, invasives).
All Climate Stressors				climate events in watersheds beyond where these systems occur has a major influence on this system.
Context				These systems have many migratory species that are subject to climate and nonclimate stressors during other stages of their life cycle that take place beyond the watersheds addressed here.

<u>Management Objectives of Participant's Agencies</u>

Mesquite Bosque

-Create and manage 2500+ acres of mesquite

-Restoration of mesquite bosque tracts to support migratory birds

-Maintain mesquite bosque (is expanding on its own)

-Protect and maintain mesquite bisques for the benefit of federal trust species

-Preserve mesquite bisques for habitat values

-Identify information needs of land managers, conduct research, and provide information

Potential Climate Change Adaptation Strategies

"No-regrets" actions to take within the next 5 years:

- Restore in-channel waters,
- reduce domestic livestock grazing pressure,
- retire surface diversion and groundwater pumping permits, where these can be identified as affecting the stream and/or alluvial aquifer(s) of concern – sometimes well upstream of the occurrence(s) of concern. Transferring upstream diversion rights to downstream rights will also allow more water to be kept in-channel for longer reaches, but will still allow the water to be withdrawn elsewhere (downstream).
- Aggressively control invasive species.
- Protect a buffer zone for natural watershed vegetation around Mesquite Bosque sites, to minimize effects of storm runoff
- Take advantage of wastewater outflows to sustain/re-establish mesquite
- **Land-use changes**
    - County zoning
    - Conservation easements
    - Education
    - Effective law enforcement to prevent clearing (mesquite is protected in AZ, so it shouldn't be cleared)
    - Federal Lands (most agencies are not destroying mesquite). Restore old ag lands to mesquite. Use mesquite in flood control drainages
    - Better monitoring of water levels
    - Law enforcement

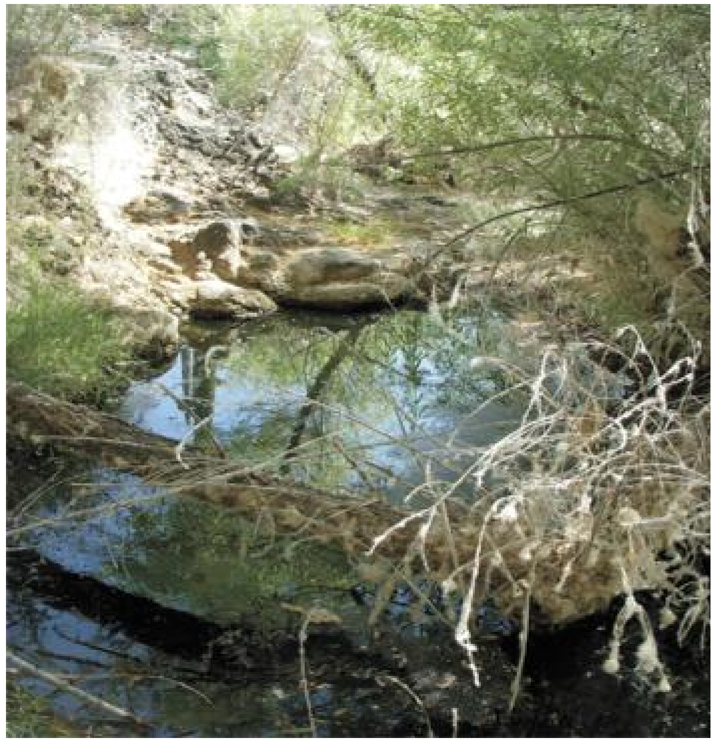
Anticipated actions over the coming 5-15 years:

- Restore agriculture lands to mesquite
- Better regulation of withdrawal
- Market the value of mesquite patches/parks in developments
- Tribal lands
- -Help with fire control and recreation control
- Public lands
- -State lands (currently their mission is to sell land to highest bidder). Need law change or limit development of sensitive areas, or restrict what buyers can do with mesquite habitats. (Anticipated Action)
- Increase capacity of culverts in anticipation of more frequent and more severe precipitation events, replace culverts and bridges that "pinch" the stream widths.
- Increase channel grade stabilization to prevent downcutting, if increased monsoonal runoff proves to be an accurate forecast.
- Protect recharge areas and their surface catchments to provide long-term insurance for continued recharge (effects may take decades to realize).
- Increased infiltration opportunities through soil and water conservation near bosque
- Plan communities and limit growth
- Retire or incentive withdrawal of water permits

"Wait and watch" actions: potential actions to anticipate over the 15-30 timeframe, with indicators to monitor and inform that future decision:

- Monitor for change in tree composition, as expansion of mesquite in washes and replacing Cottonwood or other broadleaf riparian areas may be expected.
- Continue to protect watershed and catchment surface areas.
- Novel invasive species may appear in the coming decades.
- Establish as water buffer basin

Mojave and Sonoran Springs and Seeps



CONCEPT

Springs (e.g., rheocrenes—springs that flow directly into and form a channel “spring brook”, limnocrenes- springs that flow into and form pools) and seeps (helocrenes—springs that form marshy areas or wetlands on flat or sloping ground without open bodies of water) within the Mojave and Sonoran deserts are unique ecosystems where groundwater reaches the Earth's surface. This ecosystem concept covers small springs and seeps and does not include Cienagas (covered by a separate system) or springs within river channels (covered by riparian systems). Springs and seeps are very distinct from other aquatic, wetland, and riparian ecosystems (Stevens et al. 2005). The geomorphology of springs and seeps often creates numerous microhabitats. Some springs are very small and isolated, while others have large outflows creating large spring pools and outflow creeks (Williams et al. 1985). Springs can range in flows from < 1 liter/minute to thousands of liters/minute. Highly endemic fauna occur in Mojave / Sonoran springs and seeps, including species and subspecies of fish and rare and uncommon described and undescribed springsnails (Fagan et al. 2002), many of which only occur in a single spring system. Mojave and Sonoran springs and seeps support plant species that contrast with surrounding desert vegetation such as columbine (*Aquilegia* spp.), monkey flower (*Mimulus* spp.), horsetail (*Equisetum* spp.), sedge (*Carex* spp.), orchids (e.g. *Spiranthes* spp., *Habinaria* spp.), cottonwood (*Populus* spp., and willow (*Salix* spp.).

Physical and chemical conditions, as well as connectivity among spring occurrences are the dominant factors influencing spring community biological composition (Levin and Flora 2008). These dominant factors in turn are strongly influenced by the elevations, topography, and diverse lithology of spring and seep locations. Springs may exhibit extreme water chemistry conditions (e.g., the extreme temperatures and chemistry of geothermal springs), but mostly exhibit less extreme chemistries and water discharge rates determined by the larger hydrogeologic systems from which they emerge (Shepard 1993b). The dependence on deep water sources also results in highly stable chemistries, temperatures, and water discharge rates. Spring and seep waters are often chemically unique due to the lithology and hydrogeochemistry of the aquifers that support them, and due to the effects of evaporation on low- or non-flowing springs and seeps. Evaporation in these latter settings increases the concentrations and overall salinity of their unique chemical signatures. The resulting hydrochemical uniqueness of springs and seeps makes each a unique setting for biodiversity, further supporting the development of unique biotic assemblages.

Springs and seeps are often the only permanent natural surface-water sources in arid and semi-arid regions of the Mojave and Sonoran deserts and provide vital habitat for numerous terrestrial organisms in addition to the aquatic organisms that they support. Consequently, springs create "aquatic islands in a sea of desert" (Thompson et al. 2002). The unique combination of conditions in springs allows for the existence and evolution of endemic and rare species; and springs and seeps in the Mojave and Sonoran deserts maybe considered biological "hotspots." In addition, Holsinger (1972, 1974) and Bousfield and Holsinger (1981) reported numerous described and undescribed species of amphipods from springs throughout the deserts, most of whose ecologies are little studied and therefore poorly understood. Because spring environments have relatively stable water temperatures and discharges, aquatic community structure is mostly determined by biotic interactions (i.e., primary and secondary productivity, inter- and intra-specific competition, demographic stochasticity, predation, etc.) and not by stochastic environmental events such as seasonal flooding and drought or seasonal temperature changes.

NOTE from workshop: This system may be problematic for applying the methodology. The system includes a large heterogeneity of springs and seeps. They likely vary tremendously in vulnerability, so lumping them all together for a single score for the system is not particularly useful for managers of specific areas. **Author note: all ecosystems and habitats vary in relative heterogeneity, depending on the perspective by which they are defined. The method starts with the presumption that the user has defined the type to suit their needs. The index then works within those constraints.**

Overall Climate Change Vulnerability Score: Moderate

DIRECTS EFFECTS

Forecasted Climate Stress Index: Result: **Mojave Score 0.35 High Sensitivity**
Result: **Sonoran Score 0.45 High Sensitivity**

Climate forecasts from an ensemble of downscaled global climate models are summarized for the period around 2050-2060. These forecasts indicate the relative degree of forecasted climate stress, using (in the Mojave Desert) a comparison of forecasts to 1900-1980 baseline conditions, or in the Sonoran Desert, forecasted change in temperature and precipitation between current and 2060. Sonoran may warm by 2-4 degrees F, whereas the Mojave is predicted to have a 4 -9 degree F increase. Sonoran species are already adapted to very high temps and even rapid changes in temperatures. Mojave species are also heat adapted, but not to the extreme temperatures that Sonoran species can tolerate. Predicted change in precipitation is more of a wild card. If precipitation decreases = greatest stress, if it increases minimally = no stress, and if precipitation increases significantly, this may change the rate of inflow of surface runoff from the surrounding drainage catchment, with associated turbidity and differences in water chemistry, all of which would likely be detrimental to species adapted to the unique chemistries and water clarity of the springs. Given the certainty of warming, the *in situ* stress on Spring and Seep species is low for Sonoran species and possibly more moderate for Mojave species. Given the higher uncertainty on how precipitation may change, it is difficult to rate the *in situ* stress this may have on Mojave and Sonoran Spring and Seep species. Changes to the hydrologic regime may take time, and is considered under the Hydrologic regime change below.

Dynamic Process Forecast
Hydrologic Regime Change 2060: Result: **Mojave Score 0.3 High Sensitivity**
Result: **Sonoran Score 0.2 High Sensitivity**

Current and forecasted trends—Results from projected climate averaged over all models for 2010-2050 from Climate Wizard indicate a drop in precipitation in Spring and Summer, as well as an overall <u>decrease</u> in precipitation annually by 0.5 – 1 inch. Temperatures are expected to increase by 2-4 degrees (F). This will likely result in

- Higher day time temperatures, causing increased evaporation.
- Higher night time temperatures, causing continued water stress on vegetation after sundown.

- Increased evaporation, possibly causing reduced groundwater recharge, and causing increased rates of concentration of dissolved minerals/salts in those springs and seeps with low or no discharge.
- Increased storm event intensity, with higher variation in magnitude and frequency, causing an increase in runoff inflows with erosion of surrounding surface catchments, bringing turbidity and altered chemistry to individual sites.
- Reduced groundwater recharge in the mountains and reduced recharge to basin-fill deposits along the mountain-front/basin-fill interface, eventually causing reduced discharges at spring/seep outflow points. The time-lag between onset of changes to recharge and onset of changes to spring discharge could be on the order of decades to centuries (or longer), depending on the time-length of the unique aquifer flow-paths involved for each site.
- A decline in the footprint of hydrophilic vegetation tied to the effects of altered recharge-discharge; as flow decreases, aquatic species may not be able to survive at all.
- Mountain springs may be the first to go with increased temperatures. There is often a significant time lag between when pumping out of groundwater and when you notice changes at the spring, by which time it is too late for management intervention to have an effect.
- As temperatures increase, wildlife and livestock will drink more water, stressing these systems even more.

Other models however show an <u>increase</u> in precipitation especially in July and Aug by as much as 2 inches. This may result in:

- Increased soil erosion from increase surface flows, which may negatively impact water quality
- Increased spring in flow rates Increased spring inflow rates from groundwater recharge (on a longer time frame) and surface runoff (immediate time frame) where local topography makes such catchment runoff concentration possible, potentially resulting in changes to spring pool depth levels that may benefit some species and be detrimental to other species.

Thus both a decrease in precipitation and increases in precipitation (the range of model results) will have significant changes to the hydrologic regime, and Mojave and Sonoran spring and seep species in particular are used to stable water supplies, so the effect could be enormous.

<u>INDIRECT EFFECTS</u>

Landscape Condition 1960 Result: **Mojave Score 0.8 High Resilience**
Result: **Sonoran Score 0.8 High Resilience**

Building upon spatial model results for current conditions, a review of literature and historical maps supported a relative expert estimate. Mojave and Sonoran deserts were mostly unfragmented landscapes with the footprint of major cities much smaller than today. However domestic livestock and human use around these sources of water was certainly high in some localized areas, some springs highly utilized by Native Americans and ranchers by the late 1800s. Cattle grazing occurred throughout the region and springs were very likely heavily utilized.

Landscape Condition 2010: Result: **Mojave Score 0.7 High Resilience**
Result: **Sonoran Score 0.7 High Resilience**

Mojave/Sonoran Springs and Seeps are scattered throughout the region and are located in foothills and basins as well is in mountains, so many springs are far removed from the footprint of human land development, and proportionally are less affected than low elevation riparian areas. However, as urban growth has increased in and around Phoenix and Tucson, so have the number of roads and proximity to public land access points. Proximity to roads can increase erosion and reduce water quality of springs. However in addition, visitation to springs (one of the main sources of invasive species) may not be necessarily tied to proximity to roads (Ledbetter and Stevens 2011). However domestic livestock are still the norm across the desert range and their concentration around springs is very damaging.

→ *Participant note: Scale of springs is very different from scale of landscape condition model – it would be desirable to know condition at each spring and its recharge area.* **Author note: The landscape condition model describes a 90m surface, and so scores reflect land use and fragmenting features of applicable scale to typical springs and seeps.**

Invasive Species Effects 1960: Result: **Mojave Score 0.7 High Resilience**
Result: **Sonoran Score 0.7 High Resilience**

Historic cattle grazing introduced invasive plant spp. in the late-19th -early 20th century or made areas more vulnerable to invasion through soil disturbance; these invasives spread to springs and have been an ongoing stressor since the late 1800s.

Invasive Species Effects 2010 Result: **Mojave Score 0.5 Medium Resilience**
Result: **Sonoran Score 0.5 Medium Resilience**

Enormous increase in the number of recreational users of public lands has increased recreational visitation to springs. These visitations increases the likelihood of non-native plant species introduction (Ledbetter and Stevens 2011), especially when springs are included on resource maps. One study (Ledbetter and Stevens 2011) showed that only one of 32 springs within an area of 25,600 hectares on the Mogollon Rim in central AZ did not have invasive species present. Bullfrogs and crayfish introductions are also common.

Dynamic Process Alteration
Hydrologic Regime Change 2010: Result: **Mojave Score 0.5 Medium Resilience**
Result: **Sonoran Score 0.5 Medium Resilience**

Agriculture and urban growth have caused the groundwater level to drop significantly in some areas of the desert (e.g., by 100s of feet around Tucson). This has already negatively affected many springs and seeps by reducing the amount of spring groundwater in-flows.

ADAPTIVE CAPACITY

Diversity within Plant/Animal Functional Groups: Result: **Mojave Score 0.5 Medium Resilience**
Result: **Sonoran Score 0.5 Medium Resilience**

Springs tend to be small and isolated and support limited numbers of species, both terrestrial and aquatic. It appears unlikely that multiple species within functional groups would be present at a single spring, therefore each spring is highly vulnerable to changes in water table and chemistry.

Keystone Species Vulnerability: Result **NA**

No keystone species were identified for analysis with this community type.

Bioclimate Variability: Result: **Mojave Score 1.0 High Resilience**
Result: **Sonoran Score 1.0 High Resilience**

Springs are entirely dependent on the flow of groundwater and, with the exception of the effects of air temperature on evaporation and water temperatures, and the effects of local surface runoff (if any), more or less indifferent to the local bioclimate.

Elevation Range: Result: **Mojave Score 1.0 High Resilience**
Result: **Sonoran Score 1.0 High Resilience**

Springs occur at all elevations and on a variety of landforms and substrates throughout the Mojave and Sonoran Desert region**.** Springs are groundwater dependent and it may be that some aquifers are more greatly affected by Climate Change induced changes to precipitation recharge events. However we do not have the data to connect which springs are fed by which aquifers, so in general we assume all aquifers are equally sensitive to reduction in recharge, regardless of geology. The effects of climate change on aquifer recharge, flows, and potentiometric surface (head) on springs and seeps will take place on time-scales of decades to centuries (or longer) due to the slow rates and long flow pathways typically involved. Springs supported by alluvial aquifers will show the fastest response times, while springs and seeps supported by regional bedrock aquifers will show the slowest response times. Some springs may depend on both types of aquifers.

Ecosystem Stressor Worksheet: Springs & Seeps - Non-Climate Stressors

Non-Climate Stressor	Current Scope	Current Severity	2060 Climate Scenario	Description	Mgmt Oppor tunity
Human Overpopulation -Recreation	H	H	Y	Increased use on stressed sites	H
-Land use change (development, energy, ag) – at spring or in recharge zone -Subsidence	H	H	Y	Increased stress and decreased available water.	H
Groundwater pumping	H	H	Y	Effect spring flow and spring temperature, which has a substantive effect on species.	H
Grazing by exotic large mammals	M	H	Y	Concentrates stress on a water-limited system due to more uptake.	H
Fire and postfire watershed effects	M	M	Y	More drying causes more flamibles as well as enhancing conditions for invasives.	H
Invasive plants	H	H	Y	Change in water dynamics. Enhances habitat quality for invasive animals. Crowd out endemic native plants.	H
Invasive animals	H	H	Y	Increased stress on native animal populations due to increased competition and predation	H
Altered hydrology (caused by small-scale water flow control devices such as check dams, small impoundments, diversions)	H	H	Y	Less water to an already stressed system, affecting function and resulting in reduced resilience.	H
Resource extraction (mining, bottled water)	M	H	Y	Climate change causes increased demand for bottled	H

Non-Climate Stressor	Current Scope	Current Severity	2060 Climate Scenario	Description	Mgmt Oppor tunity
				water.	
Contamination/water quality	M	M	Y	Climate change will increase the concentration of solutes.	H

Ecosystem Stressor Worksheet: Springs & Seeps - Climate Stressors

Climate Stressor	Current Scope	Current Severity	2060 Climate Scenario	Description
Increased Water Temperature				Can be greater than physiological tolerances and therefore cause distributional shifts or contractions. Increase in metabolism and decrease in dissolved oxygen.
Increased in mean and maximum air temperature				Can be greater than physiological tolerances and therefore cause distributional shifts or contractions. Increase in metabolism. Increased evaporation and evapotransporation. Increase in stress to plants and therefore lower vigor. Can cause de-synchronization of interspecific events. Some springs/seeps may go dry.
Shift in timing of precipitation events.				Plant regeneration could be threatened if there are no spring rains.
Shift in intensity of precipitation events.				Runoff, plant response and insect hatches are all related to rain intensity.
Shift in amount of precipitation.				Influences hydrogeology that maintains these systems. Can cause increased sp-specific mortality. Some springs/seeps may go dry.
Increase in extreme events (freezes, floods, heat waves, droughts, wind, and combinations of these)				Can cause shift in species composition and structure of habitat. Can exacerbate other nonclimate stressors (such fire, invasives).
All Climate Stressors				**Applies to all climate stressors:** climate events in watersheds beyond where these systems occur has a major influence on this system.
Context				These systems have many migratory species that are subject to climate and nonclimate stressors during other stages of their life cycle that take place beyond

				the watersheds addressed here.

Management Objectives of Participant's Agencies

-Conserve T&E and endemic plants and animals and their habitats
-"Restore" the hydrology and habitat to a functioning wetland ecosystem
-Return endemic species to their historic ranges
-Protect and enhance springs and seeps for the benefit of federal trust species
-Protect source aquifer that supplies springs
-Protect groundwater quality and quantity and their surface expressions (eg, seeps, springs)
-Identify information needs of land managers, conduct research, and provide information.

Potential Climate Change Adaptation Strategies

"No-regrets" actions to take within the next 5 years:

A. Altered Hydrology – Pumping and diversions

1. Restoration – get rid of impoundments; naturalize channels (use LIDAR to identify historic channels)
2. Retire water rights – require pumper to purchase extra above what they need and then retire as mitigation (monitor what they are removing).
4. Combine flows from low flow springs in a complex.
5. Create pools to provide thermal refugia.

B. Invasive Species (plants and animals)

1) Plants

-Restore hydrology (e.g., seasonal drying, favors native spp adapted to it)
-Treatment (removal) with extraction, chemicals
-Plant natives (competitive spp)
-Return fire (prescribed) in an ecologically relevant way. Return flooding.
-Restrict access to springs to reduce vectors.

2) Animal invasives

Aquatic invasives
-Small spring dessication/physical removal
-Restore hydrology/habitat (e.g., substrate) to favor natives
-Create refuge within historic habitat
Terrestrial invasives
-Remove non-native terrestrial spp (burrows, horses, cattle)
-Fencing (may require management of vegetation in low-flow systems)

- Retire near-by groundwater pumping permits, if known or strongly likely to be withdrawing from the source aquifer(s) for an individual spring\
- Take water further downstream?
- aggressively control invasive species
- Strategically remove certain springs from publically available maps
- Limit off-road vehicle use
- Determine which aquifers feed which springs and where wells affect them
- Identify low flow springs and shallow aquifer-fed springs
- Monitor a representative selection of springs to collect data on species composition and water level and inflow rate changes

- Protect a buffer zone for natural watershed vegetation around spring sites, to minimize effects of storm runoff

Anticipated actions over the coming 5-15 years:

- Determine relatedness of populations in different springs to restore to systems that are restored. Monitor water flows and seasonality. Identify species at risk and monitor populations. Consider algae as keystone.
- Protect recharge area
- Lobby against further pumping (no regrets and anticipated action)
- Anticipate changes in vegetation and pool levels in low flow and shallow aquifer springs (springs drying up, or reduction in amounts hydrophilic vegetation and populations of aquatic species)
- Using results of hydrologic study, reduce pumping pressure in source aquifers
- Continue to monitor springs, add springs to account for different aquifer sources (results from hydro study)
- Continue to lobby against increase in number of groundwater wells for agriculture or renewable energy development
- Protect recharge areas and their surface catchments to provide long-term insurance for continued recharge (effects may take decades to realize).

"Wait and watch" actions: Potential actions to anticipate over the 15-30 timeframe, with indicators to monitor and inform that future decision:

- Create artificial habitat
- Adapt management (visitor use, grazing, ORVs) based on spring prioritization
- Develop strategies for moving endangered aquatic species from dying springs

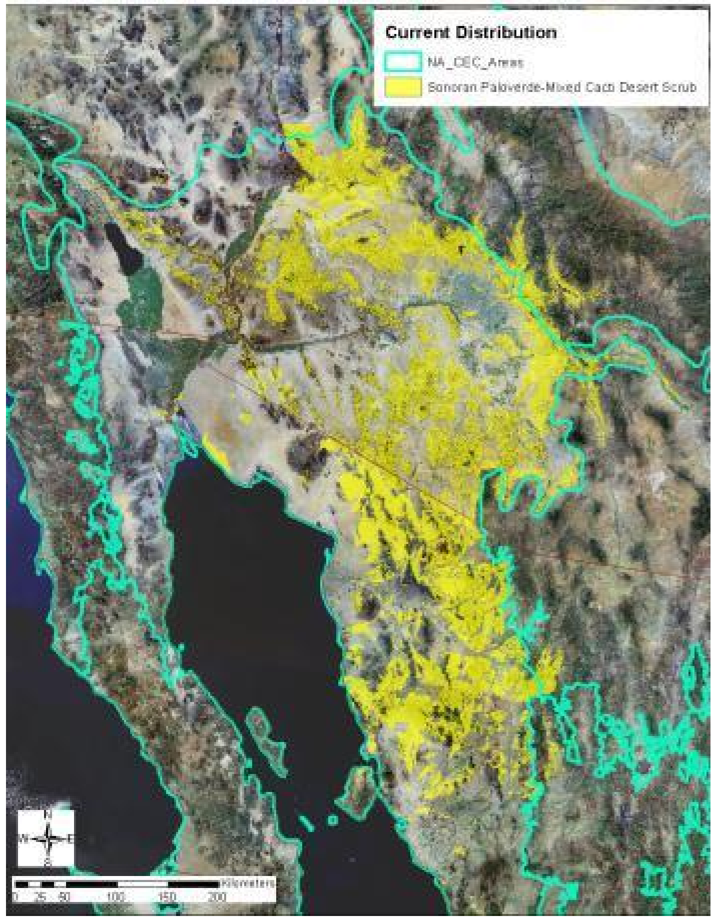
Research and Monitoring Priorities

Identify historic/endemic spring obligates, life history needs, propagation (to expand populations or transplant)

Monitor for early invasion by experienced botanists/IPM
Monitor treatment areas
Monitor natives of interest (indicator spp, endemics)

Sonoran Palo Verde–Mixed Cacti Desert Scrub

CONCEPT



This ecological system occurs on hillsides, mesas and upper bajadas in southern Arizona and extreme southeastern California. The vegetation is characterized by a diagnostic sparse, emergent tree layer of *Carnegiea gigantea* (3-16 m tall) and/or a sparse to moderately dense scrub canopy co-dominated by xeromorphic deciduous and evergreen tall shrubs *Parkinsonia microphylla* and *Larrea tridentata*, with *Prosopis* spp., *Olneya tesota*, and *Fouquieria splendens* less prominent. Other common shrubs and dwarf-shrubs include *Acacia greggii*, *Ambrosia deltoidea, A. dumosa* (in drier sites), *Calliandra eriophylla*, *Jatropha cardiophylla*, *Krameria erecta*, *Lycium* spp., *Menodora scabra*, *Simmondsia chinensis*, and many cacti, including *Ferocactus* spp., *Echinocereus* spp., and *Opuntia* spp. (both cholla and prickly-pear). The sparse herbaceous layer is composed of perennial grasses and forbs with annuals seasonally present and occasionally abundant. On slopes, plants are often distributed in patches around rock outcrops where suitable habitat is present. Outliers of this succulent-dominated ecological system occur as "Cholla Gardens" in the western Mojave in California. In this area, the system is characterized by *Opuntia bigelovii*, *Fouquieria splendens*, *Senna armata*, and other succulents, but it lacks the *Carnegiea gigantea* and *Parkinsonia microphylla* which are typical farther east. Adjacent and related communities are the Baja California del Norte Gulf Coast Ocotillo-Limberbush-Creosotebush Desert Scrub (see description at http://www.natureserve.org/infonatura/). While there are floristic overlaps, these limberbush and elephant tree communities are not treated here.

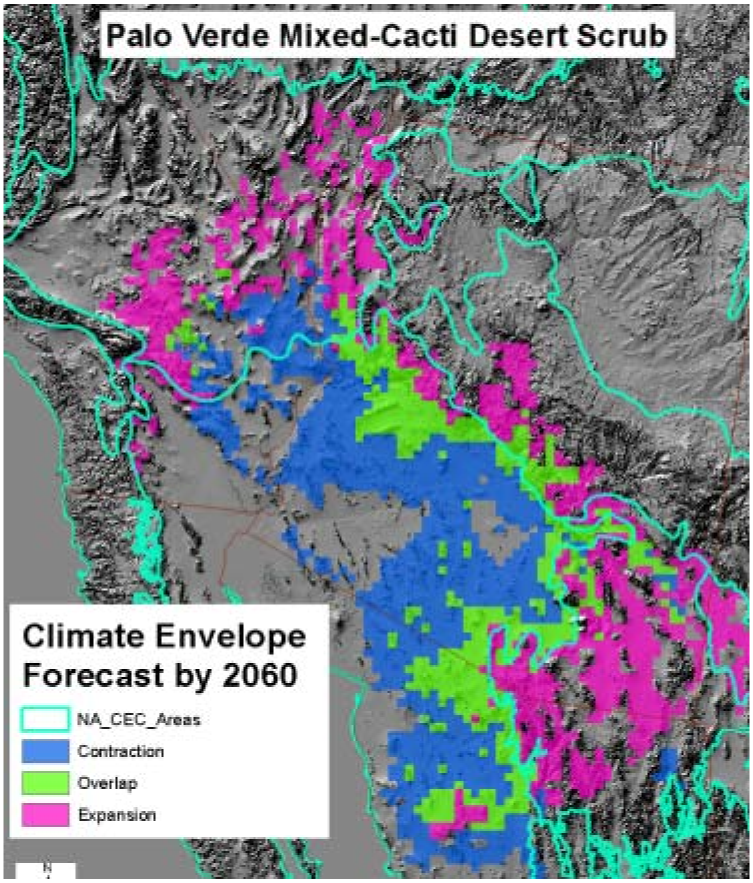
Overall Climate Change Vulnerability Score: Moderate

DIRECTS EFFECTS

Forecasted Climate Stress Index: Result **0.45 High Sensitivity**

Climate forecasts from an ensemble of downscaled global climate models are summarized for the period around 2050-2060. These forecasts indicate the relative degree of forecasted climate stress, using forecasted change in temperature and precipitation between current and 2060. The Sonoran Desert may warm by, on average, 2-4 degrees F, whereas the Mojave Desert is predicted to have a 4-9 degree F increase. Precipitation is less predictable. If precipitation increases significantly, this may change the timing or magnitude of peak and low stream flows which may be beneficial to some species and detrimental to others. Given the higher probability of warming, the stress on component species is high for a drought and heat intolerant species. With the higher uncertainty on how precipitation may change, it is difficult to rate the stress this may have on this ecosystem.

Forecasted Climate Envelope Shift Index: Result **0.21 High Sensitivity**
This spatial model indicates a very substantial contraction in bioclimate where this vegetation most likely co-occurs with creosote-bursage desert scrub, suggesting a potential expansion of creosotebush and related species throughout this portion of the distribution. A considerable area throughout the eastern margins of the Sonoran Desert contains the 'overlap' zone between current and 2060 bioclimate envelope locations, so while the relative percent area of overlap is low, the predicted core zone is contiguous. Local expert review of model output elicited comment that the prediction might be overstated.



Dynamic Process Forecast
Fire Regime Departure Index 2060: Result **0.62 Medium Sensitivity**
The continued spread of invasive species as fine fuels may continue to introduce a fire regime into this desert scrub. The appearance of additional uncharacteristic successional states resulting from this explains patterns in current and forecasted departure. Local experts comment that the 2060 forecast may be somewhat overstated because increased aridity (higher temp, more/less temperature) may decrease invasive grass cover leading to decline in fuels needed to carry fires

INDIRECT EFFECTS

Landscape Condition 1960: Result **0.8 High Resilience**
Historic ranching and agriculture took place throughout this vegetation; but until substantial urbanization and irrigated agriculture began, their proportional influence was limited. However, concentrated impacts from livestock may have been more substantial throughout the Plains of Sonora.

Landscape Condition 2010: Result **0.7 High Resilience**
With expanded urbanization and irrigated agriculture, more substantial proportions of these communities have been affected by landscape fragmentation.

Invasive Species Effects 1960: Result **0.9 High Resilience**
Building upon spatial model results for current conditions, a review of literature and historical maps supported a relative expert estimate. Past ranching and grazing would have introduced a number of invasive plant species by this time, but their overall distribution and impact would have still been somewhat limited.

Invasive Species Effects 2010: Result **0.84 High Resilience**
Invasive plant species, such as buffelgrass (*Penstimen ciliare*) and other species, have been expanding their distribution and ecological impact by introducing fire regimes in this community types over recent decades. Current spatial models, albeit limited to US distribution, indicated 16% of the current extent infested with substantial invasive plant species (BLM Sonoran Desert REA 2012).

Dynamic Process Alteration
Fire Regime Departure Index 2010: Result **0.72 High Resilience**
The introduction of invasive species as fine fuels has introduced a fire regime into this desert scrub. The appearance of additional uncharacteristic successional states resulting from this explains patterns in current and forecasted departure.

ADAPTIVE CAPACITY

Diversity within Plant/Animal Functional Groups: Result **0.7 High Resilience**
For species that provide important and characteristic ecosystem functions, such as nitrogen fixation, water absorption, soil stability, geochemical processing, food-web dynamics, etc., this indicator provides a relative measure of the diversity among characteristic species for relevant functional traits, with high diversity within each group conferring a higher degree of adaptive capacity for climate change.

Key ecological function species group is species responses to drought (severity and length), which has high diversity of characteristic dominant species with adaptations to drought (drought deciduous, (33 species).

Keystone Species Vulnerability: Result **0.7 High Resilience**

Gilded flicker (*Colaptes chrysoides*) (1.0 High): This species exhibits characteristics that both increase and decrease its vulnerability to climate change, but overall it may not be vulnerable to climate change and might actually expand its range in the region. It relies heavily on a small number of species that are critical in providing suitable habitat, and land use changes resulting from human responses to climate change could affect it, but these may be overcome by the bird's good dispersal abilities and other aspects of its ecological versatility.

Littleleaf Paloverde (*Parkinsonia microphylla*) (0.7 High): This species might be highly vulnerable (with moderate confidence) to climate change in the region, mainly due to proposed changes in moisture availability (the species is inherently tied to the summer rains) and the effects of climate change on seed dispersal. As a result, the species range may shift and perhaps leave the assessment area.

Saguaro (*Carnegiea gigantea*) (0.5 Medium**):** This species might be highly vulnerable (with moderate confidence) to climate change in the region mainly due to forecasted changes in moisture availability, and its dependence on other species that might be affected by climate change for seed dispersal. The species range might shift and/or perhaps leave the assessment area.

Bioclimate Variability: Result **0.7 High Resilience**
This type occurs in a moderately high number of isobioclimates (13/20) which is expected for a widespread type.

Elevation Range: Result **0.4 Low Resilience**
Number of 500' (152 m) elevation belts that encompass the type distribution is 5 of 12.

Expert Workshop – Non-Climate Stressors

Non-Climate Stressor	**Current Scope**	**Current Severity**	**2060 Climate Scenario**	**Description**
Burro and cattle grazing	High	High/M		No
Loss of pollinators	Low	Unknown		Yes (mining)
Illegal and military activities 100 miles around border (direct surface effects, fragmentation, noise, and fire ignitions)	Med	High		No
Off highway vehicles	Low	Moderate		No
invasive vegetation (buffel grass) and altered fire regime	Moderate	high		Yes (grazing, OHV, urbanization can increase invasives as well)
Urbanization and development including agriculture	Moderate	High		No
Mining (especially in Sonora MX)	Low	High		No
Wood-collection	Low	High		
Roads, canals	Low	high		
Disease, pathogens, pest outbreaks	Low	Unknown		
Decline in genetic variability	Low	Moderate		Limited to rare species

Ecosystem Stressor Worksheet: Climate Stressors

Novel Climate Stressor	**Current Scope**	**Current Severity**	**Description**
Plant species die-off and lower recruitment associated with warming, extreme drought			already observed, rate of die-off exceeding recruitment
Rapid loss of soils, erosion, dust storms			
Effects of changes of phenology			
Increased variability of precipitation, temperature including extreme events and effects on populations and processes			
Increased solar radiation (less atmospheric moisture) leading to declines in herps			
less water availability in tinajas affects mammals depend upon them			
drought = less plant production = increase herbivory xero-riparian systems			
increased temps and possibly reduced rainfall will lead to less water available for mammals and birds			

<u>DISCUSSION ON MANAGEMENT GOALS FOR EACH MANAGED AREA</u>

- Cabeza Prieta – wilderness and habitat conservation, some species bighorn sheep, pronghorn, and lesser long nosed bat
- Salton Sea refuge – Coachella portion, manage T&E species in dunes, some creosote bordering dunes, monitoring of conditions
- Southern CA FWS – mandate for T&E is to downlist them, anything common how to keep them from getting listed; what sort of monitoring can we suggest to do this
- BARRY GOLDWATER – maintaining ecological integrity, specifically to create training environment for military activities (air to ground munitions, increased demand for ground based activities search and rescue, no tanks) that occur on base; trying to de-list listed species

(pronghorn); keep unlisted species from being listed; do lots of monitoring at broad scales, thinking about migration more broadly beyond boundaries, think about climate change more broadly

- Pinacate – federal agency but a lot is under private land ownership; one of objectives is to change practices of people that live there (agriculture, cattle) to more sustainable practices; one strategy is to restrict these activities to certain areas; trying to update management plan to restrict collection of construction materials (gravel etc). 400,000 ha buffer zone; 200,000 ha restricted zone

- FWS Albuquerque Regional Office – As we see things changing, really change our adaptive management and monitoring to track them; prioritization and focus on things that are most vulnerable and things that have greatest likelihood of working; working on what are critical resources: keystone species, resources, processes; maintaining and restoring resiliency for soil and water resources, important habitat and species (could be rare, aquatic, areas high endemism, high biodiversity), wildlife corridors; rapidly detect, control, triage of non-native invasive species; maybe change management priority and devote less resources towards non-natives that do not cause ecosystem collapse and focus on larger effects; better fire planning, preparation; longer-term, think about opportunities to develop novel habitats and ecosystems, assisted migration, enhance wildlife corridors and connectivity, enhance adaptive capacity. Increasing FWS focus on landscape scale and need for partnerships. Also a move away from single species approaches is likely towards more resilient ecosystems.

- CEDES State agency in Sonoran: responsibility for wildlife is federal, as state wildlife agency they are coordinating with US/MX agencies especially those that migrate; work on management plans for migratory species like jaguar, pronghorn, masked bobwhite; provide technical assistance for private land owners, develop management plans for those that have important species and habitats; technical assistance to establish state-level protected areas

- PINACATE CONANP – Do wildlife monitoring (does not make management decisions), especially bats, species richness, works with AZGFD and FWS partners in Sonoita River, recovery of aquatic habitat and fish species; one issue is providing opportunities for recreation (certain areas restricted like tinajas); does monitoring of this. Monitoring feeds back to management decisions

- AZGFD – Primary management focus is wildlife in the broadest sense, non-game, sport fish; interest in habitat is largely working with land management agencies and partners to assist with management such as thinning, do monitoring in WUI interfaces; lot of work on connectivity; during droughts, will bring water to animals. Sometimes the mandate for the species leads to broader ecosystems processes and resiliency, so not to leave single.

- Organ Pipe – Mandates are columnar cacti, T&E species (pronghorn, lesser long nosed bat, Quitobaquito pupfish, etc); also wilderness (manage noxious invasive species, provide public access); from CC, be interested in those that are unique or endemic to area, or those that have a high leverage, such as keystone species, high biodiversity areas; extensive I&M program (climate, water, air quality, plants, animals, communities). See a lot of ecological correlates with climate variables. Have hypotheses of climate change effects but need to be tested; AZ rosewood, juniper species that are at high elevation, north facing slopes that are vulnerable (like to evaluate if there is any unique genetic variation in populations in organ pipe)

- TNC Hasiampa Preserve mainly aims at riparian conservation. Upland management goals unclear there. Main TNC directions are CC adaption strategies and monitoring protocols, especially at Las Cienagas, national conservation area. CC Mitigation activities lessoning focus.

Potential Climate Change Adaptation Strategies

"No-regrets" actions to take within the next 5 years:

- Fine fuel reduction (exotic annual grass control) and fire suppression in this fire sensitive system.
- Closer management of grazing intensity
- Planning to maintain contiguous natural blocks
- Aggressive prevention and control of invasive plant species
- Aggressive management of wildland fire

Non climate-change Stress: Invasive grass/altered fire regime
Management Intervention: NOTE: within the State of Sonora, state agency primarily provides technical assistance in management planning to private landowners, vs. most US participants who are land managers themselves, with their own planning processes.

When buffelgrass / invasive veg: mechanical removal for small infestations, spraying for large infestations. Mechanical thinning at high-probability ignition sites (e.g., roadsides) and around other sensitive resources.

Anticipated actions over the coming 5-15 years:

- Develop monitoring program for bats to detect changes in populations and work towards protecting habitats
- Implement a phenology monitoring protocol to document changes in timing of blooming for columnar cacti and effects on pollinators
- Hold workshops that bring together all managers that focus on an important species, and use workshop to share information (e.g., phenology, abundance), develop hypotheses of change (e.g., bat conservation international)
- Evaluate, share, analyze existing weather station information across managed areas, states, countries; and develop strategy to prioritize locations for new stations.
- Increasing fire ignition with drought years, and expanding fire patch size
- Increased densities of invasive plant populations
- In cases where phenology changes are detected, work with partner land management agencies in places that are more appropriate or suitable for bats

"Wait and watch" actions: potential actions over the 15-30 timeframe, with indicators to monitor and inform that future decision:

Novel climate-change Stress: Shifts in seasonality of Precipitation
Management Intervention: monitoring to detect severe shortage, and then subsidize locally with water tanks. Need to look at more investment in water storage.

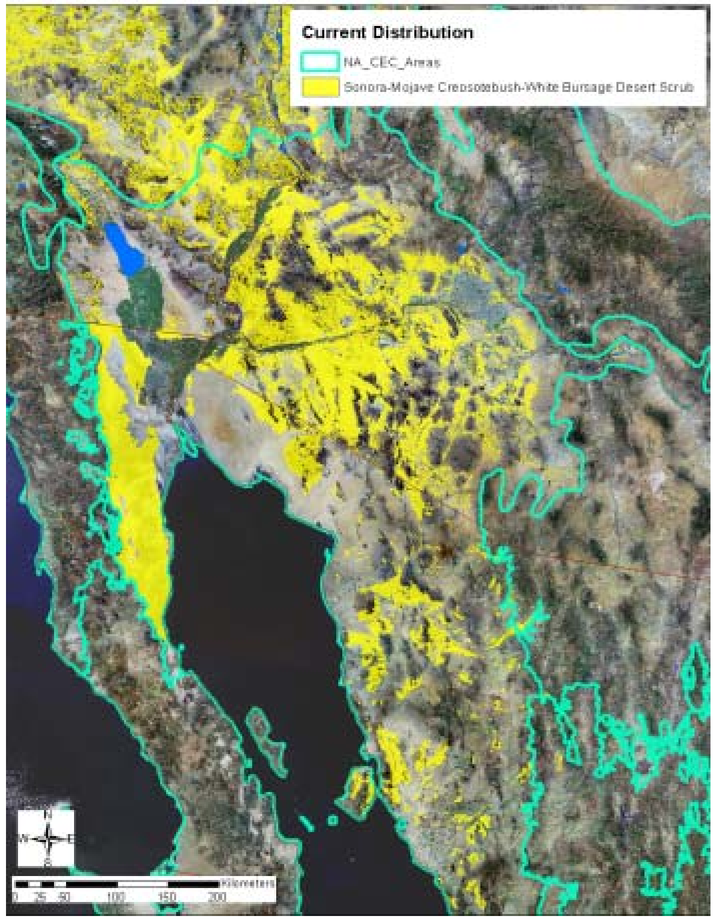
Novel climate-change Stress: Shifts in Phenology
Management Intervention: monitoring to detect shift to gauge relative vulnerabilities for sensitive resources; i.e., need to understand the nature of phenology change before strategies could be considered. E.g., this year blooming season occurred earlier, especially with trees and columnar cacti.
Primary strategy: establish phenology monitoring program targeting key phonologies of likely influence on sensitive resources.

Novel climate-change Stress: Loss of pollinators
Management Intervention: a) Establish monitoring program b) compare blooming seasons with pollinators (Lepidoptera / migratory pollinators [arrival vs. departure]) c) detect change in behavior of pollinators (specialists and generalists) d) detect changes in bat populations, and e) protect rost colonies in caves (those not currently protected). Detect changes in flower/fruit decline?

RESEARCH QUESTIONS AND NEEDS

- What is the capacity for invasive grasses to expand and therefore shift fire regime?
- Within the Sonoran Desert, what are the indicator and keystone species and what is the impact of their loss?
- How do you characterize adaptive capacity for sparsely vegetated systems (e.g. sand dunes)?
- What are the displacement effects of invasive species in creosote-bursage system?
- Are soil crusts susceptible to climate change and to what degree?
- What is the potential of strategy to inoculate soils for soil crusts?
- Need guidance and best practices on efficient monitoring protocols to track and detect plant community change associated with climate change.
- What is the relationship of precipitation regime (e.g. seasonal precipitation patterns) with plant recruitment?
- What are the contributing factors and pattern to recent plant die-off in Sonoran Desert ecological systems?
- Need a study that identifies pollinators that serve a keystone role in Sonoran Desert ecological systems.

Sonoran Desert - Sonora-Mojave Creosotebush-White Bursage Desert Scrub



CONCEPT

This ecological system forms the vegetation matrix in broad valleys, lower bajadas, plains and low hills in the Mojave and lower Sonoran deserts. This desert scrub is characterized by a sparse to moderately dense layer (2-50% cover) of xeromorphic microphyllous and broad-leaved shrubs. *Larrea tridentata* and *Ambrosia dumosa* are typically dominants, but many different shrubs, dwarf-shrubs, and cacti may codominate or form typically sparse understories. Associated species may include *Atriplex canescens, Atriplex hymenelytra*, *Encelia farinosa*, *Ephedra nevadensis, Fouquieria splendens*, *Lycium andersonii*, and *Opuntia basilaris*. The herbaceous layer is typically sparse, but may be seasonally abundant with ephemerals. Herbaceous species such as *Chamaesyce* spp., *Eriogonum inflatum*, *Dasyochloa pulchella*, *Aristida* spp., *Cryptantha* spp., *Nama* spp., and *Phacelia* spp. are common. This system can often appear as very open sparse vegetation, with the mostly barren ground surface being the predominant feature.

Overall Climate Change Vulnerability Score: High

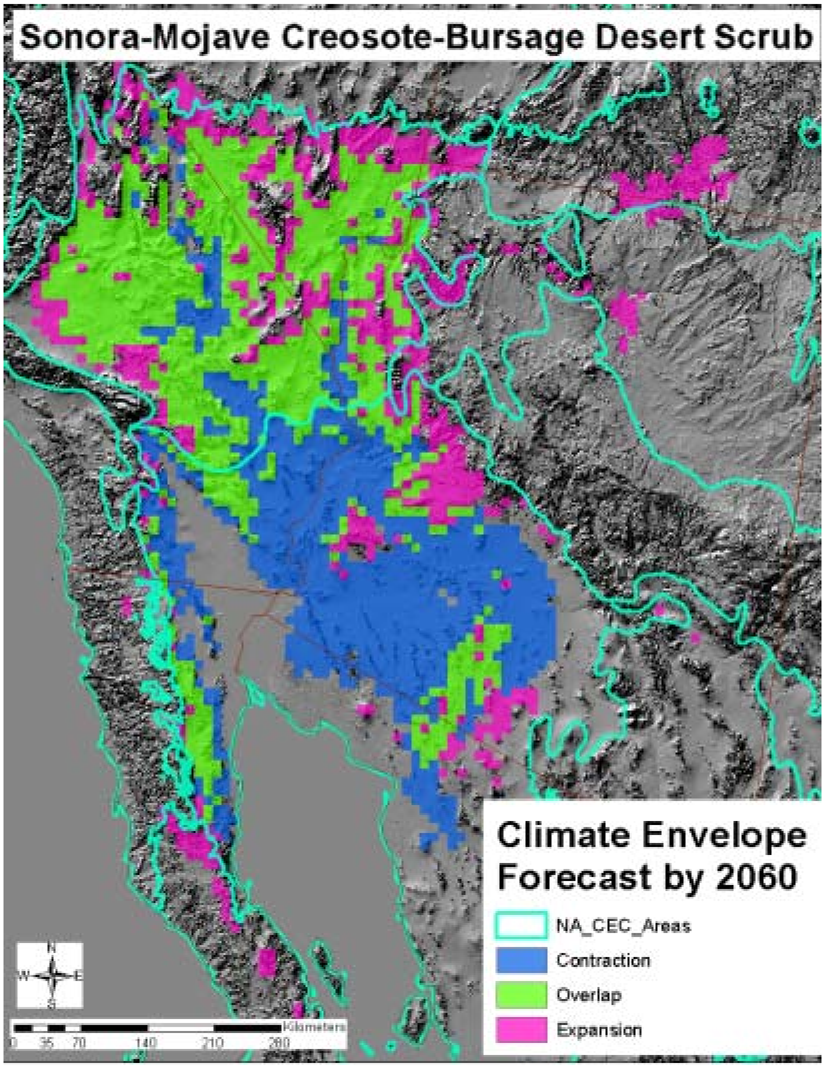
DIRECTS EFFECTS

Forecasted Climate Stress Index: Result **0.45 High Sensitivity**

Climate forecasts for 2060 indicate the relative degree of climate stress, using forecasted change in temperature and precipitation between current and 2060. The Sonoran Desert may warm by, on average, 2-4 degrees F, whereas the Mojave Desert is predicted to have a 4-9 degree F increase. Precipitation is less predictable. If precipitation increases significantly, this may change the timing or magnitude of peak and low stream flows which may be beneficial to some species and detrimental to others. Given the higher probability of warming, the stress on component species is high for a drought and heat intolerant species. With the higher uncertainty on how precipitation may change, it is difficult to rate the stress this may have on this ecosystem. Experience with extreme temperature and drought conditions have manifested extensive die-off many characteristic plant species in this community type.

Forecasted Climate Envelope Shift Index: Result **0.39 High Sensitivity**

The spatial models indicate substantial contraction of the current range throughout lowest elevations in the Lower Colorado River basin, where one might expect expansion of desert pavements. Overlap zones are concentrated were these communities commonly co-occur with Palo verde – mixed cacti desert scrub.



Dynamic Process Effects over time
Fire Regime Departure Index 2060: Result **0.6 High Sensitivity**

This system model shows an improvement in the departure score, largely the result of a predicted increase in the mid-shrub component. However, this improvement in the departure score belies the decline in the system as a result of the dramatic increase in uncharacteristic states. However, increased aridity (higher temp, more/less temperature) may decrease invasive grass cover leading to decline in fuels needed to carry fires.

INDIRECT EFFECTS

Landscape Condition 1960: Result **0.9 High Resilience**
Historic ranching and agriculture took place around the margins of this vegetation; but until substantial urbanization and irrigated agriculture began, their proportional influence was limited.

Landscape Condition 2010: Result **0.6 Medium Resilience**
With expanded urbanization and irrigated agriculture, more substantial proportions of these communities have been affected by landscape fragmentation.

Invasive Species Effects 1960: Result **0.9 High Resilience**
Past ranching and grazing would have introduced a number of invasive plant species by this time, but their overall distribution and impact would have still been somewhat limited.

Invasive Species Effects 2010: Result **0.7 High Resilience**
Invasive plant species, such as buffelgrass (*Penstimen ciliare*) and other species, have been expanding their distribution and ecological impact by introducing a wildfire regime in this community types over recent decades. Current spatial models, albeit limited to US distribution, indicated 29% of the current extent infested with substantial invasive plant species (BLM REA 2012).

Dynamic Process Alteration
Fire Regime Departure Index 2010: Result **0.38 Medium Resilience**
Analysis of the current fire regime model indicates a moderate level of current departure due to inclusion of uncharacteristic states. Forecasts show trends towards improvement in the departure score, largely the result of a predicted increase in the mid-shrub component.

ADAPTIVE CAPACITY

Diversity within Plant/Animal Functional Groups: Result **0.7 High Resilience**
For species that provide important and characteristic ecosystem functions, such as nitrogen fixation, water absorption, soil stability, geochemical processing, food-web dynamics, etc., this indicator provides a relative measure of the diversity among characteristic species for relevant functional traits, with high diversity within each group conferring a higher degree of adaptive capacity for climate change.

The key species functional group is the extended drought tolerance species functional group. Although there are relatively low number of characteristic dominant species in this group, *Larrea tridentata* has extreme resistance to high temperature and low tissue water potential caused by extended drought (Yang 1967). This species is also very long-lived with clones living over 10,000 years and so indicates remarkable robust species. It has deep roots that utilized winter precipitation (Munson et al. 2011). *Ambrosia dumosa* is short-lived low shrub with shallow roots that quickly colonizes open areas and is common on disturbed sites.

Diversity of characteristic dominant species in the extended drought tolerance vegetation functional group is relatively low at (mostly two species), however these species, especially *Larrea tridentata,* are very robust species that tolerate this extremely hot, dry, drought prone environment for millennia.

Keystone Species Vulnerability: Result **0.63 Medium Resilience**

Morafka's desert tortoise (*Gopherus morafkai*) (0.7 Medium): This species may be moderately vulnerable to climate change in the region, due primarily to effects of projected changes in moisture availability, the species' dependence on plants that are affected by seasonal precipitation patterns, possible land use changes resulting from human responses to climate change, and climate-change-induced habitat degradation (increases in invasive species and fire frequency). Published studies show major reductions in desert tortoise suitable habitat and range in the Sonoran Desert with projected climate change.

Creosotebush grasshopper (*Bootettix argentatus*) (0.7 Medium): This species may be highly to moderately vulnerable to climate change in the region, based on effects of projected changes in moisture availability, possible land use changes resulting from human responses to climate change, and consequences of the species' high degree of dietary and habitat specialization on creosotebush.

Creosotebush (*Larrea tridentata*) (0.5 Low): This species might be highly vulnerable to climate change effects, mainly due to its dependence on seasonal rainfall for successful germination and potential effects of climate change on plant pollinators. Also, land use changes by humans in response to climate change may increase vulnerability as well. The species may expand its range within the assessment area.

Bioclimate Variability Result **0.7 High Resilience**
This type occurs in a moderately high number of isobioclimates (14/20) which is expected for a widespread type.

Elevation Range: Result **0.6 Medium Resilience**
Number of 500' (152 m) elevation belts that encompass the type distribution is 7 of 12.

Ecosystem Stressor Worksheet: Creosote Bursage- Non-Climate Stressors

Non-Climate Stressor	Current Scope	Current Severity	2060 Climate Scenario	Description of linkages to CC scenarios
Burro and cattle grazing	Low	High		Weak
Loss of pollinators				Yes
Illegal and military activities 100 miles around border (direct surface effects, fragmentation, noise, and fire ignitions)	Moderate	High		No; degradation of biological soil crusts, altered water flows
Off highway vehicles	Low	Moderate		No; degradation of biological soil crusts, altered water flows
Invasive vegetation (sahara mustard)	High	high/moderate		Yes

Altered fire regime	Low	High		Yes
Urbanization and development including agriculture	Moderate	High		degradation of biological soil crusts, altered water flows
Mining and associated effects (especially in Sonora MX)	Low	High		No
Roads, canals	Low	High		
Disease, pathogens, pest outbreaks	Low	Unknown		

Ecosystem Stressor Worksheet: Creosote Bursage - Novel Climate Stressor

Novel Climate Stressor	**Current Scope**	**Current Severity**	**2060 Climate Scenario**	**Description**
Plant species die-off and lower recruitment associated with warming, extreme drought	High	high		already observed, rate of die-off exceeding recruitment
Rapid loss of soils, erosion, dust storms	Moderate/High	high		
Effects of changes of phenology	low	Unknown		
Increased variability of precipitation, temperature including extreme events and effects on populations and processes	high	high		
Increased solar radiation (less atmospheric moisture) leading to declines in herps	low	Unknown		
less water availability on aquatic species	low	Unknown		currently don't know but could have impacts in future
drought = less plant production = increase herbivory xero-riparian systems	low	Unknown		

increased temps and possibly reduced rainfall will lead to less water available for terrestrial species	low	Unknown		

Potential Climate Change Adaptation Strategies

"No-regrets" actions to take within the next 5 years:

- Fine fuel reduction (exotic annual grass control) and fire suppression in this fire sensitive system.
- Closer management of grazing intensity
- Closer management (zoning, restrictions) of OHV disturbances or other anthropogenic sources of soil disturbance
- Planning to maintain contiguous natural blocks
- Aggressive prevention and control of invasive plant species
- Treat Sahara mustard infestations near locations of high resource value areas (e.g., T&E species) depending on seasonal precipitation. Evaluate effects of further soil disturbance.

Management Intervention: If removal is desired, chemical application prior to germination of annual natives. This would depend on the timing of rainfall. Mustard would need to germinate and develop rosettes prior to annual native germination. Glyphosphate could be used if you are not afraid of hitting other plants. Express is a potential alternate in cases where you don't want to kill everything. Mitigate risk of above action in introducing new exotics, and effects of soil disturbance. Begadra bug.

- Take actions to reduce likelihood of high-frequency, high intensity and large fires, such as monitoring extent and density of vegetation that carries fire, prevention (e.g., fire restrictions), preparation, education, which will potentially help improve retention of soils (that would have otherwise been lost after fire)

Management intervention: when the land use is changed that allows for activities that are likely to alter the fire regime, plan for and implement site-specific actions that minimize the probability of ignition and spread of wildfire
Identify and monitor a change in the frequency and extent of fires that compel further actions to prevent additional fire and/or restore burned areas.
Utilize seasonal variation in fire risk (I.E., ENSO connections) to inform more strategic planning, education, prevention, and suppression actions and mitigate fire effects.

- Restrict surface disturbance of soils (ORV activity, livestock grazing). RESISTANCE
- Inventory, Map and prioritize for action erodible soils RESISTANCE
- Develop monitoring protocols, indicators, goals shared by multiple managers that have power to detect change that can be anticipated with climate change

Anticipated actions over the coming 5-15 years:

- Aggressive management of wildland fire

- Where you can anticipate or see changes in fire frequency and extent, adopt ‘resistance’ strategy to create fire breaks in these areas. A resilience strategy would be to identify species that may in fact be able to recover from these fires (depending on size and intensity)
- Evaluate feasibility of inoculating soils for biological soil crust regeneration (need water?)
- What can we do to influence or anticipate the deposition of soils from where they are removed to areas where they may be received (and what does that mean for the ‘receiving’ places, such as dry washes or xero-riparian areas)?
- Look into utility of micro- and check-dam water and soil catchments to retain some soils and facilitate recharge

“Wait and watch” actions: Potential actions to anticipate over the 15-30 timeframe, with indicators to monitor and inform that future decision:

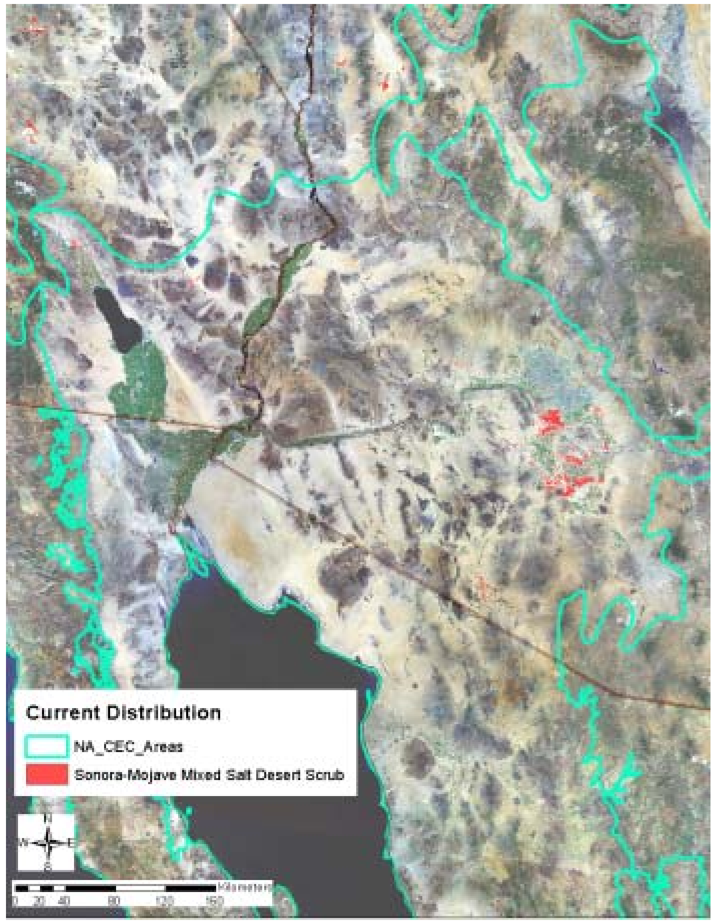
- Increasing fire ignition with drought years, and expanding fire patch size, anticipate possibility of alternative state and plan for change management objective to stabilize soil and vegetation (any) depending on monitoring
- Increased densities of invasive plant populations at higher elevations.
- Decreasing vegetation density and erosion potential to limit transformation into desert pavement.

Novel climate-change Stress: plant die-off from severe drought
Management Intervention: monitoring detects widespread die-off is occurring
Facilitate plant migration from south to north slopes, reseed and irrigate, etc.

Novel climate-change Stress: loss of key pollinators
Management Intervention: monitoring detects reduction in pollinator population, e.g., decline in long-nosed bats. Monitor across large areas such key components as mesquite and grass/forbs that are important components that enhance overall diversity.
Consider keystone plant species for pollinators (i.e., generalists vs. specialists) monitor and assess differential vulnerabilities.

Novel climate-change Stress: rapid soil loss
Management Intervention: monitoring detects locations of rapid soil loss; planning generally has identified areas of high potential for loss.
Actions: restrict ORV use and livestock grazing
Introduce drought-resistant soil crust (inoculated soils)
Use soil stabilization treatments (local mulch, native seed, organic spray?)

Sonoran Desert - Sonora-Mojave Mixed Salt Desert Scrub



CONCEPT

This ecological system includes extensive open-canopied shrublands of typically saline basins in the Mojave and Sonoran deserts; typically up to 2400m elevation. Stands most often occur around playas and in valley bottoms or basins where evapo-transpiration results in saline soils. Given map scale, there is likely more area of this vegetation than is visible. Substrates are generally fine-textured, saline soils. Vegetation is typically composed of facultatively deciduous xeromophic shrubs with one or more *Atriplex* species, such as *Atriplex polycarpa*. *Opuntia* cacti may also be common. Species of *Allenrolfea, Salicornia, Suaeda, Krascheninnikovia lanata*, or other halophytic plants are often present to codominant. A sparse to moderately dense graminoid layer ay include *Sporobolus airoides* or *Distichlis spicata* at varying densities. Forb cover is generally sparse, but annual forbs may be abundant in wet years. Conversion to agriculture and/or grazing has been among the most significant stressors on salt desert scrub.

Overall Climate Change Vulnerability Score: Moderate

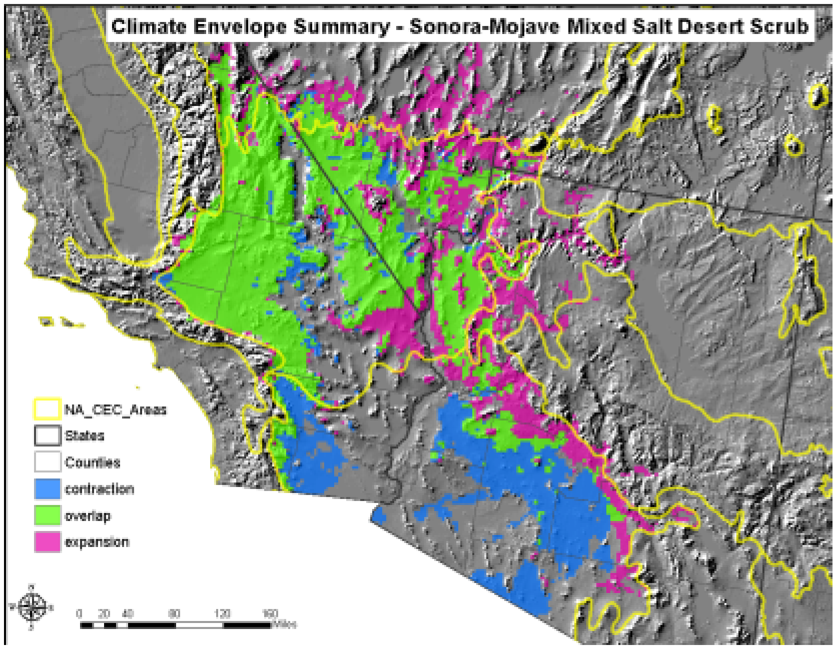
DIRECTS EFFECTS

Forecasted Climate Stress Index: Result **0.45 High Sensitivity**

Climate forecasts for 2060 indicate the relative degree of climate stress, using forecasted change in temperature and precipitation between current and 2060. The Sonoran Desert may warm by, on average, 2-4 degrees F, whereas the Mojave Desert is predicted to have a 4-9 degree F increase. Precipitation is less predictable. If precipitation increases significantly, this may change the timing or magnitude of peak and low stream flows which may be beneficial to some species and detrimental to others. Given the higher probability of warming, the stress on component species is high for a drought and heat intolerant species. With the higher uncertainty on how precipitation may change, it is difficult to rate the stress this may have on this ecosystem.

Forecasted Climate Envelope Shift Index: Result **0.21 High Sensitivity**

The spatial models indicate a strong contraction throughout the lower Colorado River basin, likely resulting from an expansion of desert pavement (and perhaps an expansion of desert playa, if precipitation increases).



Dynamic Process Effects over time
Fire Regime Departure Index 2060: Result **0.6 Moderate Sensitivity**
This system is predicted to show some moderate improvement in the composition of historic classes, with an increase in the Midshrub/PerennialGrass state relative to current conditions. However, this is overwhelmed by the 9-fold increase in the exotics class. But increased aridity (higher temp, more/less temperature) may decrease invasive grass cover leading to decline in fuels needed to carry fires

INDIRECT EFFECTS

Landscape Condition 1960: Result **0.9 High Resilience**
Historic ranching and agriculture converted of this vegetation.

Landscape Condition 2010: Result **0.7 High Resilience**
With expanded urbanization and irrigated agriculture, more substantial proportions of these communities have been affected by landscape fragmentation.

Invasive Species Effects 1960: Result **0.9 High Resilience**
Past ranching and grazing would have introduced a number of invasive plant species by this time, but their overall distribution and impact would have still been somewhat limited.

Invasive Species Effects 2010: Result **0.4 Low Resilience**
Invasive plant species, such as buffelgrass (*Penstimen ciliare*) and other species, have been expanding their distribution and ecological impact by introducing a wildfire regime in this community types over

recent decades. Current spatial models, albeit limited to US distribution, indicated 19% of the current extent infested with substantial invasive plant species (BLM REA 2012).

Dynamic Process Alteration
Fire Regime Departure Index 2010: Result **0.38 Low Resilience**
Current fire regime departure is likely to be considerable across the ecoregion, with introduction of invasive species as fine fuels.

ADAPTIVE CAPACITY

Diversity within Plant/Animal Functional Groups: Result **0.5 Low Resilience**
Very low native species diversity overall translates in low resilience for any particular functional group.

Keystone Species Vulnerability: Result **1.0 High Resilience**
Allscale (*Atriplex polycarpa*) (1.0 High)
Fourwing saltbush (*Atriplex canescens* var *angustifolia***)** (1.0 High)
These two species might not be vulnerable (with high confidence) to climate change effects in the region. *Atriplex canescens* has been called the most adaptable shrub in North America and is salt, cold, and drought resistant, and shows extreme genetic diversity across geographic and elevational gradients.

Bioclimate Variability Result **0.7 High Resilience**
This type occurs in a moderately high number of isobioclimates (13/20) which is expected for a widespread type.

Elevation Range: Result **0.8 High Resilience**
Number of 500' (152 m) elevation belts that encompass the type distribution is 9 of 12.

This type was not treated specifically by expert workshop

Potential Climate Change Adaptation Strategies

"No-regrets" actions to take within the next 5 years:

- Fine fuel reduction (exotic annual grass control) and fire suppression in this fire sensitive system.
- Closer management of grazing intensity
- Planning and restoration to build larger, contiguous natural blocks
- Aggressive prevention and control of invasive plant species

Anticipated actions over the coming 5-15 years:

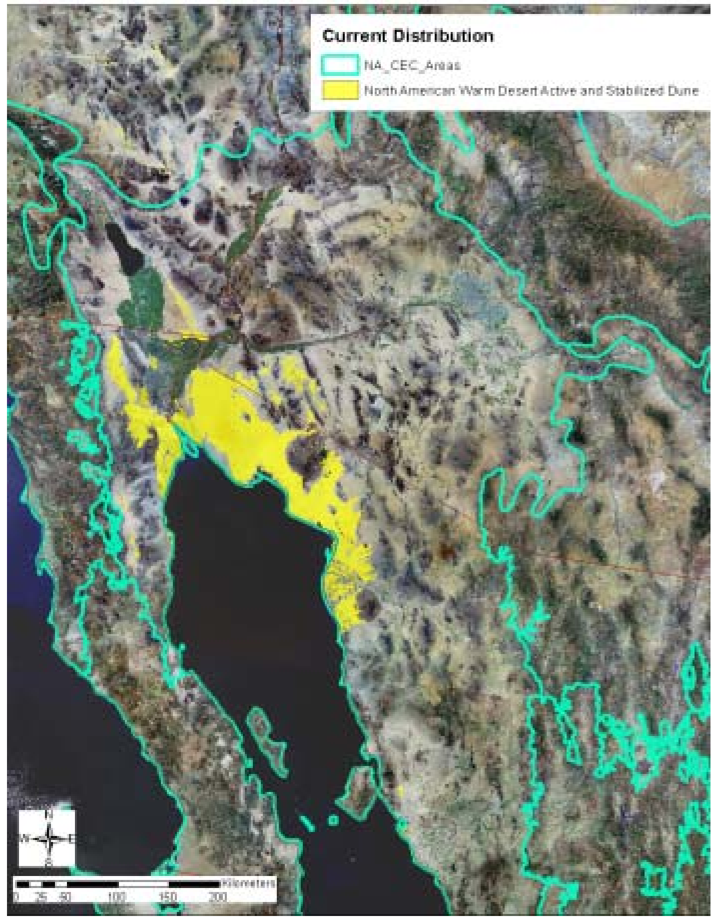
- Aggressive management of wildland fire

"Wait and watch" actions: potential actions to anticipate over the 15-30 timeframe, with indicators to monitor and inform that future decision:

- Increasing fire ignition with drought years, and expanding fire patch size
- Increased densities of invasive plant populations at higher elevations.
- Decreasing vegetation density and transformation into desert pavement.

Sonoran Desert - North American Warm Desert Active and Stabilized Dune

CONCEPT



This ecological system occurs across the warm deserts of North America and is composed of unvegetated to sparsely vegetated (generally <10% plant cover) active dunes and patches of vegetation on stabilized dunes and sandsheets. The system is defined by the presence of migrating dunes or, where the dunes are entirely anchored or stabilized, evidence that the substrate is eolian and not residual and that the substrate is likely to become actively migrating again with disturbance or increased aridity. There are some smaller, active and partially vegetated dunes along some of the larger washes and on sides of playas and basins (where sand is blown out of a wash or basin and forms dunes) and some larger dunes, but many of the larger dunes were formed during the Pleistocene when sand was blown from large drying lake basins into dunes. Characteristic plant species include *Ambrosia dumosa, Abronia villosa, Artemisia filifolia, Atriplex canescens, Eriogonum deserticola, Poliomintha* spp., *Prosopis* spp., *Psorothamnus* spp., *Rhus microphylla*, and *Sporobolus flexuosus*. Within a dunefield some species are typical of active sand, such as *Croton wigginsii, Eriogonum deserticola, Palafoxia arida var. gigantea, Panicum urvilleanum*, and *Petalonyx thurberi*, while others are common on stabilized dunes, such as *Pleuraphis rigida, Psorothamnus emoryi, Tiquilia palmeri*, and scattered *Larrea tridentata*. Dune "blowouts" and subsequent stabilization through succession are characteristic processes.

Overall Climate Change Vulnerability Score: Moderate

DIRECTS EFFECTS

Forecasted Climate Stress Index: Result **0.45 High Sensitivity**
Climate forecasts for 2060 indicate the relative degree of climate stress, using forecasted change in temperature and precipitation between current and 2060. The Sonoran Desert may warm by, on average, 2-4 degrees F, whereas the Mojave Desert is predicted to have a 4-9 degree F increase. Precipitation is less predictable. If precipitation increases significantly, this may change the timing or magnitude of peak and low stream flows which may be beneficial to some species and detrimental to others. Given the

higher probability of warming, the stress on component species is high for a drought and heat intolerant species. With the higher uncertainty on how precipitation may change, it is difficult to rate the stress this may have on this ecosystem.

INDIRECT EFFECTS

Landscape Condition 1960: Result **0.9 High Resilience**
Building upon spatial model results for current conditions, a review of literature and historical maps supported a relative expert estimate. Historic ranching and agriculture took place around the margins of this community type; but until substantial urbanization and irrigated agriculture began, their proportional influence was very limited.

Landscape Condition 2010: Result **0.85 High Resilience**
With expanded urbanization and irrigated agriculture, more substantial proportions of these communities have been affected by landscape fragmentation. This will be contingent on development of coastal areas in/near Gran Desierto.

Invasive Species Effects 1960: Result **0.9 High Resilience**
Past ranching and grazing would have introduced a number of invasive plant species by this time, but their overall distribution and impact would have still been somewhat limited.

Invasive Species Effects 2010: Result **0.7 Medium Resilience**
Invasive plant species, such as buffelgrass (*Penstimen ciliare*), Sahara mustard, (*Brassica tournefortii)* and other species, have been expanding their distribution and ecological impact by introducing a wildfire regime in this community types over recent decades. Current spatial models, albeit limited to U.S. distribution, indicated 29% of the current extent infested with substantial invasive plant species (BLM Sonoran REA 2012).

ADAPTIVE CAPACITY

Diversity within Plant/Animal Functional Groups: Result: **0.85 High Resilience**
In this system the key processes are dune stabilization and nitrogen fixation. Stabilizing dunes is critical to providing habitats for sand loving plants and animals. Destabilization of vegetated dunes has been linked to periods of extended drought (Foreman et al. 2006). Early seral dune stabilization species in Mojave desert include taxa that are typically stoloniferous grasses (*Panicum urvilleanum, Swallenia alexandrae*) or annuals such as *Abronia villosa*, *Astragalus lentiginosus, Camissonia claviformis, Crytantha angustifolia, Dicorea canescens, Eriogonum inflatum., Heliotropium convolvulaceum, Lupinus shockleyi, Oenothera deltoides, Palafoxia arida and Psorothamnus emoryi* (Bowers 1984). Later seral species help maintain stabilized condition, many are dune endemics with adaption s to burial and excavation, but may include wider ranging species such as *Atriplex canescens, Larrea tridentata, Pleuraphis rigida*, and *Prosopis glandulosa*, especially on the outer perimeters of dunefields (Bowers 1984, Keeler-Wolf 2007). Introduced annual, *Salsola tragus* is prominent in some dune systems.

Diversity of annual and early seral species in the dune stabilization functional group is variable, but is generally high for most Mojave dune systems. Estimates of 45 characteristic taxa are listed in Bowers (1984) for Algondones and Gran Desierto Dunes. Diversity of characteristic dominant species in the dune stabilization functional group is high = 0.9.

Many of these species form symbiotic relationships with nitrogen-fixing bacteria, which is an important ecological process in this N deficient system. These species include *Achnatherum hymenoides , Aristida* *purpurea, Astragalus lentiginosus, Hesperostipa comata, Lupinus arboreus, Psoralidium lanceolatum,* and *Psorothamnus polydenius* (Bowers 1982). Diversity of species in nitrogen-fixing functional group is variable, but is generally moderate for most Mojave dune systems. Estimates 7 nitrogen-fixing species listed from Bowers (1982) is moderately high = 0.8.

Keystone Species Vulnerability: Result: **0.7 High Resilience**
Desert kangaroo rat (*Dipodomys deserti*) (0.7 Medium): This species may be moderately vulnerable to climate change in the region, due primarily to effects of projected changes in moisture availability, possible land use changes resulting from human responses to climate change, and the species' dietary and substrate specializations.

Desert panicgrass (*Panicum urvilleanum*) (0.7 Medium) This species forms a sparse cover and begins to stabilize open dunes and sand deposits. Aeolian processes disturb it rather than fire. It diminishes under drought conditions.

Bioclimate Variability Result **0.4 Low (to medium) Resilience**
This type occurs in a moderate number of isobioclimates (8/20).

Elevation Range: Result **0.3 Low Resilience**
Number of 500' (152 m) elevation belts that encompass the type distribution is 4 of 12.

Potential Climate Change Adaptation Strategies

"No-regrets" actions to take within the next 5 years:

- Closer management of ORV use and access, along with grazing intensity in surrounding landscapes
- Planning and restoration to build larger, contiguous natural blocks of natural vegetation surrounding current dune fields
- Aggressive prevention and control of invasive plant species into dune fields

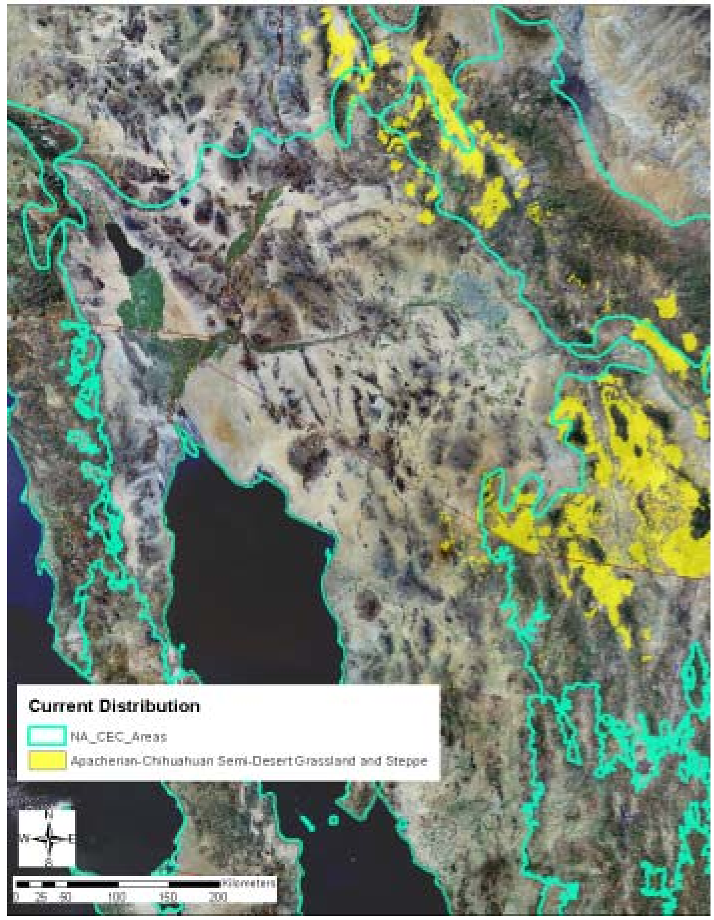
Anticipated actions over the coming 5-15 years:

- Aggressive management of wildland fire

"Wait and watch" actions: Potential actions to anticipate over the 15-30 timeframe, with indicators to monitor and inform that future decision:

- Decreasing vegetation density, expansion of dune blowout size and frequency, and transformation into greater proportional area of active dunes.

Sonoran Desert - Apacherian-Chihuahuan Semi-Desert Grassland



CONCEPT

This ecological system is a broadly defined desert grassland, mixed shrub-succulent or xeromorphic oak savanna that is typical of the Borderlands of Arizona, New Mexico and northern Mexico (Apacherian region) but extends west to the Sonoran Desert, north into the Mogollon Rim and throughout much of the Chihuahuan Desert. It is found on gently sloping bajadas that support frequent fire throughout the Sky Islands and on mesas and steeper piedmont, foothill and desert mountain slopes up to 1670 m elevation in the Chihuahuan Desert. It is characterized by typically diverse perennial grasses. Common species include grasses *Bouteloua eriopoda, Bouteloua hirsuta, Bouteloua ramosa, Bouteloua rothrockii, Bouteloua curtipendula, Bouteloua gracilis, Eragrostis intermedia, Muhlenbergia emersleyi, Muhlenbergia porteri, Muhlenbergia setifolia*, and *Pleuraphis jamesii*, succulent species of *Agave, Dasylirion*, and *Yucca*, short-shrub species of *Calliandra, Mimosa*, and *Parthenium*, and tall-shrub/short-tree species of *Acacia, Prosopis*, and various oaks (e.g., *Quercus grisea, Quercus emoryi, Quercus arizonica, Quercus oblongifolia*). *Pleuraphis mutica*-dominated semi-desert grasslands often with *Bouteloua eriopoda* or *Bouteloua gracilis* occurring on lowlands and loamy plains in the Chihuahuan Desert are classified buy NatureServe as Chihuahuan Loamy Plains Desert Grassland (CES302.061).

Overall Climate Change Vulnerability Score: Moderate

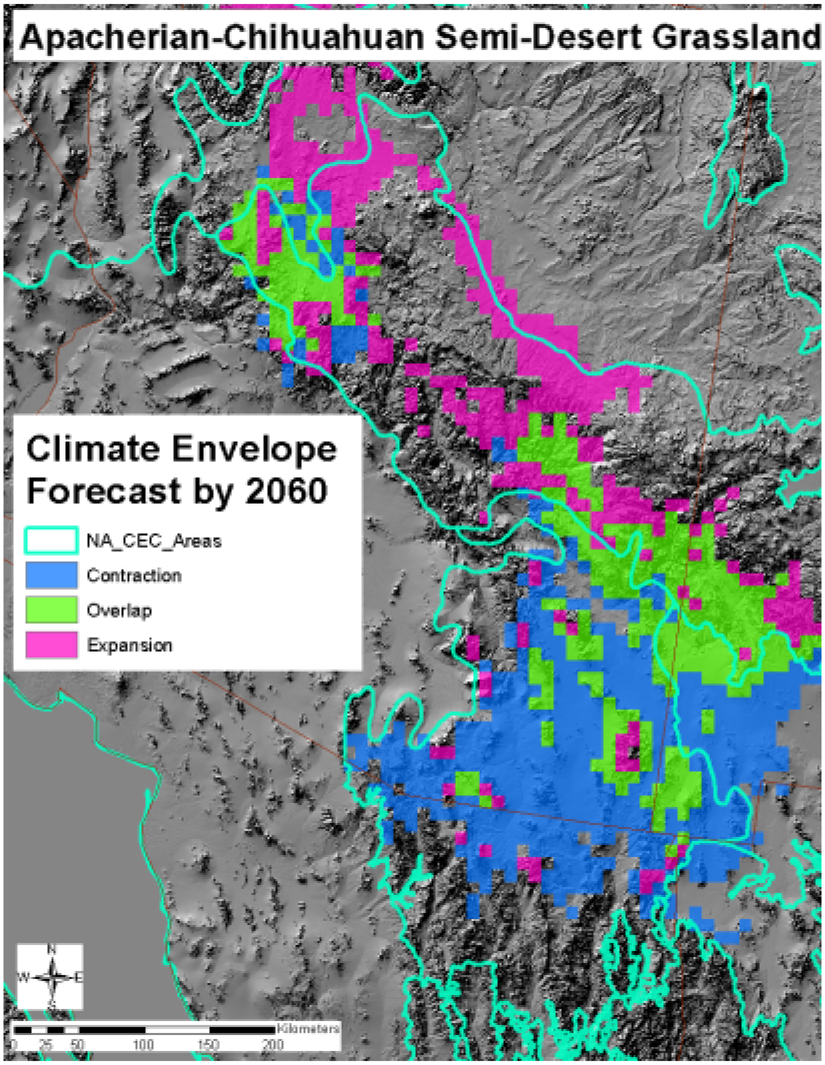
DIRECTS EFFECTS

Forecasted Climate Stress Index: Result **0.45 High Sensitivity**

Climate forecasts for 2060 indicate the relative degree of climate stress, using forecasted change in temperature and precipitation between current and 2060. The Sonoran Desert may warm by, on average, 2-4 degrees F, whereas the Mojave Desert is predicted to have a 4-9 degree F increase. Precipitation is less predictable. If precipitation increases significantly, this may change the timing or magnitude of peak and low stream flows which may be beneficial to some species and detrimental to others. Given the higher probability of warming, the stress on component species is high for a drought and heat intolerant species. With the higher uncertainty on how precipitation may change, it is difficult to rate the stress this may have on this ecosystem.

Forecasted Climate Envelope Shift Index: Result **0.24 High Sensitivity**

The area used for this calculation included the Sonoran Desert and a 100 mile buffer. Within this zone, for these grasslands, there was only a 24% overlap between current and 2060 climate envelopes. This suggests an extreme contraction in distribution among low mountains and valleys throughout the SE AZ and adjacent areas of Mexico within this study area. One might anticipate an expansion of species from adjacent desert scrub (palo verde, etc.) in that area. Elsewhere, one might expect further expansion of mesquite woodland into these grasslands.



Dynamic Process Effects over time:
Fire Regime Departure Index 2060: Result **0.86 Low Sensitivity**
This system is currently over-represented by the early state (perhaps in part from invasive grass invasion in areas), and the model predicts that this will shift back toward a historic condition dominated by the mid-late seral class. However, the percentage of the system in uncharacteristic states is predicted to continue to expand.

INDIRECT EFFECTS

Landscape Condition 1960: Result **0.6 Medium Resilience**
Historic ranching and agriculture took place throughout this vegetation, bring fire suppression and invasion of shrubland vegetation (Gori et al. 2003).

Landscape Condition 2010: Result **0.5 Medium Resilience**
With expanded urbanization and ranching, more substantial proportions of these communities have been affected by landscape fragmentation and shrub encroachment (Gori et al. 2003).

Invasive Species Effects 1960: Result **0.9 High Resilience**
Past ranching and grazing would have introduced a number of invasive plant species, including Lehmann lovegrass (*Eragrostis lehmanniana)* this time (Gori et al. 2003).

Invasive Species Effects 2010: Result **0.8 High Resilience**
Invasive plant species have been expanding their distribution and ecological impact by altering fire regimes in this community types over recent decades. Estimates are that some 14% of current extent in SE AZ is impacted by these invasive species (Gori et al. 2003).

Dynamic Process Alteration
Fire Regime Departure Index 2010: Result: **0.43 Medium Resilience**
This system is currently over-represented by the early state (perhaps in part from invasive grasses in areas).

ADAPTIVE CAPACITY

Diversity within Plant/Animal Functional Groups: Result **1.0 High Resilience**
The key functional group is perennial graminoid species that characterize this diverse community. It is common for there to be over a dozen grass species on a plot. Characteristic dominant graminoid species for the type exceed 20 so functional species diversity is high.

Keystone Species Vulnerability: Result **0.5 Medium Resilience**
Yucca moth (*Tegeticula elatella*) (0.5 Low)
Although this species may be a fairly good disperser and is associated with common geological features or derivatives, it may be negatively affected by projected changes in moisture availability. It is dependent on just one plant species (*Yucca elata*) for habitat and food, and that plant may be vulnerable to climate change within the assessment region. Additionally, it could be negatively affected by land use changes resulting from human responses to climate change. Overall, it may be highly vulnerable to climate change in the Sonoran Desert.

Bioclimate Variability: Result **0.7 High Resilience**
This type occurs in a moderately high number of isobioclimates (13/20) which is expected for a widespread type.
Elevation Range: Result **0.4 Low Resilience**
Number of 500’ (152 m) elevation belts that encompass the type distribution is 5 of 12.

This type was not treated specifically by expert workshop

Potential Climate Change Adaptation Strategies

"No-regrets" actions to take within the next 5 years:

- Planning to maintain contiguous natural blocks
- Aggressive prevention and control of invasive plant species
- Aggressive restoration of woodland invasion sites

Anticipated actions over the coming 5-15 years:

- Aggressive management of wildland fire

"Wait and Watch" actions: *Potential actions to anticipate over the 15-30 timeframe, with indicators to monitor and inform that future decision:*

- Increasing fire ignition with drought years, and expanding fire patch size
- Increased densities of invasive plant populations at higher elevations.
- Plant species invasion from adjacent desert scrub or mesquite woodland

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