Appendix D Terrestrial Ecological Systems: Conceptual Models and Ecological Status

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Overview of Appendix D

This appendix contains the conceptual models and ecological status assessment results for the terrestrial conservation elements (CEs) assessed for the Madrean Archipelago REA. Appendix A describes the methods for selection of the CEs and the change agents (CAs), as well as the collection and organization of management questions (MQs) of interest to many partners active in this ecoregion. Appendices B and C contain the assessment methods: B contains the methodological approaches to the geospatial assessments, while C contains the technical GIS documentation. Other appendices contain the conceptual models and ecological status assessment results for the aquatic CEs (Appendix E) and species (Appendix F). Three additional appendix volumes contain the ecoregional conceptual model and methods / results for the ecological integrity assessment (Appendix G); the conceptual models, methods and results for assessment of Mesquite Expansion: Restoration Opportunities (Appendix H); and the climate changes methods and results (Appendix I).

The content of this appendix is organized into the following major sections:

1. The Overview of Appendix D explains the content of the appendix to help the reader navigate the content, including a summary of how the CE conceptual models are organized, what material is provided in each one, and how the results of the assessment are organized for each CE.
2. The second section, Distribution Mapping Methods, provides a brief summary of methods used to map the distributions of the species and species assemblage CEs; detailed technical documentation of these methods is provided in Appendix C.
3. The third section, Status Assessment Methods, provides a brief summary of the status assessment methods that are specific to the CEs in this appendix; readers should reference Appendix B for complete details on the scientific rationale and technical approach to the status assessments.
4. The fourth section, Terrestrial Ecological Systems: Conceptual Models and Ecological Status, contains the conceptual models and assessment results for each CE and is the primary focus of this appendix.
5. References for this appendix as a whole are at the very end of the document. (References for each individual CE are at the end of each of the CE sections under Terrestrial Ecological Systems: Conceptual Models and Ecological Status.)

To help visually organize the content for readers, headings are **not** numbered for the sections containing the background or supporting or overview information. In addition, headings for the broader categorizations of the ecological systems (e.g., Valley Upland Division), are similarly **not** numbered. Sections containing the individual CE assessment content – conceptual models, status assessment results, and other CE-specific information – have outline-numbered headings (e.g., C-1, C-1.1, C-1.2, etc.).

Overview of the Conceptual Models

The conceptual models combine text, concept diagrams, and tabular summaries in order to state assumptions about the ecological composition, structure, dynamic processes, and interactions with major CAs within the ecoregion. These conceptual models lead then to spatial models to enable gauging the relative ecological status of each Conservation Element (CE), which will be completed in a later task of the REA. Below is described the content included for each CE.

The ecosystem conservation elements for the MAR REA were selected from NatureServe's classification of terrestrial ecological systems (Comer et al. 2003). Over three dozen ecological systems occur in the MAR, but only a select subset were chosen for the REA based on repesentativeness or or having a large portion of their distribution in the MAR; methods for selection are described in the MAR Pre-Assessment Report (Harkness et al. 2013). The descriptive material for each CE builds upon the current descriptions for terrestrial ecological systems that NatureServe has been compiling since 2003 when the ecological systems classification was first developed (see http://www.natureserve.org/explorer/index.htm to search and download existing descriptions). For this REA, additional material was added for each ecological system CE, especially focused on content describing natural and altered vegetation dynamics, as well as threats and stressors to the system. The wetland/aquatic CEs are described in Appendix E. The information developed is generally intended to cover the full range of distribution of the CE, which can extend beyond the ecoregion, and but does focus on the characteristics or dynamics as they occur within this ecoregion.

The descriptions include many names of plant species that are characteristic of the ecological system type. In the text sections these names are provided as scientific names. Vascular plant species nomenclature follows the nationally standardized list of Kartesz (1999), with very few exceptions. Nomenclature for nonvascular plants follows Anderson (1990) and Anderson et al. (1990) for mosses, Egan (1987, 1989, 1990, 1991) and Esslinger and Egan (1995) for lichens, and Stotler and Crandall-Stotler (1977) for liverworts/hornworts. Where information is available, animal or plant species of conservation or management concern have been identified that are known to be strongly associated with the ecological system.

The list of terrestrial ecological system CEs is provided in Table D-1, and each is placed within the broader conceptual model already established for the ecoregion (Harkness et al. 2013).

Table D-1. Terrestrial ecological system conservation elements (ecosystem CEs) selected for the Madrean Archipelago REA; classification follows Comer et al. 2003. The percent of ecoregion was calculated from the distribution map for each CE compared to the overall area of the MAR. Appendix G (ecological integrity) has a table listing the areal extent of all ecological systems mapped in the MAR and their % of the assessment area.

Division Level in ecoregional conceptual model	Ecosystem Name	Percent of Ecoregion
Valley Upland Ecosystems		**56.0%**
Desert Scrub	Chihuahuan Creosotebush Desert Scrub	13.2%
Semi-desert Shrub & Steppe	Apacherian-Chihuahuan Semi-Desert Grassland and Steppe	18.2%
Foothill Woodlands	Madrean Encinal	5.1%
Montane Upland Ecosystems		**13.4%**
Lower Montane Forests & Woodlands	Madrean Pinyon-Juniper Woodland	5.8%
Subalpine/Montane Forests & Woodlands	Madrean Montane Conifer-Oak Forest and Woodland (includes ponderosa pine)	2.8%
Montane Shrublands	Mogollon Chaparral	4.8%

One additional NatureServe ecological system was selected for assessment purposes, and a conceptual model has been developed for it: the Apacherian-Chihuahuan Mesquite Upland Scrub (Appendix H). From a mapping standpoint, this ecological system has been mapped as covering approximately 19.5% of the Madrean Archipelago ecoregion. However, it is a non-natural vegetation type comprised of a native woody genus, mesquite (both *Prosopis velutina* and *Prosopis glandulosa*), which has expanded its range and has become dominant in many area of the ecoregion. For the REA, it will be treated separately from the other ecosystem CEs, and its conceptual model is not provided in this appendix.

Conservation Element Characterization

This section of the conceptual model includes a narrative of the CE distribution, biophysical and hydrological setting, and floristic composition.

The first section of the conceptual model deals with the classification used, the NatureServe terrestrial ecological systems, as described above. For each CE the NatureServe name and tracking code (e.g. CES302.731) are provided; in some cases 2 or more ecological systems are conceptually combined into one CE for the MAR REA in which case all of those are listed. A second part of the classification section lists the ecological systems that are similar to those in the CE. Similarity might be due to floristic, structural or geographic overlap with the CE; in some cases similar ecological systems are listed because reviewers of the draft conceptual models expressed some confusion about the MAR CE in their comments.

For these *upland* ecosystem CEs, a crosswalk to USDA Natural Resource Conservation Service (NRCS) Ecological Site Descriptions (ESDs) applicable to the ecoregion is provided (https://esis.sc.egov.usda.gov/Welcome/pgESDWelcome.aspx). In general, crosswalks are provided only to approved ESDs by NRCS Multiple Resource Land Area (MLRA) that overlap the ecoregion; draft ESDs are being developed in New Mexico that crosswalk to some of these CEs, however because they are draft they are not included in the ESD crosswalk tables. The NRCS Site ID in the crosswalk table identifies each type as determined by NRCS. This list is not a complete cross-walk as some MLRAs do not have approved ESDs. Additionally, the user should consider that ESDs are based on landform/soil concepts, so the match between these concepts and ecological system concepts - defined as an integration between biophysical and natural floristic composition - will be imperfect and may vary from type to type.

The natural vegetation and ecosystem dynamics are described in narrative text, with supporting literature cited. For the upland ecosystem CEs, a diagrammatic representation of the natural dynamics is provided, either from one of the characteristic ESDs crosswalked to the ecological system (and hence a diagram from NRCS); or for some systems lacking ESDs, the natural dynamics diagram developed by The Nature Conservancy is presented and the source report cited.

Species of Conservation or Management Concern Associated with Ecosystem

Some species of conservation or management concern are closely associated with these ecological system CEs. These species are of conservation or management concern due primarily to their relative vulnerability to extinction through alteration of this ecosystem. These vulnerabilities stem from their sensitivity to past or current land/water uses, natural rarity, or forecasted vulnerabilities to climate change effects. Because of this strong association, the ecosystem type provides a practical way to "capture" or adequately represent these individual species and provide a reliable indication of the ecological status for each of these species. This is an approach, called "coarse filter / fine filter", originally proposed by scientists from The Nature Conservancy (Jenkins 1976, Noss 1987) and has been used extensively in a variety of forms for regional and local landscape assessments (Nachlinger et al.

2001, Noss et al. 2002). For most of these species, the ecological system type serves as the focal resource for purposes of resource assessment. Although some of the species listed in this sub-section were assessed individually (see separate conceptual models for them), most are listed to make users aware of associated species that are of concern.

The lists provided in the conceptual model were derived through consultation of State Wildlife Action Plans, or other sources, but are not definitively complete. Many reports list species of concern without providing information on related habitats or requirements. Time was not available to do detailed research on individual species in order to relate them to a MAR ecosystem CE. The sources for the list in each CM are provided. These species are listed by informal taxonomic groups, generally with common names followed by scientific names.

Change Agent Effects on the CE

In this section the primary change agents and current knowledge of their effects on the CE are characterized. Some CAs have specific effects on each CE such as the alteration of expected fire regimes and the interacting effects of introduced weed infestations. This section lists the known change agents and then moves into describing the altered ecosystem dynamics of the CE, with a narrative on the effects of CAs on the individual CE. Wildfire and invasive plant CAs are described and modeled within the context of their effects on upland ecosystem CEs. The altered dynamics section also contains a diagrammatic representation of the currently in-place ‘altered’ dynamics, again making use of either ESDs developed by NRCS, or TNC’s altered dynamics diagrams.

Conceptual Model Diagrams

For uplands, the dynamics, either natural or altered, are generally represented by state-and-transition diagrams. States (boxes) represent a vegetation community defined by a cover type and structural stage. Transitions link states through processes such as succession, disturbance, and management, and can be either deterministic or probabilistic. Deterministic transitions usually simulate successional changes by defining the number of years until a transition occurs from one successional stage to the next, in the absence of disturbance. Probabilistic transitions specify an annual transition probability of moving from one state to another. Probabilistic transitions represent disturbances (e.g., fire and drought), ecological processes (e.g. tree encroachment and natural recovery), and land management activities (e.g., seeding and prescribed fire).

Each upland ecological system CE is represented by two diagrams – one describing the natural range of variation (NRV) under historical conditions, and one describing contemporary dynamics and including uncharacteristic states such as annual grass or depleted shrub. The contemporary model includes all states and transitions from the NRV model in addition to a set of uncharacteristic states and transitions.

Ecological Status: Key Ecological Attributes and Indicators

NatureServe’s ecological integrity assessment framework identifies and outlines practical criteria for assessing the ecological status of each CE within an ecoregion (Faber-Langendoen et al. 2006, Unnasch et al. 2009). This section of the conceptual model addresses Key Ecological Attributes and their potential indicators. The ecological status is a way of describing current status via criteria, functionality, or levels of attributes and asks if they are within the normal range of variation. Is it within its “proper functioning condition”? Attributes are direct and indirect measures of ecosystem status or function. Key Ecological Attributes (or their indicators) should be measured to take the “pulse” of an ecosystem. High scores indicate high ecological integrity and high ecological functionality.

Key Ecological Attributes

The key ecological attributes for the CE within the Madrean Archipelago ecoregion are identified in this section. A **key ecological attribute** of a focal ecological resource is a characteristic of the resource's biology, ecology, or physical environment that is critical to the resource's persistence in the face of both natural and human-caused disturbance, e.g., resistance or resilience (De Leo and Levin 1997, Holling 1973, Parrish et al. 2003, Unnasch et al. 2009). Alteration of such a characteristic beyond some critical range of variation will lead to the degradation or loss of the resource within decades or less.

For each CE, a table provides identified key ecological attributes, with a brief definition, a rationale for why it is important for the CE, and a listing of stressors or change agents that might be affecting the key attribute.

Key ecological attributes of a resource include critical or dominant characteristics of the resource, such as specific characteristics of:

a) demographic or taxonomic composition;
b) functional composition;
c) spatial structure;
d) range or extent.

They also include critical biological and ecological processes and characteristics of the environment that:

a) limit the regional or local spatial distribution of the resource;
b) exert pivotal causal influence on other characteristics;
c) drive temporal variation in the resource's structure, composition, and distribution;
d) contribute significantly to the ability of the resource to resist change in the face of environmental disturbances or to recover following a disturbance; or
e) determine the sensitivity of the resource to human impacts.

Conservation of key ecological attributes contributes to current ecological integrity and to the resilience of ecological systems in the face of large-scale or long-term stressors (Parrish et al. 2003). The ecological integrity assessment framework (Unnasch et al. 2009) identifies four classes of key ecological attributes, concerning: landscape context; resource size or extent; biotic condition; and abiotic condition. These four may overlap, and provide a guide for considering and identifying key ecological attributes. They also provide a basis for integrating information on key ecological attributes.

- "Landscape context" refers both to the spatial structure (spatial patterning and connectivity) of the landscape within which the focal resource occurs; and to critical processes and environmental features that affect the focal ecological resource from beyond its immediate geographic scope.
- "Size" refers to the numerical size and/or geographic extent of a focal resource.
- "Biotic condition" refers to biological composition, reproduction and health, and succession; and critical ecological processes affecting biological structure, functional organization (e.g., food-web guild structure), and interactions.
- "Abiotic condition" refers to physical environmental features and dynamics within the geographic scope of the focal resource that significantly shape biotic conditions, such as fire, weather, and hydrologic regimes; and soil and geological conditions and dynamics.

Indicators of Key Attributes

Assessing the status of key ecological attributes requires explicit identification of indicators (also called metrics) – specific means for measuring their status. These are the detailed metrics that measure the amount or status of each key attribute. There are many potential indicators, and the choice is largely dependent on the purpose of the assessment and available data. An indicator may be a specific, measurable characteristic of the key ecological attribute; or a collection of such characteristics combined into a "multi-metric" index. Such indicators directly evaluate the condition of the KEAs and their responses to stressors (change agents).

Alternatively, indicators may evaluate the severity and extent of the stressors themselves. Such "Stressor" indicators may consist of a single measurement type, or a collection of such measurements combined into a multi-metric stressor index. Indicators of stressors are often used as indirect indicators of a key ecological attribute, because data on stressor condition is often far more readily available than data on direct indicators. Examples of stressor-based indicators include measures of overall landscape development such as the Landscape Condition Model methodology (Comer and Faber-Langendoen 2013, Comer and Hak 2009), measurements of invasive non-native annual grass distributions that affect fire regimes, or measurements of fragmentation due to development.

References for the CE

Literature is listed that is relevant to the classification, distribution, floristic composition, ecological processes, threats, stressors, or management of the CE, in some cases from portions of its range outside of the ecoregion. These are not exhaustive literature surveys, but rather an accumulation of known references. Some documents may be listed that are not cited in the narrative text.

Overview of the Status Assessment Results

Each CE summary has a section titled **Ecological Status Assessment Results and Interpretation**. This section of the individual CE material presents the results of the CE status assessments, and includes both maps and accompanying interpretive text. Readers are referenced to Appendix B (Assessment Methods) for the overall methodological approach for assessing status, and descriptions of scenarios that were used, including data inputs, process model diagrams, data outputs, and limitations. Readers can also reference Appendix C if interested in the technical documentation of GIS steps for creating the inputs, conducting the status assessment, and the resultant output files.

Maps are provided for each CE showing the status or condition scores for each individual indicator at the resolution of the analysis unit (30m pixels), as well as the CE's overall ecological status scores, which is a combination of all indicators, at both a 30m resolution and rolled up into the 4km grid cell reporting unit. The following series of status results maps and charts are provided for each CE:

Maps of individual indicator scores

- Development, 30 meter resolution
- Fire Regime, 30 meter resolution
- Vegetation Composition - Invasives, 30 meter resolution

Maps and charts of comprehensive ecological status assessment results

- Ecological status, 30 meter resolution
- Ecological status, averaged into 4 km reporting units
- Chart showing frequency distribution of ecological status scores within 4m reporting units

The individual indicator results maps are grouped together for each CE, followed by text explanation and interpretation. The overall ecological status maps and accompanying charts are presented in a second grouping, followed by interpretive text. The interpretive text for the results does include material that is repeated for each CE, so that the reader will not need to return to the methods sections repeatedly.

Distribution Mapping Methods

The distribution data for all terrestrial CEs, except Apacherian-Chihuahuan Semi-Desert Grassland and Steppe, were derived from the SW ReGap land cover mapping effort (Comer and Schulz 2007, Lowry et al. 2007). During the past 6 years, NatureServe has systematically reviewed and revised the SW ReGap data using expert input from locally knowledgeable ecologists, and combined it with Landfire land cover data where necessary to create a national land cover map (NatureServe 2013) for the coterminous U.S. All revisions have been documented in a MS Access database available upon request. This NatureServe land cover map was queried directly for the CEs' distributions. Four of the five distributions of terrestrial CEs had a one:one relationship with the NatureServe (Comer et al. 2003, Natureserve 2013) ecological system, however the distribution representing the Madrean Montane Conifer-Oak Woodland is a combination of 5 ecological systems: Madrean Lower Montane Pine-Oak Forest and Woodland, Madrean Upper Montane Conifer-Oak Forest and Woodland, Southern Rocky Mountain Ponderosa Pine Woodland, Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland, and Southern Rocky Mountain Ponderosa Pine Savanna in the MAR REA.

The distribution data for Apacherian-Chihuahuan Semi-Desert Grassland and Steppe CE was derived from a different source dataset than the other terrestrial CEs. The Nature Conservancy (TNC) completed an assessment of grasslands for the entire Madrean Archipelago sky island region, including both the U.S. and Mexico portions (Gori et al. 2012). For New Mexico, the TNC assessment integrated data from a rangeland assessment which included grasslands (Yanoff et al. 2008). TNC evaluated the historical and current extent of grasslands, and also the current condition using the results of previous assessments (Gori and Enquist 2003, Yanoff et al. 2007) and expert input. They created a geospatial dataset, in which they identified 5 classes of grasslands ranging from intact native grassland to stands completely converted to shrubland with a non-native understory, and several mosaics of these classes. For the MAR REA, four classes were subset and combined from the TNC grassland dataset: A - native grasslands, B – shrub invaded native grasslands with restoration potential, A-B – native grasslands/shrub invaded with restoration potential, and C – sacaton riparian. The conceptual model below does not include the sacaton grasslands, however for the spatial assessment to be more inclusive of native grasslands, the TNC polygons of sacaton grasslands were included in the spatial assessment. This combined dataset was then used in the REA for this CE after removing overlapping pixels of the 2 riparian aquatic CEs.

For all the terrestrial CEs, the methods described in the Status Assessment Methods section (below) and Appendix B (Assessment Methods) were used with no revisions.

Status Assessment Methods

Appendix B describes the conceptual scientific approach and rationale for the ecological status assessment (**Appendix B: Rationale for Ecological Status Assessment Approach**) and the detailed technical approach for conducting the assessment (**Appendix B: Ecological Status Assessment Technical Approach**). As described there, a raster-based spatial modeling tool, the Landscape Condition Model (LCM), was used to assess ecological status of CEs. Two categories of inputs are needed to assess ecological status using the LCM: 1) the CE response models, and 2) the spatial KEA indicator scenarios. The CE response model is a series of numeric values that characterize how each CA is expected to reduce status or condition of the CE onsite (site intensity values) and, in some cases, offsite (distance values); the response model values were assigned by ecologists on the contractor team using the information on the CE's ecology and dynamics as summarized in the CE's conceptual model. The site intensity values indicate the degree to which the impact of the specified CA features degrades the ecological status of the CE where the CA feature is present. The KEA indicator scenarios are aggregations of spatial raster datasets representing the CA features that were identified to assess each of the indicators for the CE. The starting point of the model is a theoretically perfect status or condition score of 1.0 for each pixel of a CE's distribution; zero is the lowest status score. The LCM tool applies the CE response model values for each of the CA features to the KEA indicator scenarios to calculate overall ecological status scores for the CE across its distribution. Where multiple CA features overlap, the associated response model values were multiplied to approximate a cumulative CA effect. The overall ecological status scores indicate the degree to which the combined CAs present in the CE's distribution degrade the ecological status of the CE, accounting for distance effects as appropriate. Readers should refer to Appendix B for more detail and background on how the status assessment was conducted.

Linking CE Conceptual Models to CE Status Assessments

It is important that the ecological status assessment of CEs be grounded in what is known about each of the CEs – their ecology, dynamic processes, and stressors. The conceptual models developed for the terrestrial ecological system CEs of the MAR provided the scientific context and current knowledge base from which to identify the key ecological attributes (KEAs) and their indicators to be assessed to characterize ecological status, and to characterize CE responses to CAs via the CE response models (see **Appendix B: Rationale for Ecological Status Assessment Approach)**.

KEAs, Indicators, and Scenarios

In the MAR, three primary KEA/indicator pairs were focused upon for assessment for the terrestrial CEs, for which spatial data were available: Landscape Condition/Development, Fire Regime/Altered Fire Regime, and Native Vegetation Composition/Invasive Species. For each KEA, a KEA indicator scenario, or simply, scenario (**Appendix B: Scenario Generation: Current and Future**) was developed to spatially represent the change agents comprising those stressors: development for landscape condition, Landfire Vegetation Condition Class for fire regime, and invasive species for native vegetation composition; see **Appendices B and C: Scenario Generation: Current and Future** where more details are provided about each scenario's inputs and limitations. Other key indicators of status could have included native floristic or faunal composition, current structural stages, or actual, current fire regimes, but data were not sufficient for the ecoregion to include these direct, region-wide indicators. As a result, the assessment relied on indirect, stressor-based indicators to measure the condition of the KEAs. Key ecological attributes are discussed within each CE's conceptual model.

Table D-2 lists the KEAs identified in the conceptual models for the CEs (provided in the CE section below) and the corresponding indicators and spatial KEA indicator scenarios discussed in Appendix B (Assessment Methods) and above; all of these indicators and KEA indicator scenarios were assessed for each of the terrestrial ecological system CEs.

Table D-2. List of key ecological attributes identified for CEs in the conceptual models with their corresponding indicators and KEA indicator scenarios that were assessed for each terrestrial ecological system CE.

KEA Class: **KEA Name**	**Indicator Name**	**KEA Indicator Scenario**	**Type and Description of Indicator Used**
Landscape Context: **Landscape Condition**	**Development**	***Landscape Condition***	Stressor-based: Modifications to land surface for human use (development) that affects CE directly or indirectly
Abiotic Condition: **Fire Regime**	**Fire Regime Departure**	***Fire Regime***	Stressor-based: Altered fire regimes as reflected in successional classes & their proportions
Biotic Condition: **Vegetation Composition**	**Invasive Species**	***Invasive Species***	Stressor-based: Abundance of invasive species (mesquite and exotic grasses & forbs)

CE Response Model for Terrestrial Ecological Systems

As described in Appendix B (**Ecological Status Assessment Technical Approach)** and above, the KEA scenarios were input into the LCM in conjunction with a response model for each CE; the LCM first intersected the CE distribution map with the KEA indicator scenario, and then the response model was applied to those intersecting pixels to derive a raster map of the calculated status or condition score for each pixel in the CE's distribution. The response model was constructed using information from the CE conceptual models to characterize how a CE is expected to respond in the presence of the CAs (and in some cases, a distance out from the CA) for a particular indicator; Table D-3 below provides a complete listing of all the CAs used as inputs to Vista in the KEA indicator scenarios and the associated response values (site intensity) that were used for all terrestrial ecological system CEs. Distance is not a factor in the output for terrestrial CEs, 10 m was used in model implementation for all indicators, but as this was smaller than the pixel resolution of the input data, distance was not a factor in the output.The table is provided once, but will be referred to in subsequent sections. This is to aid the reader in understanding the results without having to consult detailed methods available in other appendixes.

Table D-3. CE response model values used for all terrestrial ecological system CEs. This table lists site intensity values used for all terrestrial ecological systems for the indicators of Development, Fire Regime Departure, and Invasives. Site intensity values range from 0.0 - 1.0 and are relative to each other. Site intensity values reflect how much an activity (as reflected in the indicator) removes ecological status of the CE. A value of 0.05 removes 95% of the status, 0.5 removes 50%, 0.7 30% and so on. Where two or more activities occur within the same pixel, the intensity values were multiplied together. See Appendix B for conceptual information and Appendix C for GIS documentation and application methods. In contrast to the aquatic and species CEs, distance decay values were not used**.**

Indicator Component	**Site Intensity**
Development	
Infrastructure	
----Border Barrier - Pedestrian	0.2
----Border Barrier - Vehicle	0.4
----Communication Towers	0.3
----Below Ground Corridors	0.7
----Above Ground Corridors	0.5
Transportation	
----Dirt & 4-wheel Drive Roads	0.7
----Local/Rural/Private Roads	0.2
----Primary Highways w/ Limited Access	0.05
----Primary Highways w/o Limited Access	0.05
----Airstrips	0.5
----Railroads	0.5
Mining & Landfills	
----High Impact Mines/Landfills	0.05
----Medium Impact Mines/Landfills	0.6
----Low Impact Mines/Landfills	0.9
Energy	
----Geothermal Energy	0.5
----Wind Energy	0.5
----Solar Energy	0.5
----Oil & Gas Wells	0.5
Recreation	
----Trails - Hiking/Biking/Horse	0.9
Agriculture	
----Agriculture	0.3
Urbanization	
----Low Density Development	0.6
----Medium Density Development	0.5
----High Density Development	0.05
Fire Regime Departure	

Indicator Component	Site Intensity
Development	
----Moderate Fire Regime Departure	0.75
----Severe Fire Regime Departure	0.65
Invasives	
----Terrestrial Invasives - Low Cover (5%-10% cover)	0.9
----Terrestrial Invasives - Medium Cover (10%-25%)	0.8
----Terrestrial Invasives - High Cover (>25% cover)	0.7
----Mesquite - Low Cover (5%-15% cover)	0.85
----Mesquite - Medium Cover (15-25% cover)	0.7
----Mesquite - High Cover (>25% cover)	0.6

Response Model Values by Indicator

This section provides additional information about each indicator and how the associated site intensity values were assigned in the CE response models for the status assessment. In addition, see **Appendix B: Species Current Scenario Generation Process Model** where more details are provided about the inputs and limitations for the corresponding KEA indicator scenarios for each of the indicators.

Development Indicator

The development indicator is a stressor-based indicator of the spatial extent and intensity of human modifications to the land surface that alter the habitat of species CEs in the MAR ecoregion. The indicator takes into account the extent and density of urban development; infrastructure such as above- and below-ground distribution corridors, communication towers, and border barriers; a wide range of transportation features; mines and landfills; recreational development; agriculture; and energy development. The site intensity values assigned to the various development features ranged from 0 to 1, with the highest value of 1.0 indicating no ecologically relevant effects, and the lowest value of 0.0 indicating modifications that essentially eliminate all natural cover and ecological functions.

It is important to note that most development features were assigned much lower values than the non-development change agents (i.e., fire regime departure, and invasives); for example, site intensity values for urbanization range from 0.05 to 0.6 for high to low density development, respectively, while the lowest site intensity values for invasives start at 0.65 and range as high as 0.9. This is because many types of development (e.g., high-intensity urban development, roads) have a more severe on-site impact than the other indicators. However, except for urban development, most features associated with the development indicator are highly discrete and localized and usually not readily visible at the scale of the ecological status maps; although not visible at this scale, they are nonetheless pervasive throughout the ecoregion. In particular, effects of many of the very small, local areas of development, or small linear features (e.g. dirt roads) are not readily visible at the scale of the development indicator maps.

Fire Regime Departure Indicator

The fire regime departure indicator is an indirect measure of fire regime across the CE's estimated distribution. It is based on the Vegetation Condition Class (VCC) dataset produced by Landfire, which was developed to compare historical reference conditions with current conditions for individual ecological system types. Landfire VCC is calculated based on changes to species composition, structural stage, and canopy closure, and derived by comparing expected (historical) proportions of structural stages with current proportions for the individual ecological system. This then results in a ranking of departure from expected historical range of variability, which can be interpreted as "how has the disturbance regime (for the REA purposes and relevant to this ecoregion: fire regime) changed from its historical variability for this individual CE." Two departure categories, *Severe Vegetation Departure* and *Moderate Vegetation Departure*, were used in the status assessments for this REA and are displayed in the fire regime maps. The The two departure categories were assigned different site intensity values: *Severe Vegetation Departure* was assigned 0.65 for all of the terrestrial CEs, and *Moderate Vegetation Departure* was assigned a higher value of 0.75, reflecting the expected lesser degree of impact.

Invasive Species Indicator

The invasive species indicator serves as an indirect (stressor-based) measure of vegetation composition, by measuring the cover of invasive species. It is based on a combination of two Integrated Landscape Assessment Project (ILAP, http://westernlandscapesexplorer.info/IntegratedLandscapeAssessmentProject) models of percent cover of 1) non-native grasses and forbs and 2) native woody increasers (mesquite). For each of these, the ILAP data included canopy cover on a continuous scale from 0% to over 90%; for the response models these continuous variables were broken into three classes of cover (see Table D-3). Each of the three classes was assigned site intensity values between 0 and 1 as shown in Table D-3. Higher values correspond to limited (but still significant) ecological impact, and lower values correspond to greater impact to the CE.

Overall Ecological Status Scoring

An overall "full" scenario (all KEA indicator scenarios combined into one) and associated overall ecological status map were also generated for each CE to provide overall CE status; however, such products typically beg the question of which indicators are driving the status at different locations. Therefore, as described above, the individual KEA indicator scenarios that represent relevant indicators (i.e., Development, Fire Regime Departure, and Invasive Species) were also assessed individually to illuminate their effects and inform understanding and potential management action.

Considerations and Limitations

As described in Appendix B (**Ecological Status Assessment Technical Approach** section) geospatial modeling always introduces assumptions and abstractions of actual ecosystem processes and CA effects. The many factors that can be observed and measured in the field cannot be fully captured with existing data and geospatial modeling. While the geospatial results can be field tested to some degree and calibrated to field observations, there will not be a one-to-one comparability between the KEAs & indicators identified in the CE conceptual models and what can be assessed with existing data. This methodology also does not model interactions between CAs, for example to calculate an increase in the distribution or intensity of one CA based on the presence or effects of another CA. However, in some cases the inputs used for the MAR (e.g., fire condition) are based on more complex models that do incorporate such interactions. Also note that some CAs are indicative of a current potential for impacts on CEs such as the invasives data from ILAP being predictive of the likelihood for presence of invasive species, rather than an actual mapped distribution of them.

Although ILAP had modeled data for percent cover of exotic invasive herbs, the ILAP team notes that it is a model with moderate uncertainty due to the lack of field-based input data for known locations (and cover) of invasive plants. The ILAP model for mesquite density/cover is a better model than that for invasive exotic herbs, as there are more field-based locations for known occurrences of mesquite; and the input data were vegetation sampling plots, which include percent cover estimates and not just presence/absence. But both of these datasets are modeled "predicted" distributions of the 2 types of invasives, not actual mapped distribution of them that has been field-verified. Outside of the ILAP data, there is a lack of comprehensive (MAR-wide) current distribution or risk of occurrence data for exotic invasive plants. This is an important data gap; there are some efforts by local groups (e.g. Southern Arizona Buffelgrass Coordination Center, http://www.buffelgrass.org/SABCC) to develop spatial data for invasives but these are somewhat local in scale, and there do not appear to be any ecoregion-wide comprehensive databases compiled for the MAR.

The Landfire Vegetation Condition Class (VCC) dataset is not a direct measure of fire risk or fire regime departure from expected historical range of variability. It was developed to compare historical reference conditions with current conditions for an individual ecological system type (Rollins et al. 2007). It provides a categorized measure of the difference between current vegetation type and structure, and estimated vegetation type, Biophysical Setting, (BpS) and structure from the time just prior to European settlement. It is calculated based on changes to species composition, structural stage, and canopy closure, and derived by comparing expected (historical) proportions of structural stages with current proportions (Rollins et al. 2007) within large enough summary landscape units to adequately represent the historical conditions versus current conditions. Landfire VCC calculations are done within variable size watersheds (4th, 5th or 6th level watersheds), depending upon the fire regime group to which each vegetation type (BpS) is assigned.

Hence the results from this indicator should not be over-interpreted relevant to current fire regime conditions; rather it provides a useful overview of where disturbance regimes in general are different from the expected historical regimes. Those differences can be due to a number of factors, such as impacts of drought and warmer temperatures over the past 20 to 30 years, increases in invasive grasses that introduce a regime of frequent fires to desert scrub ecosystems, the invasion of mesquite into upland grasslands due to the effects of many decades of land use practices, or effects of grazing or other activities that might alter the structural and compositional characteristics of the ecosystem.

As with all land cover mapping, limitations pertain to the age of the satellite imagery used for the mapping (ca. 1999 to 2001), the scale (1 acre minimum mapping unit), and both spatial and thematic resolution of the mapping.

The spatial representation of the Madrean Montane Conifer-Oak Forest and Woodland CE's distribution is a combination of several individual ecological systems, as is the conceptual model above. It's important to recognize that these individual ecological systems do have different fire regimes, positions in the landscape (north versus south slopes for example; or occurring at higher elevation), and species composition/structural characteristics, and hence different responses to disturbance, invasives, or human activities. However, the areal extent, even of the combined distribution, is small relative to the entire MAR. The fire regime departure indicator should be interpreted with caution relevant to this CE; however, is has been documented in the literature (Barton 1999, Barton et al. 2001, Danzer et al. 1996, Kaib et al. 1996, Schussman and Gori 2006, Smith 2006a, Swetnam and Baisan 1996, USDA-USFS 2009) that fire suppression, logging and other activities have lead to significant changes in fire regimes for many of the montane forests and woodlands of the southwestern U.S. There are no other limitations specific to the five upland CEs mapped derived from the SW ReGap land cover mapping products (Comer and Schulz 2007, Lowry et al. 2007).

As explained above, the distribution for the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe CE was derived from a different dataset than for the other five upland CEs. The TNC mapping of grasslands throughout the MAR (Gori and Enquist 2007, Gori et al. 2012) was completed more recently than the SW ReGap mapping, included many field-verified locations, and in addition has much value added because of the work to assign current condition classes to the mapped areas of grassland. Because the TNC data is spatially represented as large polygons of grasslands in different conditions (including areas of historical grasslands), the resultant distribution for this CE is not a “pixelated” predicted distribution. It is also important to note that the grassland polygons represent general areas of grasslands, and within those there are undoubtedly areas of woodlands, shrublands, bare ground, or even human development (the later can be seen in the results for the landscape condition – development indicator below).

References Cited

Anderson, L. E. 1990. A checklist of *Sphagnum* in North America north of Mexico. The Bryologist 93:500-501.

Anderson, L. E., H. A. Crum, and W. R. Buck. 1990. List of mosses of North America north of Mexico. The Bryologist 93:448-499.

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. Ecological systems of the United States: A working classification of U.S. terrestrial systems. NatureServe, Arlington, VA.

Comer, P. and D. Faber-Langendoen. 2013. Assessing Ecological Integrity of Wetlands from National to Local Scales: Exploring the Predictive Power, and Limitations, of Spatial Models. National Wetlands Newsletter Special Issue on Wetland Mapping and Assessment. Environmental Law Institute. Washington DC. Vol. 35 No. 3 May/June 2013.

Comer, P. J., and J. Hak. 2009. NatureServe landscape condition model. Internal documentation for NatureServe Vista decision support software engineering, prepared by NatureServe, Boulder, CO.

Comer P. J., and K. A. Schulz. 2007. Standardized Ecological Classification for Mesoscale Mapping in the Southwestern United States. *Rangeland Ecology & Management.* 60:3:324–335. [Journal Article]

De Leo, G. A., and S. Levin. 1997. The multifaceted aspects of ecosystem integrity. Conservation Ecology [online]1(1): 3. Available from the Internet. URL: http://www.consecol.org/vol1/iss1/art3/

Egan, R. S. 1987. A fifth checklist of the lichen-forming, lichenicolous and allied fungi of the continental United States and Canada. The Bryologist 90:77-173.

Egan, R. S. 1989. Changes to the "Fifth checklist of the lichen-forming, lichenicolous and allied fungi of the continental United States and Canada," edition I. The Bryologist 92:68-72.

Egan, R. S. 1990. Changes to the "Fifth checklist of the lichen-forming, lichenicolous and allied fungi of the continental United States and Canada," edition II. The Bryologist 93:211-219.

Egan, R. S. 1991. Changes to the "Fifth checklist of the lichen-forming, lichenicolous and allied fungi of the continental United States and Canada," edition III. The Bryologist 94:396-400.

Esslinger, T. L., and R. S. Egan. 1995. A sixth checklist of the lichen-forming, lichenicolous, and allied fungi of the continental United States and Canada. The Bryologist 98:467-549.

Faber-Langendoen, D., J. Rocchio, M. Schafale, C. Nordman, M. Pyne, J. Teague, T. Foti, and P. Comer. 2006. Ecological Integrity Assessment and Performance Measures for Wetland Mitigation. Final Report to US EPA Office of Water and Wetlands. NatureServe, Arlington, VA.

Harkness, M., M. Reid, P. Crist, L. Misztal, T. Van Devender, G. Kittel, D. Braun, and R. Unnasch. 2013. Madrean Archipelago Rapid Ecoregional Assessment: Pre-Assessment Report. Prepared for the U.S. Department of the Interior, Bureau of Land Management. NatureServe, Boulder, CO.

Holling, C. S. 1973. Resilience and stability of ecological systems. Annual Review of Ecology and Systematics 4: 1-23.

Jenkins, R. E. 1976. Maintenance of natural diversity: approach and recommendations. In: K. Sabol (ed.) Transactions–Forty -first North American Wildlife and Natural Resources Conference. Washington, D. C. March 21-25, 1976. Pp. 441-451.

Kartesz, J. T. 1999. A synonymized checklist and atlas with biological attributes for the vascular flora of the United States, Canada, and Greenland. First edition. In: J. T. Kartesz and C. A. Meacham. Synthesis of the North American Flora, Version 1.0. North Carolina Botanical Garden, Chapel Hill, NC.

Lowry, J. H, Jr., R. D. Ramsey, K. A. Thomas, D. Schrupp, W. Kepner, T. Sajwaj, J. Kirby, E. Waller, S. Schrader, S. Falzarano, L. Langs, G. Manis, C. Wallace, K. Schulz, P. Comer, K. Pohs, W. Rieth, C. Velasquez, B. Wolk, K., Boykin, L. O'Brien, J. Prior-Magee, D. Bradford and B. Thompson. 2007. Land cover classification and mapping. Chapter 2. In: J. S. Prior-Magee, K. G. Boykin, D. F. Bradford, W. G. Kepner, J. H. Lowry, D. L. Schrupp, K. A. Thomas, and B. C. Thompson (eds). Southwest Regional Gap Analysis Final Report. U.S. Geological Survey, Gap Analysis Program, Moscow, ID. Available online at: http://fws-nmcfwru.nmsu.edu/swregap/report/SWReGAP%20Final%20Report.pdf

Nachlinger, J., K. Sochi, P. Comer, G. Kittel, and D. Dorfman. 2001. Great Basin: an ecoregion-based conservation blueprint. The Nature Conservancy, Reno, NV. 160 pp. + appendices.

NatureServe. 2013. Terrestrial Ecological Systems of the Conterminous United States. Version 2.9. Completed in cooperation with USGS Gap Analysis Program and inter-agency LANDFIRE. Reflecting early 2000s land cover and MMU approx. 2 hectares. NatureServe, Arlington, VA, USA. Digital map.

Noss, R. F. 1987. From plant communities to landscapes in conservation inventories: A look at The Nature Conservancy (USA). Biological Conservation 41:11-37.

Noss, R. F., C. Carroll, K. Vance-Borland, and G. Wuerthner. 2002. A multicriteria assessment of the irreplaceability and vulnerability of sites in the Greater Yellowstone Ecosystem. Conservation Biology 16(4): 895-908.

Parrish, J. D., D. P. Braun, and R.S. Unnasch. 2003. Are we conserving what we say we are? Measuring ecological integrity within protected areas. Bioscience 53(9): 851-860.

Rollins, M.G., B.C. Ward, G. Dillon, S. Pratt, and A. Wolf. 2007. Developing the LANDFIRE Fire Regime Data Products. Documentation available on-line at: http://www.landfire.gov/documents_vcc.php

Stotler, R., and B. Crandall-Stotler. 1977. A checklist of liverworts and hornworts of North America. The Bryologist 80:405-428.

USDA-NRCS. 2014. Selected Approved Ecological Site Descriptions for Major Land Resource Area 041-Southeastern Arizona Basin and Range. US Department of Agriculture. Natural Resource Conservation Service. Website accessed September 2014. https://esis.sc.egov.usda.gov/Welcome/pgApprovedSelect.aspx?type=ESD

Unnasch, R.S., D. P. Braun, P. J. Comer, G. E. Eckert. 2009. The ecological integrity assessment framework: A framework for assessing the ecological integrity of biological and ecological resources of the National Park System**.** Report to the National Park Service.

Terrestrial Ecological Systems: Conceptual Models and Ecological Status

The individual CE content follows the below structure:

1. Ecological System X
   - 1.1. Conceptual Model
     - 1.1.1. Classification
     - 1.1.2. Summary
     - 1.1.3. Species of Conservation or Management Concern
     - 1.1.4. Natural Dynamics
       - 1.1.4.1. Natural Dynamics Model
     - 1.1.5. Change Agent Effects on the CE
       - 1.1.5.1. List of Primary Change Agents
       - 1.1.5.2. Altered Dynamics
       - 1.1.5.3. Altered Dynamics Model
     - 1.1.6. Ecological Status: Key Ecological Attributes and Indicators
       - 1.1.6.1. Key Ecological Attributes
     - 1.1.7. Relationship of KEAs to Fundamentals of Rangeland Health
     - 1.1.8. Conceptual Model Diagrams
   - 1.2. CE-Specific Assessment Methods
   - 1.3. Considerations and Limitations
   - 1.4. Ecological Status Assessment Results and Interpretation
     - 1.4.1. Current Ecological Status: Development, Fire Regime, Invasives
     - 1.4.2. Current Ecological Status: All Change Agents
   - 1.5. References for the CE

VALLEY UPLAND DIVISION

Desert Scrub

D-1 Chihuahuan Creosotebush Desert Scrub Ecological System

D-1.1 Conceptual Model

D-1.1.1 Classification

The ecosystem conservation elements for the MAR REA were selected from NatureServe's classification of terrestrial ecological systems (Comer et al. 2003). Over three dozen ecological systems occur in the MAR, but only a select subset were chosen for the REA. The CE concept provided in this conceptual model includes this NatureServe ecological system type:

- Chihuahuan Creosotebush Desert Scrub (CES302.731)

There are other terrestrial ecological systems in the NatureServe classification that also occur in the MAR, or in adjacent ecoregions, which are similar to this CE concept but are not included in this conservation element. These are listed here to help the reader understand what is not included in this conceptual model; each of these other ecological systems has information that can be searched for and reviewed on NatureServe's on-line Explorer website (http://explorer.natureserve.org/servlet/NatureServe). The System Code beginning with CES

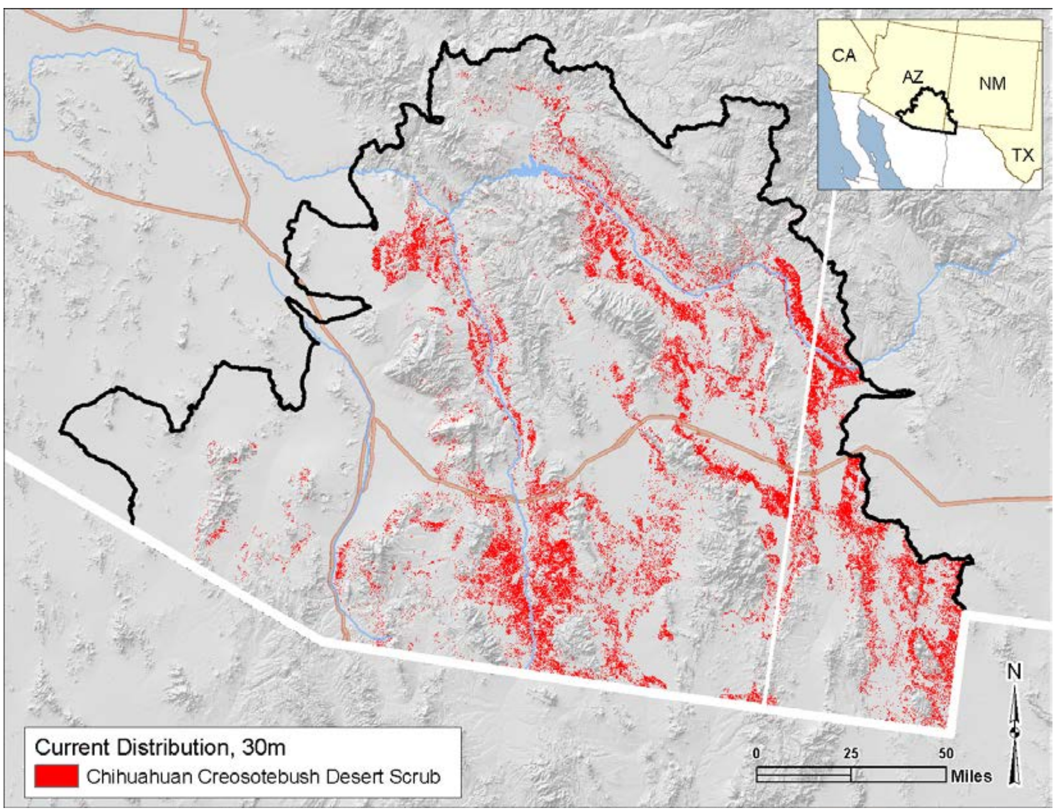
(Community Ecological System) is an information rich database code that refers to the North American Ecological Division (302) where the system primarily occurs and the number used to identify the system (Comer et al. 2003).

- Chihuahuan Mixed Desert and Thornscrub (CES302.734)
- Sonora-Mojave Creosotebush-White Bursage Desert Scrub (CES302.756); west edge of MAR
- Chihuahuan Mixed Desert and Thornscrub (CES302.734)
- Possibly degraded Apacherian-Chihuahuan Semi-Desert Grassland and Steppe (CES302.735)

D-1.1.2 Summary

This ecological system is the common lower elevation desert scrub that occurs throughout much of the Chihuahuan Desert and has recently expanded into former desert grasslands in the northern portion of its range. Stands typically occur in flat to gently sloping desert basins and on alluvial plains, extending up into lower to mid positions of piedmont slopes (bajada). Substrates range from coarse-textured loams on gravelly plains to finer-textured silty and clayey soils in basins. Soils are alluvial, typically loamy and non-saline, and frequently calcareous as they are often derived from limestone and to a lesser degree igneous rocks. A pebbly desert pavement may be present on the soil surface (Figure D-2).

Figure D-1. Distribution of Chihuahuan Creosotebush Desert Scrub at 30m resolution. The distribution was derived from the NatureServe (2013) terrestrial ecological systems map. Appendix G (ecological integrity) has a table listing the areal extent of this ecological system and its % of the assessment area.



Adjacent ecosystems may include Apacherian-Chihuahuan Semi-Desert Grassland and Steppe (CES302.735), Chihuahuan Mixed Desert and Thornscrub (CES302.734), Apacherian-Chihuahuan Mesquite Upland Scrub (CES302.733), and Madrean Juniper Savanna (CES305.730). Less commonly at upper elevations it may occur adjacent to Madrean Encinal (CES302.795) or Mogollon Chaparral (CES302.741) (Brown 1982b). The environmental description is based on several references, including Brown (1982b), Dick-Peddie (1993), Gibbens et al. (2005), Henrickson and Johnston (1986), Huerta-Martínez et al. (2004), MacMahon (1988), MacMahon and Wagner (1985), Muldavin et al. (2000b), Muldavin et al. (2002), and NatureServe Explorer (2013).

Figure D-2. Chihuahuan Creosotebush Desert Scrub on the east side of Dos Cabezas near Apache Pass (source http://azfirescape.org).

The vegetation is characterized by a moderate to sparse shrub layer (<10% cover on extremely xeric sites) that is typically strongly dominated by *Larrea tridentata* with *Flourensia cernua* often present to codominant (Figure D-2). A few scattered shrubs or succulents may also be present, such as *Agave lechuguilla, Parthenium incanum, Jatropha dioica, Koeberlinia spinosa, Lycium* spp., *Mortonia scabrella,* and *Yucca* spp. Additionally *Flourensia cernua* will often strongly dominate in silty basins that are included in this ecological system. In general, shrub diversity is low as this ecological system lacks codominant thornscrub and other mixed desert scrub species that are common on the gravelly mid to upper piedmont slopes. However, shrub diversity and cover may increase locally where soils are deeper and along minor drainages with occasional *Atriplex canescens, Gutierrezia sarothrae*, or *Prosopis glandulosa*. Herbaceous cover is usually low and composed of grasses, and some annual forbs. A cryptogamic soil crust is common in undisturbed stands. Common species may include *Bouteloua eriopoda, Dasyochloa pulchella (= Erioneuron pulchellum), Muhlenbergia porteri, Pleuraphis mutica, Scleropogon brevifolius*, and *Sporobolus airoides*. Included in this ecological system are *Larrea tridentata*-dominated shrublands with a sparse understory that occur on gravelly to silty, upper basin floors and alluvial plains. In some locations the invasive non-native *Pennisetum ciliare* (buffelgrass) may be abundant.

The vegetation description is based on several references, including Brown (1982b), Dick-Peddie (1993), Gibbens et al. (2005), Henrickson and Johnston (1986), Huerta-Martínez et al. (2004), MacMahon (1988), MacMahon and Wagner (1985), Muldavin et al. (2000b), Muldavin et al. (2002), and NatureServe Explorer (2013).

A crosswalk of this system to USDA Natural Resource Conservation Service (NRCS) approved Ecological Site Descriptions (ESD) by Major Land Resource Areas (MLRA) is provided in Table D-4 (USDA-NRCS 2014). For complete list of ESDs for MLRA 41 see https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD.)

Table D-4. Chihuahuan Creosotebush Desert Scrub ecosystem CE crosswalk with approved Ecological Site Descriptions (provisional cross-walk).

MLRA	Ecological Site Description Name	Site ID
041-Southeastern Arizona Basin and Range	Limy Fan 8-12" p.z. */ Larrea tridentata / Muhlenbergia porteri* (/ creosote bush / bush muhly)	R041XB 206AZ
041-Southeastern Arizona Basin and Range	Limy Slopes 8-12" p.z. */ Larrea tridentata - Acacia constricta / Muhlenbergia porteri – Aristida* (/ creosote bush - whitethorn acacia / bush muhly - threeawn)	R041XB 207AZ
041-Southeastern Arizona Basin and Range	Limy Upland 8-12" p.z. / *Larrea tridentata / Muhlenbergia porteri - Aristida* (/ creosote bush / bush muhly - threeawn)	R041XB 208AZ
041-Southeastern Arizona Basin and Range	Gypsum Upland 8-12" p.z. / *Larrea tridentata - Acacia constricta* / (/ creosotebush - whitethorn acacia /)/	R041XB 219AZ
041-Southeastern Arizona Basin and Range	Gypsum Slopes 8-12" p.z. / *Larrea tridentata - Acacia neovernicosa / Pleuraphis mutica – Aristida* (/ creosotebush - viscid acacia / tobosa - Aristida)	vR041X B231AZ
041-Southeastern Arizona Basin and Range	Limy Upland 12-16" p.z. / *Larrea tridentata - Acacia constricta / Muhlenbergia porteri – Aristida* (/ creosote bush - whitethorn acacia / bush muhly - threeawn)	R041XC 309AZ

D-1.1.3 Species of Conservation or Management Concern

Listed below are species of conservation or management concern that are associated with Creosotebush Scrub from the BLM Gila District (USDI-BLM 2010) and from the list of typical Threaten-Endangered Species/Species of Concern/Species of Interest (TE/SOC/SOI) species associations in Desert Communities from Coronado National Forest Ecological Sustainability Report (USDA-USFS 2009); and Species of Greatest Conservation Need (SGCN) from the New Mexico Comprehensive Wildlife Conservation Strategy NMDGF (2006).

Birds: Le Conte's Thrasher (*Toxostom lecontei*)

Reptiles: Gray-Checkered Whiptail (*Cnemidophorus dixoni*), Red-backed Whiptail (*Aspidoscelis xanthonota*)

D-1.1.4 Natural Dynamics

The Chihuahuan Creosotebush Desert Scrub CE is a stable ecosystem that is well suited to the hot, very dry basins and low hills where it occurs. The dominant and diagnostic species, *Larrea tridentata* is very long-lived species (some clones have been estimated to be over 10,000 years). It is highly adapted to minimized evapotranspiration both daily and seasonally using stomatal regulation, resinous leaves, and a leaf structure and habit to minimize self-shading and maximize photosynthesis during favorable growing periods (Hamerlynck et al. 2002, Ogle and Reynolds 2002). *Larrea tridentata* is poorly adapted to fire because of its highly flammable, resinous leaves and limited sprouting ability after burning although it may survive lower intensity fires (Brown and Minnich 1986, Humphrey 1974, Marshall 1995, Paysen et al. 2000). McLaughlin and Bowers (1982) reported that burned individuals surviving a fire regained their former size in five years.

Historic fire regimes for Chihuahuan Creosotebush Desert Scrub are difficult to quantify but fires were rare with a fire return interval (FRI) ranging from 300-1000 years - 500 on average (from Landfire BpS Model 2510740). The fire characteristics range from low to moderate to high intensity, moderate severity, stand replacing crown fires that occur during spring, summer and fall seasons. Fires tend to be small or medium in size and need unusual conditions (e.g., a drought following an unusually wet year so there are adequate fine fuels are available to carry a fire) (Brown and Minnich 1986, Paysen et al. 2000).

Weather stress such as drought also affects this community by reducing vegetation cover (especially grasses) every 80 years or so, but does cause significant shrub mortality although shrubs may die-back some (from Landfire BpS Model 2510740) (Humphrey 1974).

Herbivory by native herbivores in the Chihuahuan Creosotebush Desert Scrub CE includes small mammals, reptiles and invertebrates. *Larrea* leaves are not edible to most animals; however seeds are used by many small mammals (Paysen et al. 2000).

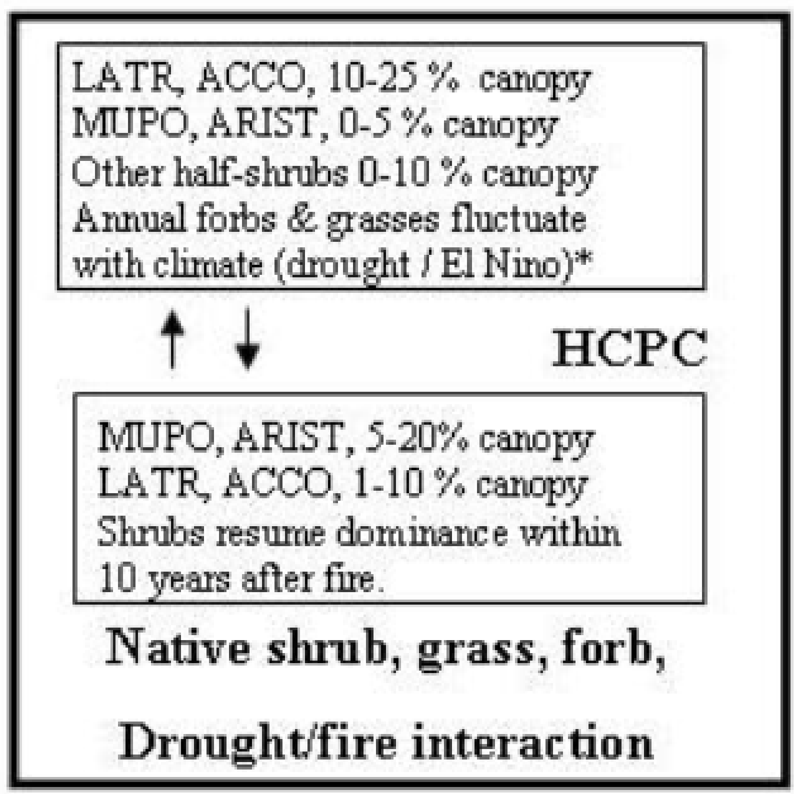
A good condition/proper functioning Chihuahuan Creosotebush Desert Scrub is large and uninterrupted, the surrounding landscape is also in good condition; the biotic condition is within normal range of variation: the weeds are few, the native plants are robust, have expected abundance and reproduction; birds, mammals, reptiles, insects and amphibian species present are indicative of reference, un-molested conditions; the fire regime is functioning at near historical conditions with FRI (fire return interval) of stand replacing fires every 300-1000 years, soils have not been excessively eroded.

A poor condition/non-functioning ecosystem is highly fragmented, or much reduced in size from its historical extent; the surrounding landscape is in poor condition either with highly eroding soils, many non-native species or a large percentage of the surrounding landscape has been converted to pavement or disturbed by off road vehicles; the biotic condition is at the limit or beyond natural range of variation, e.g. vegetation composition is altered and is not dominated by native shrubs such as *Larrea tridentata* and *Flourensia cernua.* Characteristic birds, mammals, reptiles, and insect species are not present at expected abundances or the ratio of species shows an imbalance of predator to prey populations; abiotic condition is poor with evidence of high soil erosion, rill and gullies present or exposed soil sub horizons. Non-native grasses invasion provides fine fuels that may increase fire frequency, intensity and severity.

D-1.1.4.1 Natural Dynamics Model

Conceptual historical state-and-transition models were developed by several ecology teams (Muldavin et al. 2012, Schussman 2006) and NRCS for the Chihuahuan Creosotebush Desert Scrub ecosystem. Below is a conceptual historical state and transition model of the Historic Climax Plant Community (HCPC) portion of the state and transition model for Limy Fan 8-12" p.z. / *Larrea tridentata / Muhlenbergia porteri* ESD R041XA107AZ was taken directly from the 041-Southeastern Arizona Basin and Range MLRA at: https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD. This model is representative of the Chihuahuan Creosotebush Desert Scrub (Figure D-3).

Figure D-3. Conceptual state and transition model of historical conditions for the Chihuahuan Creosotebush Desert Scrub CE.. This model is the Historic Climax Plant Community (HCPC) portion of a larger model that was taken directly from NRCS ESD R041XB206AZ Limy Fan 8-12" p.z. / *Larrea tridentata / Muhlenbergia porteri*.



Model description was taken directly from ESD R041XB206AZ:

Description of State and Transition Model

The following model discussion was excerpted directly from the Ecological Site Description (ESD) for R041XB206AZ. Limy Fan 8-12" p.z. / *Larrea tridentata / Muhlenbergia porteri* from the 041-Southeastern Arizona Basin and Range MLRA.
https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD

"The potential plant community is a shrub-land dominated by creosotebush. Annual forbs and grasses are very important in the plant community on this site. Cryptogams (lichens, mosses) and blue-green algae are also important in the plant communities on this site. With continuous heavy grazing, bush muhly is removed from the plant community and creosotebush increases. Areas of this site mapped in alluvial fan positions are very susceptible to rill and gully erosion."

D-1.1.5 Change Agent Effects on the CE

This section of the conceptual model presents a narrative description of the primary change agents and current knowledge of their effects on Chihuahuan Creosotebush Desert Scrub ecosystem. The section contains two sub-sections: (1) A list of primary change agents identified for the CE; and (2) a discussion of altered dynamics caused by these agents.

D-1.1.5.1 List of Primary Change Agents

Occurrences of this desert scrub ecological system are directly affected by livestock grazing, direct and indirect wildfire suppression activities, land development, and non-native plant species invasion. Table D-5 identifies the most likely impacts associated with each of these stressors.

Table D-5. Stressors and their likely impacts on the Chihuahuan Creosotebush Desert Scrub ecosystem CE in the Madrean Archipelago ecoregion.

Stressor	Impacts
Land Use	
Livestock grazing	Although limited in extent in desert scrub, grazing by livestock (incompatible stocking rates, season of use, or duration) can affect the structure and composition of desert plant communities, as well as soil structure and water infiltration (Milchunas 2006). Livestock movement can be a vector for invasive non-native plant seed (USDA-USFS 2009).
Development	
Transportation infrastructure Roadways/railways and transmission lines	Fragmentation from transportation infrastructure leads to disruptions in ecological processes such as fire, dispersal of invasive non-native species, and can alter hydrological processes such as surface flow when excessive runoff from roads creates gullies. Additionally increased mortality from road kill affects wildlife (USDA-USFS 2009).
Suburban/Rural (include Military), Mines/Landfill	This stress contributes to altered fire regimes, increased erosion, direct habitat loss/conversion, increased groundwater pumping, fragmentation, and invasive non-native species dispersal.
Energy (Renewable wind/solar), Oil/Gas	This stress contributes to altered fire regimes, increased erosion, direct habitat loss/conversion, increased groundwater pumping, fragmentation, and invasive non-native species dispersal.
Uncharacteristic Fire Regime	Fire is not a natural disturbance process in desert communities. Fire kills many native desert plants. No native desert species of conservation concern are adapted to fire (USDA-USFS 2009).

Stressor	Impacts
Invasive non-native Species	Invasive non-native grasses out-compete and replace native desert plants. These grasses burn easily, and so fire frequency and severity increases. Invasive non-native grasses fill gaps needed by some species, reduce available native foods, and shift prey species assemblages. Species diversity suffers (USDA-USFS 2009).
Climate change	Alteration of precipitation and evapotranspiration rates and timing may result in more frequent drought periods and higher intensity precipitation events, which following drought can cause significant erosion of topsoil (Finch 2012, Garfin et al. 2012).

D-1.1.5.2 Altered Dynamics

Altered dynamics are not an issue with historical stands of Chihuahuan Creosotebush Desert Scrub as it is a stable vegetation type with robust ecological dynamics, although it can be sensitive to anthropogenic disturbance such as mechanical/chemical removal. However, in the U.S., much of the current extent of this desert scrub is the result of recent expansion of *Larrea tridentata* into former desert grasslands in the last 150 years from the combined effects of drought, overgrazing by livestock, and/or decreases in fire frequency over the last 70-250 years (Ahlstrand 1979, Buffington and Herbel 1965, Donart 1984, Dick-Peddie 1993, Gibbens et al. 2005). This system now includes vast areas of loamy plains that have been converted from *Pleuraphis mutica* and *Bouteloua eriopoda* desert grasslands to *Larrea tridentata* scrub. This system also includes expanding *Flourensia cernua* shrublands that occur in former (now degraded) tobosa (*Pleuraphis mutica*) flats and loamy plains. Presence of *Scleropogon brevifolius* is common on these degraded sites. Dick-Peddie (1993) suggested that absence of *Flourensia cernua* as codominant and presence of *Dasyochloa pulchella, Acourtia nana (= Perezia nana)*, and *Yucca elata* may be indicators of recent conversion of desert grasslands into desert scrub, but more research is needed. Conversely, *Larrea tridentata* shrublands with a sparse understory on remnant early Holocene erosional surfaces (often with desert pavement), may indicate historical distributions of *Larrea tridentata* desert scrub in the Chihuahuan Desert (Muldavin et al. 2000b).

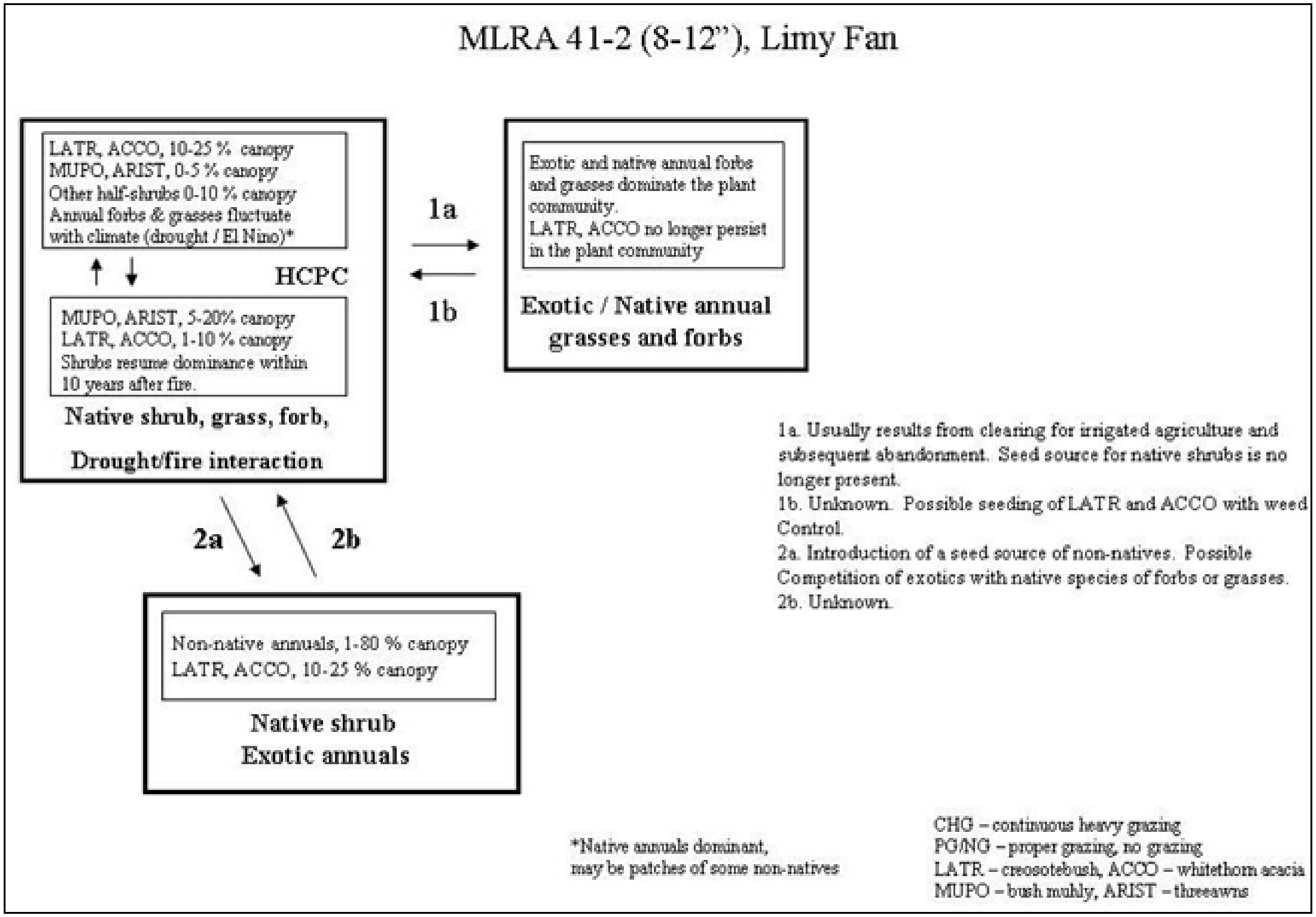
The impact of livestock grazing to the historical stands of desert scrub is expected to be relatively small because there is little forage available for them in this type, but where livestock grazing or other anthropomorphic disturbance occurs there may be increased soil erosion.

Altered (uncharacteristic) fire regimes greatly influence ecosystem processes. The historical desert scrub has a very long fire return interval (FRI) ranging from 300-1000 years (500 years on average) (from Landfire BpS Model 2510740). *Larrea tridentata* and other desert scrub plant species are sensitive to burning, most do not resprout and are slow to recover, and therefore burning should be a rare event to be avoided. Invasion of non-native grasses provides fine fuels that may increase fire frequency, intensity and severity.

D-1.1.5.3 Altered Dynamics Model

Conceptual state-and-transition models were developed by several ecology teams (Muldavin et al. 2012, Schussman 2006) and NRCS for the Chihuahuan Creosotebush Desert Scrub ecosystem. Below is a conceptual state and transition model of the current conditions for the NRCS ESD R041XB206AZ for Limy Fan 8-12" p.z. / *Larrea tridentata / Muhlenbergia porteri* that was taken directly from the 041-Southeastern Arizona Basin and Range MLRA at: https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD. This model is representative of the Chihuahuan Creosotebush Desert Scrub (Figure D-4). It includes the Historic Climax Plant Community (HCPC) as part of the model.

Figure D-4. Conceptual state and transition model of current conditions for the Chihuahuan Creosotebush Desert Scrub CE. This model was taken directly from NRCS ESD R041XB206AZ Limy Fan 8-12" p.z. / *Larrea tridentata / Muhlenbergia porteri* and includes the Historic Climax Plant Community (HCPC) portion with the larger model.



Model description taken directly from ESD R041XB206AZ:

Description of State and Transition Model

The following model discussion was excerpted directly from Ecological Site Description (ESD) for R041XB206AZ. Limy Fan 8-12" p.z. / *Larrea tridentata / Muhlenbergia porteri* from the 041-Southeastern Arizona Basin and Range MLRA.
https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD

The HCPC portion of this model represents this ecosystem under natural dynamic conditions. The Altered Dynamic portions of this community are shown with arrows indicating introduction of non-native annual grasses and forbs.

“The potential plant community is a shrub-land dominated by creosotebush. Annual forbs and grasses are very important in the plant community on this site. Cryptogams (lichens, mosses) and blue-green algae are also important in the plant communities on this site. With continuous heavy grazing, bush muhly is removed from the plant community and creosotebush increases. Areas of this site mapped in alluvial fan positions are very susceptible to rill and gully erosion.”

D-1.1.6 Ecological Status: Key Ecological Attributes and Indicators

D-1.1.6.1 Key Ecological Attributes

Table D-6 identifies the key ecological attributes for the CE within the Madrean Archipelago ecoregion. A **key ecological attribute** of a focal ecological resource is a characteristic of the resource’s biology, ecology, or physical environment that is critical to the resource’s persistence in the face of both natural and human-caused disturbance. Alteration of such a characteristic beyond some critical range of variation will lead to the degradation or loss of the resource within decades or less. The KEAs table lists the identified key ecological attributes, with a brief definition, a rationale for why it is important for the CE, and a listing of stressors or change agents that might be affecting the key attribute.

Table D-6. Key ecological attributes (KEAs) of Chihuahuan Creosotebush Desert Scrub ecosystem CE in the Madrean Archipelago ecoregion. Indicators for these KEAs can be used to determine the ecological status for this CE; see **Table D-2** for a list of the indicators assessed in this REA.

***KEA Class:* Name**	**Definition general**	**Rationale general**	**Stressors general**
***Landscape Context:* Landscape Condition**	This attribute is the amount of anthropogenic disturbance of the ecosystem that can be identified using a Land Condition Model Index (LCM). It incorporates a number of development features (including roads, urban/rural areas, agriculture, mines, transmission corridors, and energy development) that degrade the condition of the landscape.	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance (Comer and Hak 2009)	Stressors to landscape condition include multiple sources of fragmentation (reduces connectivity) that alter ecological processes (e.g., fire or surface hydrology), degrade wildlife habitat and disrupt wildlife migration patterns by creating barriers to species movement. Stressors include livestock grazing (reduces fine fuel that carry fire), urban and exurban development, and road building.
***Size/Extent:* Patch Size Distribution**	The distribution of patch sizes (number and size class frequency) is a measure of fragmentation in this historically matrix or large patch ecosystem. Historical patch size/frequency is compared with current patch size/frequency.	This attribute is used to evaluate level of ecosystem fragmentation that interferes with landscape scale ecological processes. The current average patch size and total number of patches of the type are compared to earlier conditions where data are available.	Stressors include conversion to agriculture/pasture, commercial/industrial/residential use and construction of transportation infrastructure - roads, pipelines, transmission lines - that interfere with large-scale ecological processes such as fire or surface hydrology.

KEA Class: Name	Definition general	Rationale general	Stressors general
Size/Extent: **Ecosystem "Occurrence" Extent**	This attribute assesses the current size (ha) of the occurrence or stand as affects its biodiversity richness, structural complexity, and "internal" ecological processes, especially landscape scale processes like fire. Patch Size is measured as percentage of the Minimum Dynamic Area (MDA) for the ecosystem. This CE is a Matrix/Large Patch type that functions best when patches are large ranging from 20 to 2000 hectares (approximately 50 to 5000 acres) for large patch to 2000 to 405,000 hectares (approximately 5000 to 1,000,000 acres) for matrix.	The area necessary to maintain ecological processes and ensure persistence is an ecosystem's minimum dynamic area (Pickett and Thompson 1978). Ecosystems with patch sizes above the minimum dynamic area (MDA) tend to exhibit vegetation structure and composition, landscape scale ecological processes, and soil and hydrology that are functioning within the natural range of variation. However, the role of patch size in assessing ecological integrity is complex and related to the larger landscape context. Fragmentation from roads and subdivisions has reduced the size of many patches so that the fire regime cannot be restored to pre-1882 frequency without management action i.e., prescribed fire. The MDA to maintain the fire regime (or any natural disturbance regime) under the historical range of natural variation for this ecological system has not been determined. Little empirical study has been done in ecosystems outside of eastern forests to determine the MDA; Faber-Langendoen et al. (2012b) developed criteria for rating patch size based on the spatial patterning of the ecosystem (i.e., matrix, large patch, small patch, or linear) and provide a discussion of the protocol for assessing size/extent.	Stressors to ecosystem extent include actions such as development and fire exclusion that directly or indirectly convert the ecosystem to other land uses or cover types, or actions such as roads that fragment large patches into many small patches.
Biotic Condition: **Terrestrial Fauna**	The taxonomic and functional (e.g., guild) composition of the native faunal assemblage of the ecosystem including birds, mammals, reptiles and amphibians, and invertebrates; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term). Monitoring populations of key native fauna will provide information on the condition of these important components of this ecosystem.	The taxonomic and functional composition of the faunal assemblage is an important aspect of the ecological integrity of an ecosystem. Many native species of birds, mammals, reptiles and amphibians, and invertebrates use this ecosystem as habitat for feeding, resting, breeding, and movement; and their patterns of use vary over time (seasonal, annual, longer-term). These species vary in their sensitivity to different stresses such as alterations to vegetation composition, fire frequency, and water availability. Alterations in the taxonomic and functional composition of the terrestrial faunal assemblage beyond its natural ranges of variation therefore strongly indicate the types and severities of stresses imposed on the ecosystem.	Stressors to the taxonomic and functional composition of the faunal assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, floral composition, and abiotic condition of the ecosystem; and incursions of non-native species that alter the food web or directly compete with or prey on the native fauna.

KEA Class: Name	Definition general	Rationale general	Stressors general
***Biotic Condition:* Vegetation Composition**	The overall plant species composition and diversity of an ecosystem is an important aspect of its ecological integrity and largely defines it.	The taxonomic and functional composition of the plant species assemblage is an important aspect of the ecological integrity of a terrestrial ecosystem; many ecological processes and environmental variables affect it (drought, fire regime, anthropomorphic disturbance). Invasive non-native grasses may out-compete and replace native desert plants. These grasses burn easily, and so fire frequency and severity increases (USDA-USFS 2009). Livestock grazing can affect the structure and composition of some desert scrub, as well as soil structure and water infiltration, and species diversity. Plant species vary in their sensitivity to different stresses such as livestock grazing or fire. This can alter the taxonomic composition of the terrestrial floral assemblage beyond its natural range of variation and strongly indicate the types and severities of stresses imposed on the ecosystem.	Stressors to the taxonomic and functional composition of the plant assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, vegetation structure, and abiotic condition of the ecosystem; especially altered fire regime, improper livestock grazing management, and incursions of non-native species that alter the food web or directly compete with the native plants.
***Biotic Condition:* Vegetation Structure**	An assessment of the overall structural complexity of the vegetation layers, including presence or cover of multiple strata, age and structural complexity of main canopy layer, and expected frequencies of successional or age classes.	Vegetation structure is an important reflection of dynamics and creates heterogeneity within the community. The distribution of total cover, crown diversity, stem size, and age classes or cohorts reflects natural disturbance regimes across the landscape and affects the maintenance of biological diversity, particularly of species dependent upon specific stages. An open canopy of shrubs with low cover of grass vegetation is typical of the Chihuahuan Creosotebush Desert Scrub CE.	Alteration of vegetation structure can come from a variety of stressors, including changes in fire regime (e.g. too frequent), other removal of woody species especially with herbicide, livestock grazing or concentrated native herbivory that removes native perennial herbaceous plants, climate change, and various kinds of mechanical disturbance that damages or removes vegetation.

KEA Class: Name	Definition general	Rationale general	Stressors general
Abiotic Condition: **Soil Condition**	Soil is basic to the proper functioning of a terrestrial ecosystem. Good soils will enhance the resilience and function of an ecosystem. Poor condition soil will limit the function of an ecosystem and if not addressed can permanently degrade a site. Soil condition includes indicators of multiple soil properties such as soil structure (particle and pore size, vertical profile, soil aggregates) and surface condition such as presence of soil crusts.	The condition of soil/surface substrate directly affects the functioning of the ecosystem. Soil/surface substrate condition of a site can be directly evaluated using indicators of soils disturbance such as evidence of erosion and disrupted soil processes and properties. The types of disturbances (stressors) can also be recorded to indicate condition such as livestock trampling and recreational vehicles. These disturbances can directly affect soil properties by disturbing soil crusts, compacting pore space that reduces water infiltration and percolation, changing other structural characteristics, and can expose soils to increased erosional forces.	Excessive livestock trampling, vehicle use (motorbikes, off-road vehicles, construction vehicles), filling and grading, plowing, other mechanical disturbance to the soil surface, excessive soil movement (erosion or deposition) as evidenced by gully, rill, or dune formation. Climate change and drought can also lead to increased potential for erosion.
Abiotic Condition: **Fire Regime**	Fire is a natural agent of disturbance in upland vegetation communities that maintains species composition, vegetation structure, and sustains ecological processes such as nutrient cycling.	Altered (uncharacteristic) fire regime greatly influences ecosystem processes. For Chihuahuan Creosotebush Desert Scrub fire return interval (FRI) is very long ranging from 300-1000 years (500 years on average) (from Landfire BpS Model 2510740). The fire intensity varies from low to high intensity, moderate severity stand replacing crown fires that occur during spring, summer and fall seasons. Fires tend to be small or medium in size and need unusual conditions to burn. Fire is detrimental to this ecosystem.	Burning fire-sensitive ecosystems such as Chihuahuan Creosotebush Desert Scrub results in decreased woody species density and cover, changes in wildlife species assemblages, and often increased fine fuels that increase frequency of fire in future. The dominate shrub, creosotebush is highly flammable and readily killed by even low intensity fire and rarely re-sprouts (Marshall 1995)

D-1.1.7 Relationship of KEAs to Fundamentals of Rangeland Health

The key ecological attributes and indicators listed in Table D-6 also encompass the four fundamentals of rangeland health (USDI-BLM 2006), as shown in Table D-7. The KEA of Landscape Condition specifically refers to watershed conditions; all other KEAs refer specifically to Ecological Processes and Habitat. However, many of the indirect indicators for the KEAs for Abiotic Condition focus on stressors that arise as a result of modifications to the watershed or water quality, the fourth Fundamental. These relationships are also indicated in Table D-7. Further information about interpretation and assessment of these fundamentals of rangeland health can be found in Pellant et al. (2005).

Table D-7. Key Ecological Attributes (KEAs) for the Chihuahuan Creosotebush Desert Scrub ecosystem and their relationship to fundamentals of rangeland health.

Indicator	Watershed	Ecological Processes	Water Quality	Habitat
Landscape Condition	X	X		X
Patch Size	X	X		X
Terrestrial Fauna				X
Vegetation Composition		X		X
Soil Condition		X	X	X
Fire Regime	X	X		X

D-1.1.8 Conceptual Model Diagrams

See Figure D-3 and Figure D-4 above.

D-1.2 Ecological Status Assessment Results and Interpretation

This section of the appendix presents and discusses the results of the ecological status assessment for the Chihuahuan Creosotebush Desert Scrub CE. The presentation addresses each indicator separately, and then addresses the overall assessment, which integrates the results of all individual indicators. The results are presented using a common framework, in which the status of an indicator – or the combination of all indicators – is scored on a scale from 0.0 to 1.0, where 0.0 indicates a condition of complete replacement of reference ecological conditions due to the impacts of stressors, and 1.0 indicates a condition of no alteration of reference ecological conditions. The same color ramp is used for all results, yellow to dark blue, where yellow equals low scores, green moderate scores and dark blues high scores.

D-1.2.1 Current Ecological Status: Development, Fire Regime, Invasives

The maps below (

Figure D-5) show the ecological status results for each of the three individual indicators – development, fire regime departure, and invasives – for the Chihuahuan Creosotebush Desert Scrub.

The development indicator is a stressor-based indicator of the spatial extent and intensity of human modifications to the land surface that alters ecosystems or habitat in the MAR ecoregion. The indicator takes into account the density of urban development; infrastructure such as above- and below-ground distribution corridors, communication towers, and border barriers; a wide range of transportation features; mines and landfills; recreational development; agriculture; and energy development. The scoring is on a continuous scale from 0 to 1, with the highest score of 1.0 indicating no ecologically relevant modifications, and the lowest score of 0.0 indicating modifications that essentially eliminate all natural cover and ecological functions.

The development indicator results shown in the first map of

Figure D-5 show several large areas and corridors of intense development throughout the ecoregion, representing areas of municipal and agricultural development. Development impacts are especially noticeable in and around residential communities in the ecoregion such as Benson, Bisbee, Douglas, Huachuca City, Sierra Vista, Stafford, and Tombstone; and along corridors associated with interstate highway 10 and many other larger roads. Effects of many of the very small, local areas of development, or small linear features (e.g. dirt roads) will not be obvious at the scale of this map. However spatial results indicate most of the land condition has low density of development for Chihuahuan Creosotebush Desert Scrub ecosystem.

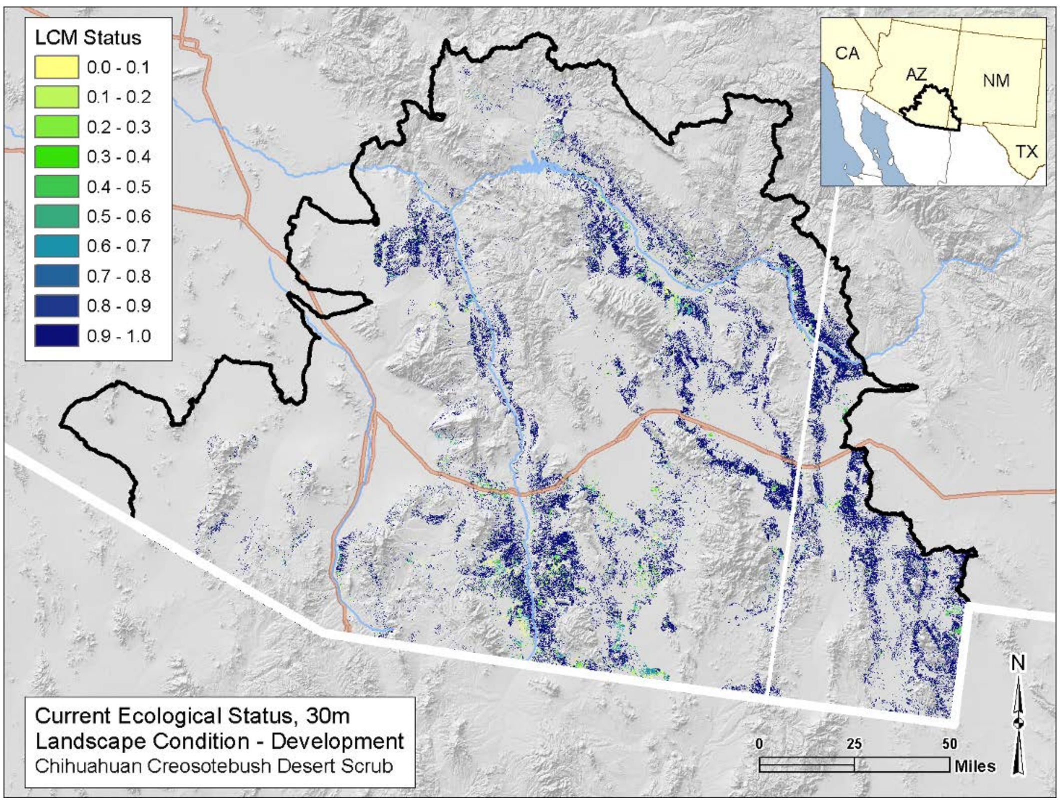
It is important to note that most development impacts are scored much lower than non-development change agents; for example, site intensity values for urbanization ranged from 0.05 to 0.6 for high to low density development, respectively. This is because development typically has a much stronger on-site impact than the other indicators. However, except for urban development, most development impacts occur at smaller scales than can be displayed in these maps, but still are pervasive throughout much of the ecoregion. In particular, effects of many of the very small, local areas of development, or small linear features (e.g. dirt roads) will not be obvious at the scale of the development indicator map.

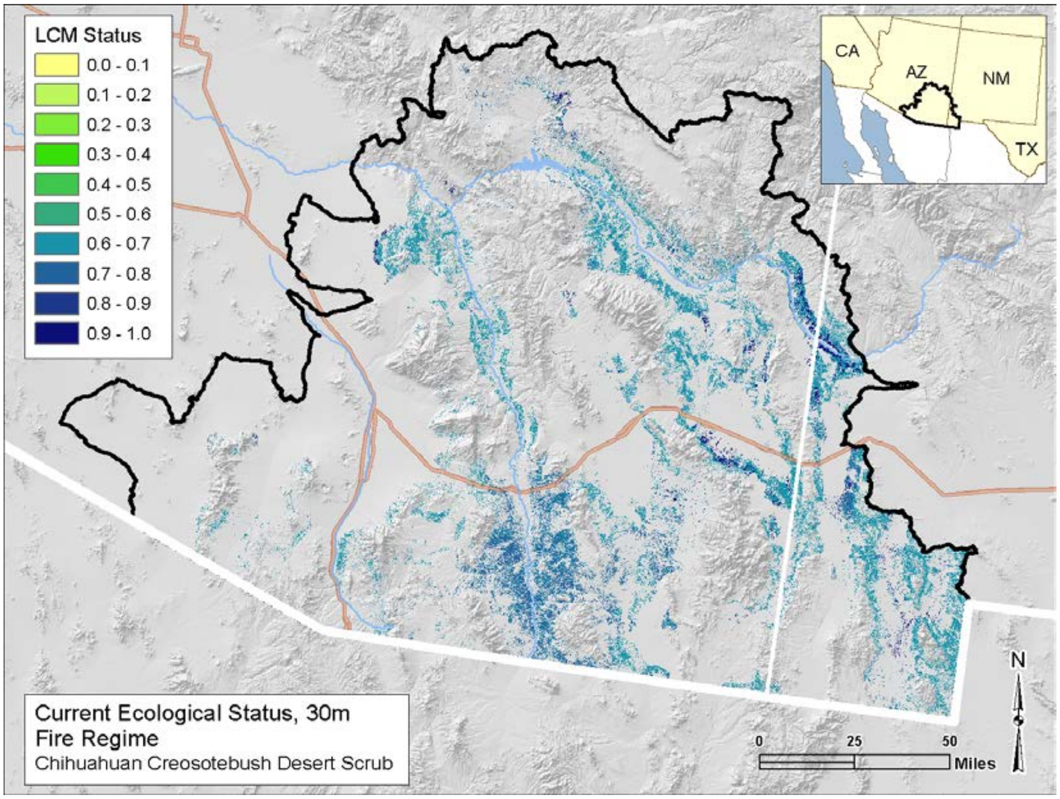
The second indicator is an indirect measure of fire regime. It is based on the Vegetation Condition Class (VCC) dataset produced by Landfire, which was developed to compare historical reference conditions with current conditions for an individual ecological system type (see **Status Assessment Methods** above). The result of VCC is a ranking of departure from expected historical range of variability, which can be interpreted as “how has the disturbance regime [for the REA purposes and relevant to this ecoregion: fire regime] changed from its historical variability for this individual CE”. Only Severe Vegetation Departure (0.65) and Moderate Vegetation Departure (0.75) were used and are displayed in the map; no to minor departure was scored as 1 (dark blue in the map).

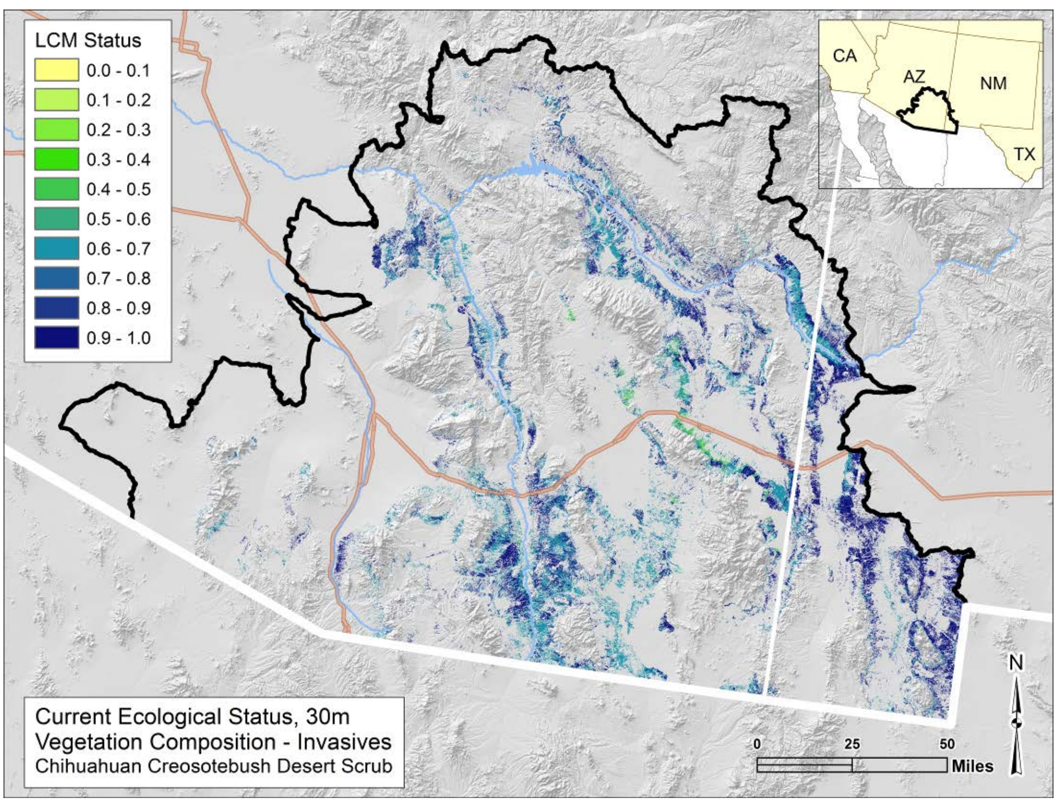
The second map in

Figure D-5 show much of the area of this CE is in severe departure throughout the ecoregion. The Chihuahuan Creosotebush Desert Scrub rarely burned historically largely because of the lack of fine fuels necessary to carry fire (Brown and Minnich 1986, Paysen et al. 2000). The historical fire return interval (FRI) ranged from 300-1000 years - 500 on average (from Landfire BpS Model 2510740). The introduction of non-native annual grasses provides fuels, especially following a wet period (Brown and Minnich 1986, Paysen et al. 2000). Altered (uncharacteristic) fire regime greatly influences ecosystem processes and increased fire frequency is detrimental to this ecosystem.

Figure D-5. Scores for three indicators for Chihuahuan Creosotebush Desert Scrub: development indicator (first map), fire regime departure indicator (second map), and invasive species indicator (third map) for each 30m pixel. At the ecoregion scale, many development features are not readily visible (i.e. secondary roads or highways, railroads, small agricultural fields). Yellow (equivalent to 0) indicates high impacts from the CA, dark blue (equivalent to 1) indicates little to no impact from the CA. Only 3 classes of fire regime condition are scored: no to little departure (dark blue), moderate departure and severe departure (lighter blues). For the invasives indicator results, higher cover of mesquite or invasive exotics will score between .4 and .6 (light greens), while lower cover scores between .6 and .8 (light blues).




LCM Status
0.0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1.0
CA
AZ
NM
TX
Current Ecological Status, 30m
Fire Regime
Chihuahuan Creosotebush Desert Scrub
0
25
50
Miles
N


LCM Status
0.0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1.0
CA
AZ
NM
TX
Current Ecological Status, 30m
Vegetation Composition - Invasives
Chihuahuan Creosotebush Desert Scrub
0
25
50
Miles
N

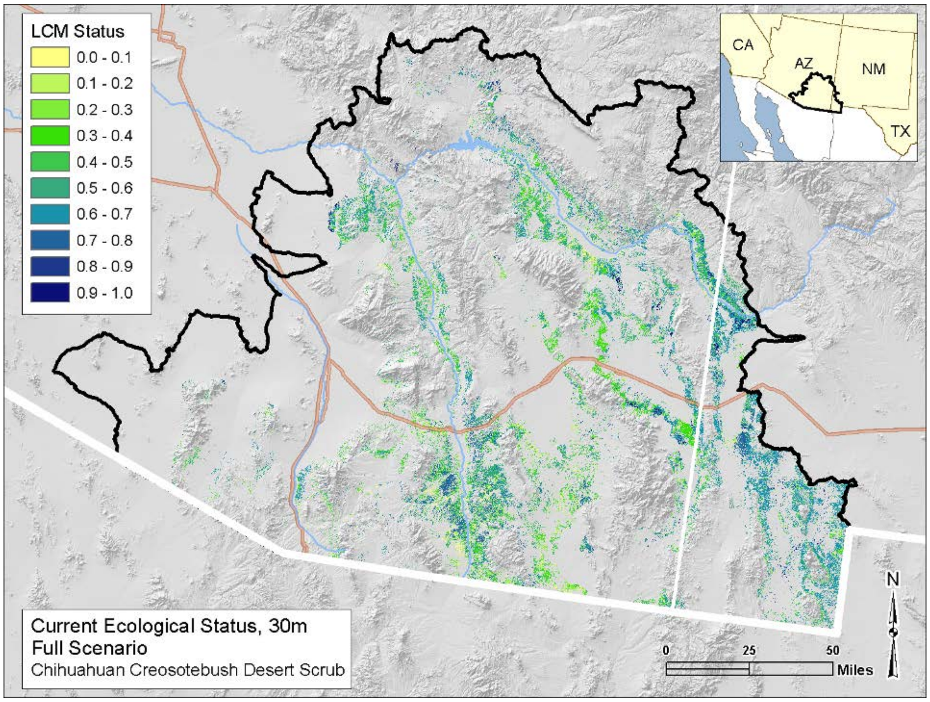
The third indicator is an indirect measure of vegetation composition, by measuring the cover of invasive species. It is a combination non-native grass and forbs and native woody increasers (mesquite cover), as described previously in this appendix. The scoring is on a continuous scale, from 1.0 indicating no ecologically relevant amounts of invasive species to 0.0 indicating a conversion to non-native grasses and forbs and/or invasive mesquite. Table D-3 shows the cover classes used and the site intensity values for them, for this CE. The values range from 0.65 to 0.90. Either or both non-native invasive and native invasive woody cover may occur in a single pixel. If both occur, then values for that pixel are multiplied to create a new combined, lower indicator score.

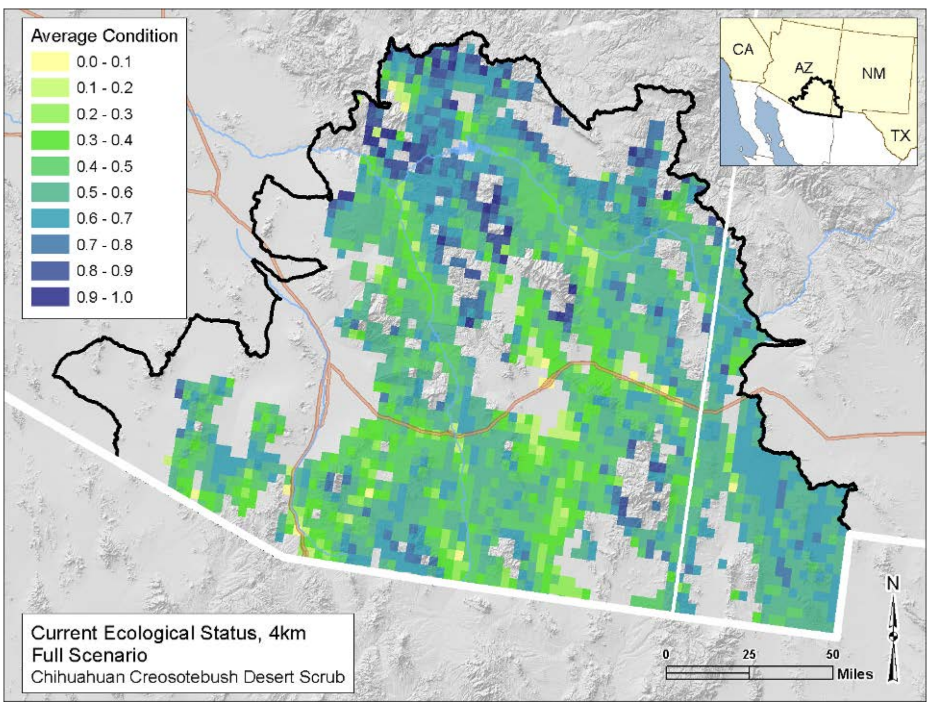
The results shown in the third map of

Figure D-5 indicate relatively low to moderate invasion of exotic grasses and forbs, and/or invasive mesquite in the Chihuahuan Creosotebush Desert Scrub CE in the eastern part of the ecoregion. However, in the south-central region (Sulfur Springs Valley), there appears to be some significant cover of invasives, as well as around the edges of the Gila River Valley. The Chihuahuan Creosotebush Desert Scrub CE environment is extremely xeric so increases of less xeric exotic grass and forb species, and invasive native mesquite are not that significant in some areas. However, as discussed in the conceptual model and for the fire regime indicator, even a modest amount of cover by invasive grasses can lead to a change in fire regime (Brown and Minnich 1986, Paysen et al. 2000).

D-1.2.2 Current Ecological Status: Full Scenario

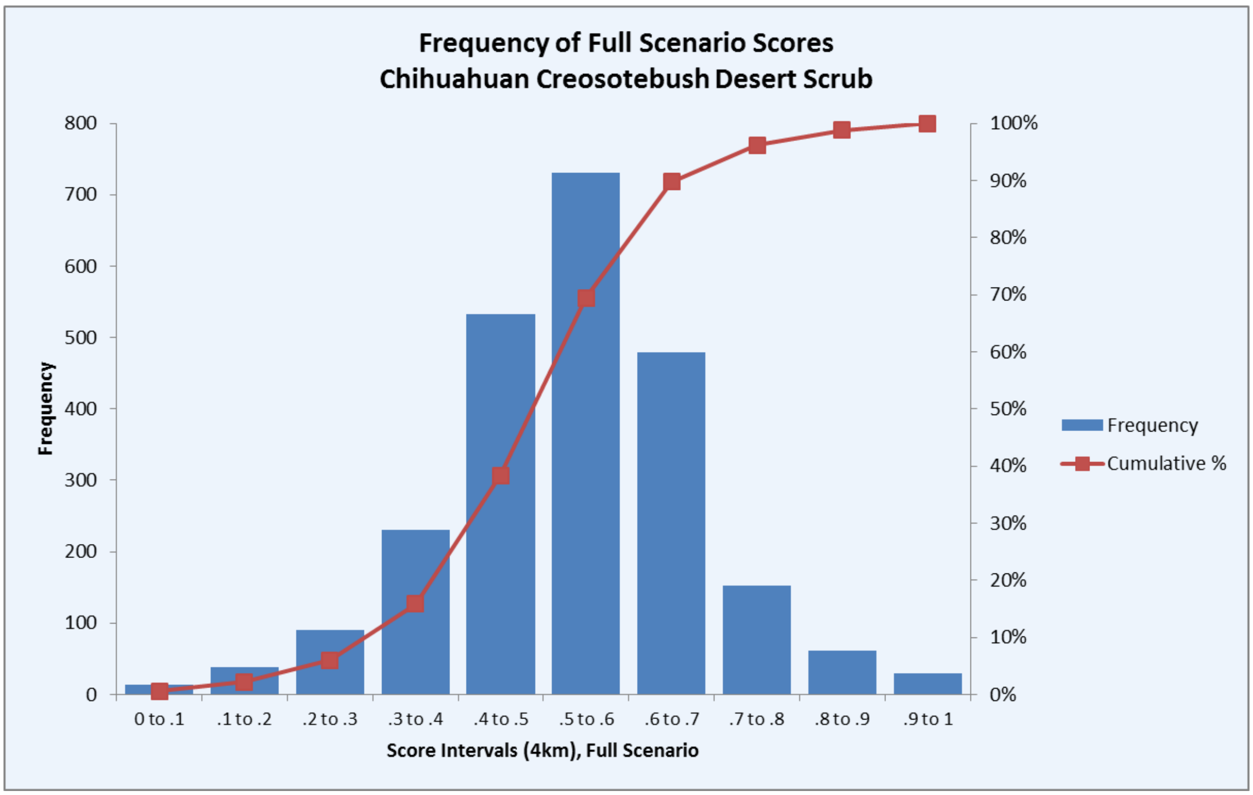
Figure D-6. Overall ecological status scores for Chihuahuan Creosotebush Desert Scrub for all indicators combined (development, fire regime and invasives) for each 30m pixel (top) and 4km grid cells (bottom). The score for each 4km cell is an average of all 30m pixels that are scored for the CE. Yellow scores (equivalent to 0) indicate high impacts from the CAs, dark blue (equivalent to 1) indicate little to no impact from the CAs.





The first map in Figure D-6 illustrates the result of all of the indicators combined into a single ecological status score per pixel of the CE's distribution. The combined, per-pixel status scores are noticeably lower than the individual scores for each indicator. The combined status score for each pixel was summarized to the reporting unit (e.g., 4km grid) by taking the average status score from all the pixels of the CE within the reporting unit. The results, shown in the second map of Figure D-13 and in the frequency diagram (Figure D-7) indicate the widespread general degradation of the Chihuahuan Creosotebush Desert Scrub CE across its range in the ecoregion; notice some 90% of the 4km grid cells fall at or below a 0.7 score. There are a few local areas of better ecological conditions, a result of low level of development, low or no cover of invasive species, and moderate fire regime departure.

Figure D-7. Frequency distribution of the 4km ecological status scores for the Chihuahuan Creosotebush Desert Scrub, with cumulative percent. The x-axis represents the 0.1 increment scoring intervals, while the y-axis shows the number of grid cells in each interval (left) and the cumulative percentage of the grid cells for each interval (right). For this CE, most of the status scores fall in the range from 0.4 to 0.7.



D-1.3 References for the CE

Ahlstrand, G. M. 1979. Preliminary report of the study of the Guadalupe Mountains and Carlsbad Caverns national parks. Pages 31-44 in: H. H. Genoways and R. J. Baker, editors. Biological Investigations in the Guadalupe Mountains National Park, Texas. USDI National Park Service, Proceedings and Transactions. Series No. 4, Washington, DC.

Brooks, M.L., T.C. Esque and T. Duck. 2003. Fuels and fire regimes in creosotebush, blackbrush, and interior chaparral shrublands. Report for the Southern Utah Demonstration Fuels Project, USDA Forest Service, Rocky Mountain Research Station, Fire Science Lab, Missoula, MT. 17 pp.

Brown, D. E., 1982b. Chihuahuan Desertscrub. Pages 169-179 In: Brown, D. E., editor. 1982. Biotic communities of the American Southwest-United States and Mexico. Desert Plants Special Issue 4(1-4):1-342.

Brown, D.E. and R.A. Minnich. 1986. Fire and changes in creosote bush scrub of the western Sonoran Desert, California. The American Midland Naturalist. 116(2): 411-422.

Buffington, L. C., and C. H. Herbel. 1965. Vegetational changes on a semidesert grassland range from 1858 to 1963. Ecological Monographs 35(2):139-164.

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. Ecological systems of the United States: A working classification of U.S. terrestrial systems. NatureServe, Arlington, VA.

Comer, P. J., and J. Hak. 2009. NatureServe landscape condition model. Internal documentation for NatureServe Vista decision support software engineering, prepared by NatureServe, Boulder, CO.

Dick-Peddie, W. A. 1993. New Mexico vegetation: Past, present, and future. University of New Mexico Press, Albuquerque. 244 pp.

Donart, G. B. 1984. The history and evolution of western rangelands in relation to woody plants communities. Page 1235-1258 in: National Research Council/National Academy of Sciences. Developing strategies for rangeland management. Westview Press, Boulder, CO. 2022 pp.

Faber-Langendoen, D., J. Rocchio, S. Thomas, M. Kost, C. Hedge, B. Nichols, K. Walz, G. Kittel, S. Menard, J. Drake, and E. Muldavin. 2012b. Assessment of wetland ecosystem condition across landscape regions: A multi-metric approach. Part B. Ecological Integrity Assessment protocols for rapid field methods (L2). EPA/600/R-12/021b. U.S. Environmental Protection Agency Office of Research and Development, Washington, DC.

Finch, D.M. editor. 2012. Climate change in grassslands, shrublands, and deserts of the interior American West: a review and needs assessment. Gen. Tech. Rep. RMRS-GTR-285. USDA Forest Service Service, Rocky Mountain Research Station, Fort Collins, CO.

Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy. editors. 2013. Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment, A report by the Southwest Climate Alliance. Washington, DC: Island Press.

Gibbens, R. P., R. P. McNeely, K. M. Havstad, R. F. Beck, and B. Nolen. 2005. Vegetation change in the Jornada Basin from 1858 to 1998. Journal of Arid Environments 61(4):651-668.

Hamerlynck, E.P., J.R. Mcauliffe, E.V. McDonald, and S.D. Smith. 2002. Ecological response of two Mojave Desert shrubs to soil horizon development and soil water dynamics. Ecology 83:768-779.

Henrickson, J. and M.C. Johnston. 1986. Vegetation and community types of the Chihuahuan Desert. Pages20-39 in: J.C. Barlow, A.M. Powell and B.N. Timmermann, eds. Chihuahuan Desert--U.S. and Mexico, II: Proceedings of the 2nd symposium on resources of the Chihuahuan Desert region; 1983 October 20-21; Alpine, TX. Alpine, TX: Sul Ross State University, Chihuahuan Desert Research Institute.

Huerta-Martínez, F. M., J. A. Vázquez-García, E. García-Moya, L. López-Mata, and H. Vaquera-Huerta. 2004. Vegetation ordination at the southern Chihuahuan Desert (San Luis Potosi, Mexico). Journal of Plant Ecology 174(1):79-87.

Humphrey, R.R. 1974. Fire in the deserts and desert grassland of North America. In: Kozlowski, T. T.; Ahlgren, C. E., eds. Fire and ecosystems. New York: Academic Press: 365-400.

LANDFIRE: LANDFIRE National Vegetation Dynamics Models. (2007, January - last update). [Homepage of the LANDFIRE Project, U.S. Department of Agriculture, Forest Service; U.S. Department of Interior], [Online]. Available: <http://www.landfire.gov/index.php> [2007, February 8].

MacMahon, J. A. 1988. Warm deserts. Pages 232-264 in: M. G. Barbour and W. D. Billings, editors. North American terrestrial vegetation. Cambridge University Press, New York.

MacMahon, J. A., and F. H. Wagner. 1985. The Mojave, Sonoran and Chihuahuan deserts of North America. Pages 105-202 in: M. Evenari and D. W. Goodall, editors. Ecosystems of the world 12A: Hot deserts and arid shrublands. Elsevier, New York.

Marshall, K. A. 1995. *Larrea tridentata*. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/ [2013, May 13].

McLaughlin, S.P., and J.E. Bowers. 1982. Effects of wildfire on a Sonoran Desert plant community. Ecology 63(1): 246-248.

Milchunas, D.G. 2006. Responses of plant communities to grazing in the southwestern United States. Gen. Tech. Rep. RMRS-GTR-169. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 126 p.

Muldavin, E. 2012. Integrated Landscape Assessment Project (ILAP) VDDT/Path State-and-Transition Model Documentation Arizona and New Mexico (Region 3) Arid Lands (nonforests) March 2012. Pp. 55.

Muldavin E., G. Bell, et al. 2002. Draft ecoregional conservation assessment of the Chihuahuan Desert. Pronatura Noreste. 87 pp.

Muldavin, E., Y. Chauvin, and G. Harper. 2000b. The vegetation of White Sands Missile Range, New Mexico: Volume I. Handbook of vegetation communities. Final report to Environmental Directorate, White Sands Missile Range. New Mexico Natural Heritage Program, University of New Mexico, Albuquerque. 195 pp. plus appendices.

NatureServe. 2013. International Ecological Classification Standard: International Vegetation Classification. Central Databases. NatureServe, Arlington, VA.

NMDGF [New Mexico Department of Game and Fish]. 2006. Comprehensive Wildlife Conservation Strategy for New Mexico. New Mexico Department of Game and Fish. Santa Fe, NM. 526 pp + appendices.

Ogle, K. and J.F. Reynolds. 2002. Desert dogma revisited: coupling of stomatal conductance and photosynthesis in the desert scrub, Larrea tridentata. Plant, Cell and Environment 25:909-921.

Paysen, T.E., J.R. Ansley, J.K. Brown, G.J. Gottfried, S.M. Haase, M.J. Harrington, M.G. Narog, S.S. Sackett and R.C. Wilson. 2000. Chapter 6: Fire in western shrubland, woodland, and grassland ecosystems. Pages 121-159 in: J.K. Brown and J. Kapler-Smith, eds. Wildland fire in ecosystems: effects of fire on flora. Gen. Tech. Rep. RMRS-GTR-42-vol. 2. Ogden, UT: USDA Forest Service, Rocky Mountain Research Station. 257 pp.

Pellant, M., P. Shaver, D.A. Pyke, and J.E. Herrick. 2005. Interpreting indicators of rangeland health, version 4. Technical Reference 1734-6. BLM/WO/ST-00/001+1734/REV05. U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center, Denver, CO. 122 pp.

Pickett, S.T.A., and J.N. Thompson. 1978. Patch dynamics and the size of nature reserves. Biological Conservation 13: 27-37.

USDI-BLM [U.S. Bureau of Land Management]. 2006. 43CFR4180.1 Fundamentals of Rangeland Health. Code of Federal Regulations and Federal Register, Accessed February 2013 http://federal.eregulations.us/cfr/section/2006/04/18/43-cfr-4180.1

USDA-NRCS. 2014. Selected Approved Ecological Site Descriptions for Major Land Resource Area 041-Southeastern Arizona Basin and Range. US Department of Agriculture. Natural Resource Conservation Service. Website accessed September 2014. https://esis.sc.egov.usda.gov/Welcome/pgApprovedSelect.aspx?type=ESD

USDA-USFS [U.S. Forest Service]. 2009. Ecological sustainability report. Coronado National Forest. United States Department of Agriculture. Forest Service. Southwest Region. February 2009. Pp. 118.

Semi-desert Shrub & Steppe

D-2 Apacherian-Chihuahuan Semi-Desert Grassland and Steppe Ecological System

D-2.1 Conceptual Model

D-2.1.1 Classification

The ecosystem conservation elements for the MAR REA were selected from NatureServe's classification of terrestrial ecological systems (Comer et al. 2003). Over three dozen ecological systems occur in the MAR, but only a select subset was chosen for the REA. The CE concept provided in this conceptual model includes this NatureServe ecological system type:

- Apacherian-Chihuahuan Semi-Desert Grassland and Steppe (CES302.735)

There are other terrestrial ecological systems in the NatureServe classification that also occur in the MAR, or in adjacent ecoregions, which are similar to this CE concept but are not included in this conservation element. These are listed here to help the reader understand what is not included in this conceptual model; each of these other ecological systems has information that can be searched for and reviewed on NatureServe's on-line Explorer website (http://explorer.natureserve.org/servlet/NatureServe). The System Code beginning with CES (Community Ecological System) is an information rich database code that refers to the North American Ecological Division (302) where the system primarily occurs and the number used to identify the system (Comer et al. 2003).

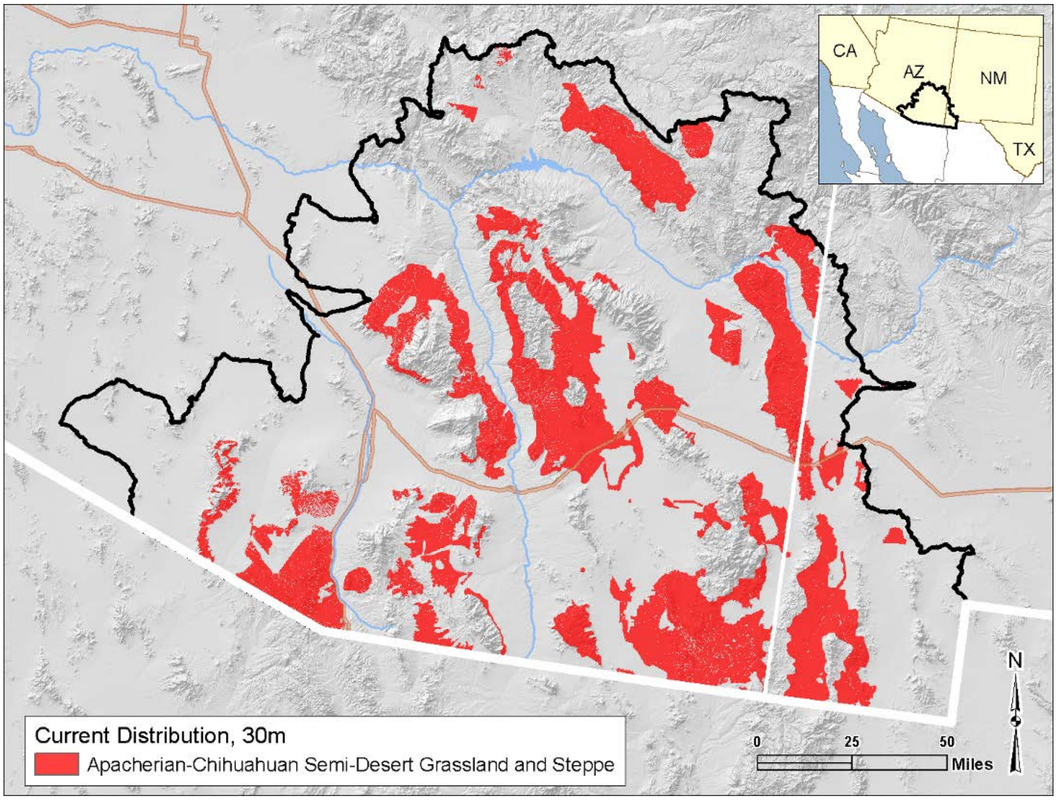
- Chihuahuan Loamy Plains Desert Grassland (CES302.061) – upland tobosa - grama
- Chihuahuan Sandy Plains Semi-Desert Grassland (CES302.736) – black grama
- Chihuahuan-Sonoran Desert Bottomland and Swale Grassland (CES302.746) - Tobosa/Sacaton swale (intermittently flooded)

This CE is the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe, which is the same as the mixed semi-desert grassland in Schussman (2006a). The other grasslands mentioned are not included in this CE. Similar grasslands include the *Pleuraphis mutica*-dominated semi-desert grasslands often with *Bouteloua eriopoda* or *Bouteloua gracilis* occurring on lowlands and loamy plains in the Chihuahuan Desert (Chihuahuan Loamy Plains Desert Grassland, CES302.061) and the *Bouteloua eriopoda* or *Sporobolus flexuosus* dominated grasslands associated with sandy soils which are classified as Chihuahuan Sandy Plains Semi-Desert Grassland (CES302.736). Neither of these is included in this CE.

D-2.1.2 Summary

This ecosystem is a broadly defined desert grassland and mixed shrub-succulent type 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 in central Arizona and east into Trans Pecos or West Texas and throughout much of the Chihuahuan Desert. It is found on gently sloping alluvial erosional fans and piedmonts (bajadas) that lie along mountain fronts of the isolated basin ranges throughout the Sky Island mountain archipelago and on to foothill slopes up to 1670 m elevation in the Chihuahuan Desert (Figure D-8).

Figure D-8. Distribution of Apacherian-Chihuahuan Semi-Desert Grassland and Steppe at 30m resolution. The distribution was derived from the land cover mapping work completed by The Nature Conservancy (Gori et al. 2012). Appendix G (ecological integrity) has a table listing the areal extent of this ecological system and its % of the assessment area.



Adjacent ecological systems may include Madrean Juniper Savanna (CES305.730), Madrean Pinyon-Juniper Woodland (CES305.797) and Madrean Encinal (CES305.795) at higher elevations and Chihuahuan Mixed Desert and Thornscrub (CES302.734) and Apacherian-Chihuahuan Mesquite Upland Scrub (CES302.733) at lower elevations. Substrates are a mixture of alluvium and colluvium and are variable, ranging from silt to loam to coarse sand, and are often shallow, well-drained and rocky. The environmental description is based on several references, including Brown (1982), Burgess (1995), Dick-Peddie (1993), McAuliffe (1995), Muldavin et al. (2000b), Schussman (2006), and NatureServe Explorer (2013).

Figure D-9. Apacherian-Chihuahuan Semi-Desert Grassland and Steppe (source http://azfirescape.org).

The vegetation in this mixed semi-desert grassland ecosystem is variable. It is characterized by the dominance of a typically diverse layer of perennial grasses with scattered stem succulents and shrubs. Frequent species include the grasses *Aristida ternipes, Bouteloua chondrosioides, Bouteloua curtipendula, Bouteloua eriopoda, Bouteloua gracilis, Bouteloua hirsuta, Bouteloua ramosa, Bouteloua repens, Bouteloua rothrockii, Digitaria californica, Eragrostis intermedia, Heteropogon contortus, Hilaria belangeri, Leptochloa dubia, Muhlenbergia porteri,* with *Muhlenbergia emersleyi, Muhlenbergia setifolia* at upper foothill elevation, succulent species of *Agave, Dasylirion, Nolina, Opuntia*, and *Yucca*, and short-shrub species of *Calliandra, Mimosa*, and *Parthenium*. Tall-shrub/short-tree species of *Acacia, Prosopis*, *Juniperus*, and various oaks (e.g. *Quercus grisea, Quercus emoryi, Quercus arizonica, Quercus oblongifolia*) may be present with low cover.

Similar grasslands include the *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 as Chihuahuan Loamy Plains Desert Grassland (CES302.061) and the *Bouteloua eriopoda* or *Sporobolus flexuosus* dominated grasslands associated with sandy soils which are classified as Chihuahuan Sandy Plains Semi-Desert Grassland (CES302.736). These other grasslands systems are not included in this mixed semi-desert grassland CE.

Many of the historical semi-desert grassland and savanna areas have been converted through intensive grazing and other land uses, some to Apacherian-Chihuahuan Mesquite Upland Scrub (CES302.733)

(*Prosopis* spp.-dominated). The vegetation description is based on several references, including Brown (1982), Burgess (1995), Dick-Peddie (1993), Muldavin et al. (2000b), Schussman (2006a), and NatureServe Explorer (2013) Brown and Makings (2014).

A crosswalk of this system to USDA Natural Resource Conservation Service (NRCS) approved Ecological Site Descriptions (ESD) by Major Land Resource Areas (MLRA) is provided in Table D-8 (USDA-NRCS 2014). For complete list of ESDs for MLRA 41 see https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD.

Table D-8. Apacherian-Chihuahuan Semi-Desert Grassland ecological system crosswalk with approved Ecological Site Descriptions (provisional cross-walk).

MLRA	Ecological Site Description Name	Site ID
041-Southeastern Arizona Basin and Range	Loamy Upland	R041XA 001NM
041-Southeastern Arizona Basin and Range	Clay Hills	R041XA 003NM
041-Southeastern Arizona Basin and Range	Gravelly Slopes	R041XA 004NM
041-Southeastern Arizona Basin and Range	Hills	R041XA 005NM
041-Southeastern Arizona Basin and Range	Limy Slopes 16-20" p.z. / *Krameria erecta - Dalea formosa / Bouteloua eriopoda - Hesperostipa neomexicana* (/ littleleaf ratany - featherplume / black grama - New Mexico feathergrass)	R041XA 104AZ
041-Southeastern Arizona Basin and Range	Limy Upland 16-20" p.z. / *Krameria erecta - Nolina microcarpa / Bouteloua eriopoda - Aristida purpurea var. nealleyi* (/ littleleaf ratany - sacahuista / black grama - blue threeawn)	R041XA 105AZ
041-Southeastern Arizona Basin and Range	Loamy Slopes 16-20" p.z. / *Agave palmeri - Nolina microcarpa / Bouteloua curtipendula - Eragrostis intermedia* (/ Palmer's century plant - sacahuista / sideoats grama - plains lovegrass)	R041XA 107AZ
041-Southeastern Arizona Basin and Range	Loamy Upland 16-20" p.z. / *Baccharis pteronioides - Agave palmeri / Bouteloua gracilis - Eragrostis intermedia* (/ yerba de pasmo - Palmer's century plant / blue grama - plains lovegrass)	R041XA 108AZ
041-Southeastern Arizona Basin and Range	Clay Loam Upland 16-20" p.z. / / *Bouteloua gracilis - Hilaria belangeri* (/ / blue grama - curly-mesquite)	R041XA 109AZ
041-Southeastern Arizona Basin and Range	Sandy Loam Upland 16-20" p.z. / *Baccharis pteronioides / Bouteloua curtipendula - Bouteloua gracilis* (/ yerba de pasmo / sideoats grama - blue grama)	R041XA 110AZ
041-Southeastern Arizona Basin and Range	Loamy Swale 16-20" p.z. / / *Bouteloua gracilis - Bouteloua curtipendula* (/ / blue grama - sideoats grama).	R041XA 115AZ
041-Southeastern Arizona Basin and Range	Basalt Hills 12-16" p.z	R041XC 301AZ
041-Southeastern Arizona Basin and Range	Clayey Slopes 12-16" p.z. / / *bouteloua curtipendula - pleuraphis mutica* (/ / sideoats grama - tobosagrass)	R041XC 303AZ
041-Southeastern Arizona Basin and Range	Clay Loam Upland 12-16" p.z. / *Calliandra eriophylla / Pleuraphis mutica - Bouteloua curtipendula* (/ fairyduster / tobosagrass - sideoats grama)	R041XC 305AZ
041-Southeastern Arizona Basin and Range	Granitic Hills 12-16" p.z. / *Eriogonum wrightii - Calliandra eriophylla / Bouteloua curtipendula - Artemisia ludoviciana* (/ bastardsage - fairyduster / sideoats grama - white sagebrush)	R041XC 306AZ
041-Southeastern Arizona Basin and Range	Limestone Hills 12-16" p.z. / *Dalea formosa - fouquieria splendens / Bouteloua curtipendula - Hesperostipa neomexicana* (/ featherplume - ocotillo / sideoats grama - New Mexico feathergrass)	R041XC 307AZ
041-Southeastern Arizona Basin and Range	Limy Slopes 12-16" p.z. / *Calliandra eriophylla - Krameria erecta / Bouteloua eriopoda - Bouteloua curtipendula* (/ fairyduster - littleleaf ratany / black grama - sideoats grama)	R041XC 308AZ

041-Southeastern Arizona Basin and Range	Loamy Swale 12-16" p.z. / / *Bouteloua gracilis - Bouteloua curtipendula* (/ / blue grama - sideoats grama)	R041XC 311AZ
041-Southeastern Arizona Basin and Range	Loamy Upland 12-16" p.z. / *Calliandra eriophylla - Krameria erecta* / *Bouteloua curtipendula - Bouteloua chondrosioides* (/ fairyduster - littleleaf ratany / sideoats grama - sprucetop grama)	R041XC 313AZ
041-Southeastern Arizona Basin and Range	Loamy Slopes 12-16" p.z. / *calliandra eriophylla* / *bouteloua curtipendula* (/ fairyduster / sideoats grama)	R041XC 314AZ
041-Southeastern Arizona Basin and Range	Sandy Loam 12-16" p.z. Deep / *Eriogonum wrightii* / *Bouteloua curtipendula - Digitaria californica* (/ bastardsage / sideoats grama - Arizona cottontop)	R041XC 318AZ
041-Southeastern Arizona Basin and Range	Sandy Loam Upland 12-16" p.z. / *Eriogonum wrightii - Calliandra eriophylla* / *Bouteloua eriopoda - Bouteloua curtipendula* (/ bastardsage - fairyduster / black grama - sideoats grama)	R041XC 319AZ
041-Southeastern Arizona Basin and Range	Granitic Upland 12-16" p.z. / *Calliandra eriophylla - Krameria erecta* / *Bouteloua repens - Bouteloua eriopoda* (/ fairyduster - littleleaf ratany / slender grama - black grama)	R041XC 322AZ
041-Southeastern Arizona Basin and Range	Volcanic Hills 12-16" p.z. Loamy / *Eriogonum wrightii* / *Bouteloua curtipendula - Bouteloua hirsuta* (/ bastardsage / sideoats grama - hairy grama)	R041XC 323AZ
041-Southeastern Arizona Basin and Range	Volcanic Hills 12-16" p.z. Clayey / *Eriogonum wrightii* / *Bouteloua curtipendula - Pleuraphis mutica* (/ bastardsage / sideoats grama - tobosagrass)	R041XC 330AZ

D-2.1.3 Species of Conservation or Management Concern

Below are listed some species of concern associated with this ecological system CE. These are species of conservation or management concern that are associated with healthy grasslands from the BLM Gila District (USDI-BLM 2010). Pronghorn (*Antilocapra Americana),* Black-tailed Prairie Dog (*Cynomys ludovicianus*) and Desert Ornate Box Turtle (*Terrapene ornata*) are included in this list, however they are addressed elsewhere in this assessment as species CEs and have individual conceptual models. Grassland-dependant birds are also treated as an assemblage CE, with a conceptual model.

Amphibians: Great Plains Narrow-mouthed Toad (*Gastrophryne olivacea*), Lowland Burrowing Treefrog (*Smilisca fodiens*), Sonoran Green Toad (*Bufo retiformis*).

Birds: Arizona Grasshopper Sparrow (*Ammodramus savannarum ammolegus*), Baird's sparrow (*Ammodramus bairdii*), Botteri's Sparrow (*Peucaea botterii arizonae*), Ferruginous Hawk (*Buteo regalis*) (breeding population only), Loggerhead Shrike (*Lanius ludovicianus*), Masked Bobwhite (*Colinus virginianus ridgwayi*), Northern Aplomado Falcon (*Falco femoralis septentrionalis*), Northern Harrier (*Circus cyaneus),* Scaled Quail (*Callipepla squamata*), and Western Burrowing Owl (*Athene cunicularia hypogaea*).

Mammals: Banner-tailed Kangaroo Rat (*Dipodomys spectabilis*), Black-tailed Prairie Dog (*Cynomys ludovicianus*), Gunnison's Prairie Dog (*Cynomys gunnisonii*), Pronghorn (*Antilocapra Americana*).

Reptiles: Desert Ornate Box Turtle (*Terrapene ornata*), Slevin's Bunchgrass Lizard (*Sceloporus slevini*).

Additional grassland birds from lists compiled by Gori et al. (2012) include: Brewer's sparrow, Cassin's sparrow, chestnut-collared longspur, clay-colored sparrow, eastern meadowlark, golden eagle, horned lark, lark bunting, lark sparrow, long-billed curlew, McCown's longspur, mountain plover, prairie falcon, sandhill crane, short-eared owl, and vesper sparrow.

D-2.1.4 Natural Dynamics

The Nature Conservancy review of the Historical Range of Variation for Semi-Desert Grassland is the primary source for this section (Schussman 2006a). Their work on the mixed native grassland type relates directly to the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe CE, however, this CE does not include other grasslands addressed in Schussman (2006a) such as the valley bottom or black grama grasslands.

These semi-desert grasslands are complex with many stands having a shrub or stem succulent component (*Agave* and *Yucca* spp.) under natural conditions (Burgess 1995). This woody component increases in density over time in the absence of disturbance such as fire (Burgess 1995, Gori and Enquist 2003, Schussman 2006a). Under historic natural conditions (also called natural range of variability, NRV), this ecosystem ranges from open perennial grasslands with low cover of shrubs to grasslands with a moderately dense shrub layer and succulent layer (Burgess 1995, Gori and Enquist 2003). An exception is that some stands with deep argillic horizons appear resistant to shrub and tree invasion without disturbance (McAuliffe 1995).

It is well documented that frequent stand replacing fire (fire return interval (FRI) of 2.5 to 10 years) was a key ecological attribute of this semi-desert grassland ecosystem historically before 1890 (Bahre 1985, Kaib et al. 1996, McPherson 1995, Wright 1980). Other evidence of the importance of fire in maintaining desert grasslands includes the widespread conversion of grasslands to shrublands during the century of fire suppression (McPherson 1995) and the results of prescribed burning on decreasing shrub cover and increasing grass cover (Bock and Bock 1992, Robinett 1994). Additional evidence that frequent fire is a key ecological attribute of this ecosystem is that many common shrubs, subshrubs and cacti are fire-sensitive and individuals are killed when top burned, at least when they are young (< 10 years old) (McPherson 1995), while native perennial grasses quickly recover from burning (Bock and Bock 1992; Martin 1983; Wright 1980). Below is a conceptual state-and-transition model (Figure D-10) of this ecosystem under historic natural range of variation (NRV) conditions.

Herbivory by native herbivores in the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe is varied and ranges from invertebrates and rodents to pronghorn (Finch 2004, Parmenter and Van Devender 1995, Whitford et al. 1995). Soil dwelling invertebrates include tiny nematodes and larger termites and ants and are important in nutrient cycling and effect soil properties, such as bulk density (Whitford et al. 1995). Above ground invertebrates such as grasshoppers can significantly impact herbaceous cover when populations are high.

Herbivory by native mammals also impacts these grasslands. Historically populations of large mammals such as pronghorn (*Antilocarpa Americana*), mule deer (*Odocoileus hemionus*) and elk (*Cervus elaphus*) were once abundant in this ecosystem (Parmenter and Van Devender 1995). Populations were greatly reduced and in the case of pronghorn, extirpated, during the 1800s and early 1900s, but effective game management has restored many populations, although habitat changes will limit restoration in other areas (Parmenter and Van Devender 1995). The historic impact of large native ungulates on this ecosystem is not known, however in the case of wintering elk it may have been significant locally. The current impact is assumed to be relatively small in this ecosystem.

Herbivory from native small mammals such as rodents, is significant as they are the dominant mammals in the semi-desert grassland ecosystem. There is also high diversity of these rodents, especially ground-dwelling ones such as spotted ground squirrels (*Spermophilus spilosoma*), and bannertail and Ord kangaroo rats (*Dipodomys spectablilis* and *D. ordii*). These burrowing rodents have a substantial effect on vegetation composition, soil structure and nutrient cycling (Finch 2004, Parmenter and Van Devender 1995). Historically, black-tail prairie dogs (*Cynomys ludovicianus*) had extensive colonies but were greatly reduced or extirpated from semi-desert grasslands in Arizona by 1960s and their numbers and impacts are still small (Parmenter and Van Devender 1995). Other rodents such as kangaroo rats are still abundant in semi-desert grasslands.

Invertebrate animals are also significant in semi-desert grassland. They are both abundant and extremely diverse ranging from single celled protozoans, bacterial and soil nematodes and mites to larger arachnids, millipedes, cockroaches, crickets, grasshoppers, ants, beetles, butterflies, moths, flies, bees, wasps, and true bugs (Whitford et al. 1995). Invertebrates are important for nutrient cycling, pollination, and subterranean species of ants and termites can impact soil properties such as bulk density, infiltration permeability and storage (Whitford et al. 1995). Grasshoppers feed on grasses and forbs and can consume significant amounts of forage when their populations are high. Many species of butterflies, flies, bees, and moths are important for pollination. Some species such as Yucca moths (*Tegeticula yuccasella*) and *Yucca* species have obligate mutualistic relationships (Whitford et al. 1995). More study and review is needed to fully understand the many functional roles animals have within the semi-desert grassland ecosystem.

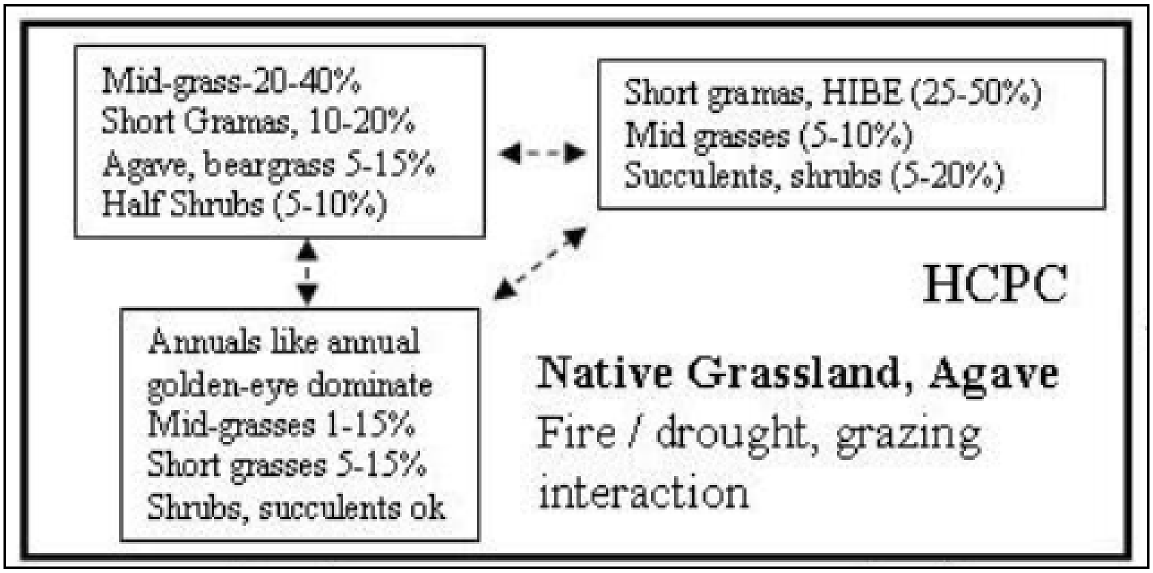
A good condition/proper functioning mixed semi-desert grassland ecosystem is large and uninterrupted, the surrounding landscape is also in good condition; the biotic condition is within normal range of variation, the weeds are few, the native plants are robust, have expected abundance and reproduction; shrub cover is generally low; birds, mammals, reptiles, insects and amphibian species present are indicative of reference, un-molested conditions; the fire regime is functioning at near historical conditions with FRI (fire return interval) of stand replacing fires every 2.5 to 10 years; soils have not been excessively eroded.

A poor condition/non-functioning ecosystem is highly fragmented, or much reduced in size from its historical extent; the surrounding landscape is in poor condition either with highly eroding soils, many non-native species or a large percentage of the surrounding landscape has been converted to pavement or highly maintained agriculture (row crops, irrigated crops, etc.); the biotic condition is at the limit or beyond natural range of variation, i.e. vegetation structure is converted from perennial grass dominated to shrub dominated vegetation, or vegetation is dominated by non-native species such as Lehmann lovegrass (*Eragrostis lehmanniana*). Impacts from herbivory have significantly altered the vegetation structure of plant species composition, i.e. low cover of native grasses, high cover of seral species (such as *Aristida* spp. or annuals. Characteristic birds, mammals, reptiles, and insect species are not present at expected abundances or the ratio of species shows an imbalance of predator to prey populations; abiotic condition is poor with evidence of high soil erosion, rill and gullies present or exposed soil sub-horizons. The fire regime is no longer high-frequency, rather fires are occurring at longer intervals, allowing shrubs or trees to become established.

D-2.1.4.1 Natural Dynamics Model

Conceptual historical state-and-transition models were developed by several ecology teams (Muldavin et al. 2012, Schussman 2006a), and NRCS for the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe. Below is a conceptual historical state and transition model of the Historic Climax Plant Community (HCPC) for NRCS ESD R041XA107AZ was taken directly from the 041-Southeastern Arizona Basin and Range MLRA at: https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD. This model is representative of the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe CE (Figure D-10).

Figure D-10. Conceptual state and transition model of historical conditions for the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe CE. This model is the Historic Climax Plant Community (HCPC) portion of a larger model that was taken directly from NRCS ESD R041XA107AZ Loamy Slopes 16-20" p.z., *Agave palmeri - Nolina microcarpa* / *Bouteloua curtipendula - Eragrostis intermedia*.



Model description was taken directly from ESD R041XA107AZ:

Description of State and Transition Model

"The historic native state includes the plant communities that occur on the site, including the historic climax plant community. This state includes other plant communities that naturally occupy the site following fire, drought, flooding, herbivores, and other natural disturbances. The historic climax plant community represents the natural climax community that eventually re-occupies the site with proper management.

The potential plant community on this site is dominated by warm season perennial mid-grasses. The major grass species are well dispersed throughout the plant community. Stands of Palmer agave occur in dense patches and are not well dispersed through areas of the site. Several species of low shrubs, cacti and other succulents, and forbs are well represented in this plant community. The aspect is open grassland to savannah. North slopes will often have an open canopy of oaks and / or juniper. South slopes will be agave dotted grassland.

Naturally occurring fires in June-August were an important factor in shaping this plant community. Fire-free intervals range from 10-20 years. Without disturbance like grazing or fire, perennial mid-grasses can become decadent and forbs like annual goldeneye, cudweed and camphorweed can increase to dominate the plant community. This site is the principal habitat for the Agave Palmeri in southeastern Arizona, an important food source for the endangered lesser long-nosed bat in June, July, and August. Dense stands of this species occur scattered throughout areas of this site. Nectar production in these stands ranges from 6-10 gallons per acre.

Periodic drought can occur in this LRA and cause significant grass mortality. Droughts in the early 1930s, mid 1950's, 1975-1976, 88-89, 95-96 and 2002 resulted in the loss of much of the grass cover on this site. The site recovers rapidly, however, due to excellent covers of stone, cobbles and gravel and the favorable climate that prevails in this common resource area. "

D-2.1.5 Change Agent Effects on the CE

This section of the conceptual model presents a narrative description of the primary change agents and current knowledge of their effects on Apacherian-Chihuahuan Semi-Desert Grassland and Steppe ecosystem. The section contains two sub-sections: (1) A list of primary change agents identified for the CE; and (2) a discussion of altered dynamics caused by these agents.

List of Primary Change Agents

Occurrences of this grassland ecological system can be directly affected by livestock grazing, direct and indirect wildfire suppression, land development, non-native plant species invasion. Table D-9 identifies the most likely impacts associated with each of these stressors.

Table D-9. Stressors and their likely impacts on the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe ecosystem in the Madrean Archipelago ecoregion.

Stressor	Impacts
Land Use	
Livestock grazing	Grazing of native vegetation by livestock at incompatible stocking rates, season of use, or duration can be detrimental to grass vigor resulting in decline of grass cover and shifts in species composition to more grazing tolerant or less palatable species (Milchunas 2006). Over time this often results in increased woody cover or bare ground and erosion. Heavy grazing can indirectly decrease fire return intervals by removing fine fuels that carry fire (McPherson 1995).
Recreation	This mostly relates to off road vehicle use, which creates addition roads and trails that fragment grassland and contribute to increase soil erosion and compaction and non-native species dispersal (USDA-USFS 2009).
Development	
Transportation infrastructure Roadways/railways and transmission lines	Fragmentation from transportation infrastructure leads to disruptions in ecological processes such as fire, dispersal of invasive non-native species, and can alter hydrological processes by changing surface flows such as when excessive runoff from roads creates gullies that can lower water tables. Additionally, destruction of wildlife habitat and disruption of wildlife migration patterns can also occur (Bahre 1991, Bock and Bock 2002, Finch 2004, Heinz Center 2011, Marshall et al. 2004, McPherson 1997, Ockenfels et al. 1994, Schussman 2006a).
Suburban/Rural (include Military), Mines/Landfill	This stress contributes to altered fire regimes, increased erosion, direct habitat loss/conversion, increased groundwater pumping, fragmentation, invasive non-native species dispersal and disruption of wildlife migration patterns. (Bahre 1991, Finch 2004, McPherson 1997).

Stressor	Impacts
Energy (Renewable wind/solar), Oil/Gas	This stress contributes to altered fire regimes (e.g. fire suppression to protect infrastructure), increased erosion, direct habitat loss/conversion, increased groundwater pumping, fragmentation, and invasive non-native species dispersal.
Agriculture	This stress contributes to increased erosion, direct habitat loss/conversion, fragmentation, increased groundwater pumping, and invasive non-native species dispersal.
Uncharacteristic Fire Regime	Fire suppression has increased woody species, changed woody species composition and lead to an uncharacteristic fire regime in many stands (Barton 1999, Gori and Enquist 2003, Muldavin et al. 2002, Turner et al. 2003).
Invasive Non-native Species	Replacement of native vegetation with non-native grass species such as *Eragrostis lehmanniana* and *Eragrostis curvula*. These species are better adapted to frequent fire and increase in relative abundance over native grasses after burning (Anable et al. 1992, Cable 1971, Gori and Enquist 2003, Schussman 2006a).
Climate change	Alteration of precipitation and evapotranspiration rates and timing, may result in more frequent drought periods and higher intensity precipitation events, which following drought can cause significant erosion of topsoil (Finch 2012, Garfin et al. 2012).

D-2.1.5.1 Altered Dynamics

These native mixed semi-desert grasslands are the dominant grassland type within this ecoregion and range from open grasslands with low shrub canopy cover (less than 10% cover) to denser grassland with higher shrub and succulent cover. Over time without fire or other disturbance, stands become dominated by woody vegetation and convert to shrublands or woodlands (Gori and Enquist 2003). Conversion to juniper woodlands or mesquite or creosotebush shrublands is common when trees or mesquite exceed 15% cover (Gori and Enquist 2003). There are many interacting factors that have contributed to the expansion of shrubs into grassland, including climate, soils, fire, herbivory, grazing history, and existing vegetation. These grasslands were historically maintained as open grasslands with low shrub cover by fire return intervals of 2.5 to 10 years (Brown and Archer 1999, McPherson 1995, Robinett 1994, Wright 1980). The NRCS model (above) has fire free period as 10-20 years, which is less frequent, but still in considered a relatively frequent fire regime. The interaction of drought and livestock grazing tends to diminish perennial grass cover and abundance to the extent that herbaceous fuels are lowered so that fire frequency declines, and the lowered fire frequency permits a more rapid rate of shrub increase (Brown and Archer 1999, McPherson 1995, Robinett 1994, Wright 1980). Gori and Enquist (2003) found there is a loss of perennial grasses and increases of bare ground over time as grasslands are converted to shrublands. If not protected by surface rock, top soil erosion can occur, changing the site to be less suitable for grass recolonization (McAuliffe 1995).

Although fire may play a more important role in controlling shrub encroachment and maintaining perennial grass cover in the mixed native grassland types in AZ, other disturbances may be the cause of shrub encroachment in the black grama and valley bottom types (which are not part of this CE concept).

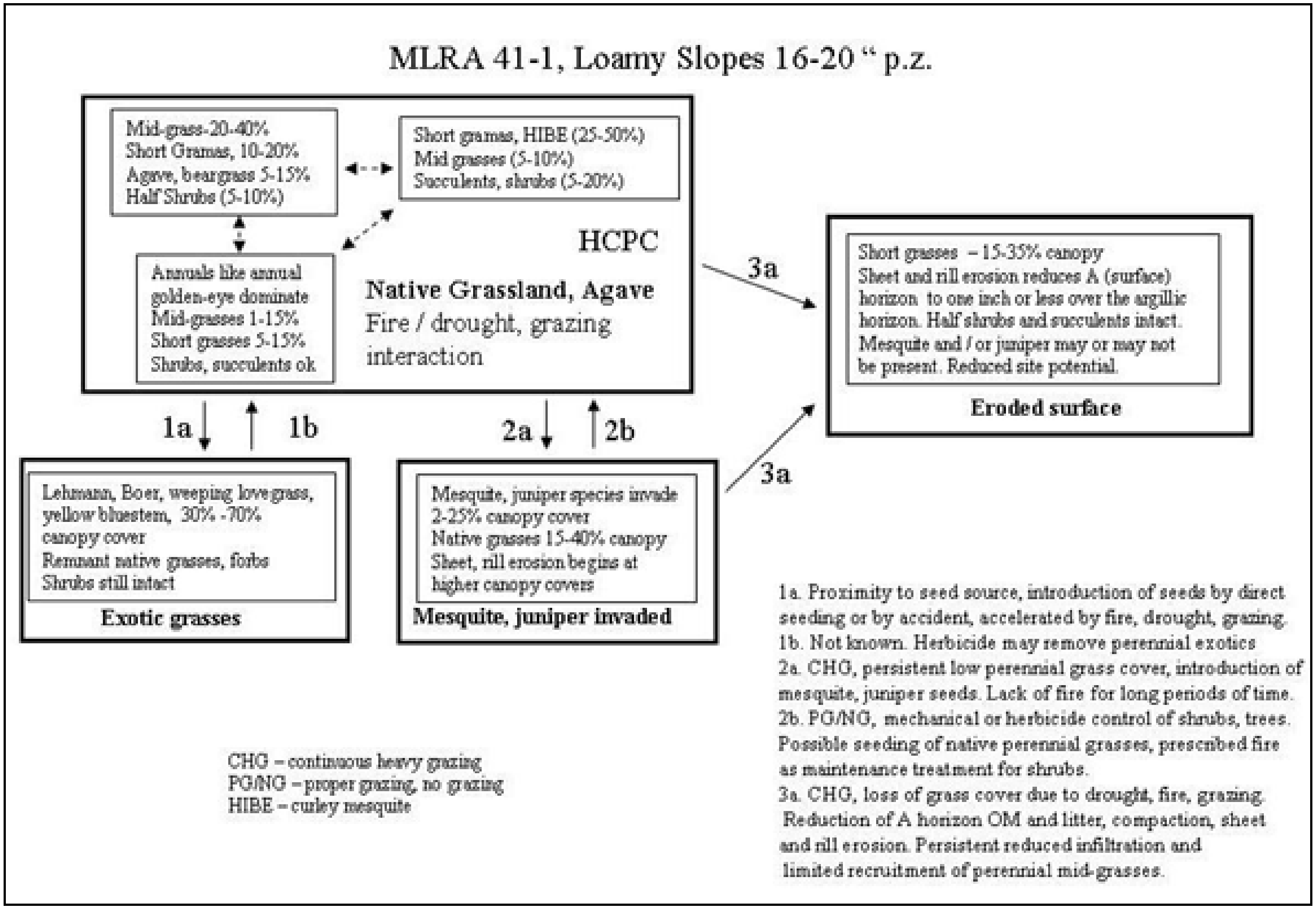
Hydrological alterations also occurred in many semi-desert grasslands during early anglo-American settlement time with a period of arroyo formation from 1865 to 1915 (Cooke and Reeves 1976). During this time many broad valley bottom drainages were incised, lowering water tables. This resulted in changes to more xeric vegetation because of decreased water availability, as well as increased sediment movement, altered hydrologic relationships, and loss of productive land (Cooke and Reeves 1976). There is debate about the causes of these hydrologic changes. Cooke and Reeves (1976) found strong evidence that arroyo formation in this ecoregion was initiated by building ditches, canals, roads and embankments along channels that altered valley floor hydrology.

The introduction of two invasive non-native, perennial grasses, Lehmann and Boer lovegrasses (*Eragrostis lehmanniana* and *Eragrostis curvula*) has greatly impacted many semi-desert grasslands in this ecoregion (Anable et al. 1992, Cable 1971, Gori and Enquist 2003). Anable et al. (1992) and Cable (1971), found Lehmann lovegrass is a particularly aggressive invader and alters ecosystem processes, vegetation composition, and species diversity.

D-2.1.5.2 Altered Dynamics Model

Conceptual state-and-transition models were developed by several ecology teams (Muldavin et al. 2012, Schussman 2006a), and NRCS for the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe ecosystem. Below is a conceptual state and transition model of the current conditions for the NRCS ESD R041XA107AZ that was taken directly from the 041-Southeastern Arizona Basin and Range MLRA at: https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD. This model is representative of the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe CE (Figure D-11). It includes the Historic Climax Plant Community (HCPC) as part of the full model.

Figure D-11. Conceptual state and transition model of current conditions for the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe CE. This model was taken directly from NRCS ESD R041XA107AZ Loamy Slopes 16-20" p.z. / *Agave palmeri - Nolina microcarpa / Bouteloua curtipendula - Eragrostis intermedia* and includes the Historic Climax Plant Community (HCPC) portion with the larger model.



Model description was taken directly from ESD R041XA107AZ:

Description of State and Transition Model

The HCPC portion of this model represents this ecosystem under natural dynamic conditions. The Altered Dynamic portions of this community are shown with arrow indicating introduction of non-native forage grasses such as *Eragrostis lehmanniana* or *E. curvula*; invasion by shrubs and small trees (primarily species of *Prosopis* and *Juniperus*) resulting from extended periods of lack of fire; and an eroded surface with low grass cover (including reduction or loss of A soil horizon, reduced soil infiltration, soil organic material, ground cover, litter, and increased soil compaction, sheet and rill erosion).

The model also indicates the possibility of restoration of the HCPC with the application of both mechanical and herbicide treatments. Many acres of degraded grasslands within the MAR, particularly in New Mexico (both mesquite and creosote invaded sites) have been the target of restoration efforts with both mechanical removal of shrubs and herbicide treatments (Lister, pers comm.), combined with reintroduction of the native perennial grasses and prescribed fire.

Descriptions of altered states are excerpted directly from Ecological Site Description (ESD) for R041XA107AZ below:

"Exotic grasses

This state occurs where non-native lovegrass species or yellow bluestem, have invaded from adjacent areas or roads and ROWs with a seed source. As these species increase to dominate the plant community, native perennial grasses and forbs decrease to remnant amounts. Fire will usually act to increase species like Lehmann lovegrass. The native half shrubs seem to be able to stay in the plant community. It is not known how *Agave palmeri* fares under this condition.

Shrub invaded

This state occurs where mesquite, wait a bit mimosa, one-seed juniper and / or alligator juniper have invaded or increased to dominate the plant community. This occurs in the absence of fire for long periods of time, with continuous grazing and in the presence of a seed source of these species. As canopy levels of trees and shrubs approach 30%, sheet and rill erosion can begin to accelerate.

Eroded surface

This state occurs where severe soil compaction and trailing has resulted in loss of plant cover and an increase in runoff. Sheet and rill erosion accelerates and the surface (A) horizon is removed faster than it can be replaced by down-slope soil movement and weathering of the ridgetops. When the subsurface argillic (clayey) horizons are exposed, the site has lost its potential productivity. The plant community will shift from warm season plants to cool season plants and the ratio of runoff to infiltration will increase.

With continuous, heavy grazing, mid-grasses are removed from the plant community and replaced by short grasses such as curly mesquite, slender grama and sprucetop grama. With severe deterioration, shrubby species such as wait-a-bit mimosa, one-seed and alligator juniper, and mesquite can increase to dominate the site. With good management, native mid-grasses will be able to regain their dominance in the plant community, unless soil erosion is severe enough to strip away the surface horizon. Mesquite and Lehmann lovegrass are at the upper limits of their elevation range, but can increase on the site, especially below 5000 feet elevation and on southern exposures. Climatic warming may allow these two species to push higher in elevation as time goes by. Naturally occurring fires in June-August were an important factor in shaping this plant community. Fire-free intervals range from 10-20 years. Without disturbance like grazing or fire, perennial mid-grasses can become decadent and forbs like annual goldeneye, cudweed and camphorweed can increase to dominate the plant community. This site is the principal habitat for the *Agave palmeri* in southeastern Arizona, an important food source for the endangered lesser long-nosed bat in June, July, and August. Dense stands of this species occur scattered throughout areas of this site. Nectar production in these stands ranges from 6-10 gallons per acre.

Periodic drought can occur in this LRA and cause significant grass mortality. Droughts in the early 1930s, mid 1950s, 1975-1976, 88-89, 95-96 and 2002 resulted in the loss of much of the grass cover on this site. The site recovers rapidly, however, due to excellent covers of stone, cobbles and gravel and the favorable climate that prevails in this common resource area."

D-2.1.6 Ecological Status: Key Ecological Attributes and Indicators

This section of the conceptual model addresses Key Ecological Attributes and their potential indicators. The ecological status is a way of describing current status via criteria, functionality, or levels of attributes and asks if they are within the normal range of variation.

D-2.1.6.1 Key Ecological Attributes

Table D-10 identifies the key ecological attributes for the CE within the Madrean Archipelago ecoregion. A **key ecological attribute** of a focal ecological resource is a characteristic of the resource's biology, ecology, or physical environment that is critical to the resource's persistence in the face of both natural and human-caused disturbance. Alteration of such a characteristic beyond some critical range of variation will lead to the degradation or loss of the resource within decades or less. The KEAs table lists the identified key ecological attributes, with a brief definition, a rationale for why it is important for the CE, and a listing of stressors or change agents that might be affecting the key attribute.

Table D-10. Key Ecological Attributes (KEA) of Apacherian-Chihuahuan Semi-Desert Grassland and Steppe ecosystem CE in the Madrean Archipelago ecoregion. Indicators for these KEAs can be used to determine the ecological status for this CE; see **Table D-2** for a list of the indicators assessed in this REA.

***KEA Class:* Name**	**Definition general**	**Rationale general**	**Stressors general**
***Landscape Context:* Landscape Condition**	This attribute is the amount of anthropogenic disturbance of the ecosystem that can be identified using a Land Condition Model Index (LCM). It incorporates a number of development features (including roads, urban/rural areas, agriculture, mines, transmission corridors, and energy development) that degrade the condition of the landscape.	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance (Comer and Hak 2009)	Stressors to landscape condition include multiple sources of fragmentation (reduces connectivity) that alter ecological processes (e.g., fire or surface hydrology), degrade wildlife habitat and disrupt wildlife migration patterns by creating barriers to species movement. Stressors include livestock grazing (reduces fine fuel that carry fire), urban and exurban development, and road building.
***Size/Extent:* Patch Size Distribution**	The distribution of patch sizes (number and size class frequency) is a measure of fragmentation in this historically matrix or large patch ecosystem. Historical patch size/frequency is compared with current patch size/frequency.	This attribute is used to evaluate level of ecosystem fragmentation that interferes with landscape scale ecological processes. The current average patch size and total number of patches of the type are compared to earlier conditions where data are available.	Stressors include conversion to agriculture/pasture, commercial/industrial/residential use and construction of transportation infrastructure - roads, pipelines, transmission lines - that interfere with large-scale ecological processes such as fire or surface hydrology.

KEA Class: Name	Definition general	Rationale general	Stressors general
Size/Extent: **Ecosystem "Occurrence" Extent**	This attribute assesses the current size (ha) of the occurrence or stand as affects its biodiversity richness, structural complexity, and "internal" ecological processes, especially landscape scale processes like fire. Patch Size is measured as percentage of the Minimum Dynamic Area (MDA) for the ecosystem. This CE is a Matrix/Large Patch type that functions best when patches are large ranging from 20 to 2000 hectares (approximately 50 to 5000 acres) for large patch to 2000 to 405,000 hectares (approximately 5000 to 1,000,000 acres) for matrix.	The area necessary to maintain ecological processes and ensure persistence is an ecosystem's minimum dynamic area (Pickett and Thompson 1978). Ecosystems with patch sizes above the minimum dynamic area (MDA) tend to exhibit vegetation structure and composition, landscape scale ecological processes, and soil and hydrology that are functioning within the natural range of variation. However, the role of patch size in assessing ecological integrity is complex and related to the larger landscape context. Fragmentation from roads and subdivisions has reduced the size of many patches so that the fire regime cannot be restored to pre-1882 frequency without management action i.e., prescribed fire. The MDA to maintain the fire regime (or any natural disturbance regime) under the historical range of natural variation for this ecological system has not been determined. Little empirical study has been done in ecosystems outside of eastern forests to determine the MDA; Faber-Langendoen et al. (2012b) developed criteria for rating patch size based on the spatial patterning of the ecosystem (i.e., matrix, large patch, small patch, or linear) and provide a discussion of the protocol for assessing size/extent.	Stressors to ecosystem extent include actions such as development and fire exclusion that directly or indirectly convert the ecosystem to other land uses or cover types, or actions such as roads that fragment large patches into many small patches.

KEA Class: Name	Definition general	Rationale general	Stressors general
Biotic Condition: **Terrestrial Fauna**	The taxonomic and functional (e.g., guild) composition of the native faunal assemblage of the ecosystem including birds, mammals, reptiles and amphibians, and invertebrates; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term). Monitoring populations of key native grassland fauna will provide information on the condition of these important components of semi-desert grasslands (Finch 2004).	The taxonomic and functional composition of the faunal assemblage is an important aspect of the ecological integrity of an ecosystem. Many native species of birds, mammals, reptiles and amphibians, and invertebrates use this ecosystem as habitat for feeding, resting, breeding, and movement; and their patterns of use vary over time (seasonal, annual, longer-term) (Finch 2004, Parmenter and Van Devender 1995, Whitford et al. 1995). These species vary in their sensitivity to different stresses such as alterations to vegetation composition, fire frequency, and water availability. Alterations in the taxonomic and functional composition of the terrestrial faunal assemblage beyond its natural ranges of variation therefore strongly indicate the types and severities of stresses imposed on the ecosystem.	Stressors to the taxonomic and functional composition of the faunal assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, floral composition, and abiotic condition of the ecosystem; and incursions of non-native species that alter the food web or directly compete with or prey on the native fauna.

KEA Class: Name	Definition general	Rationale general	Stressors general
Biotic Condition: **Vegetation Composition**	The overall plant species composition and diversity of an ecosystem is an important aspect of its ecological integrity and largely defines it.	The taxonomic and functional composition of the plant species assemblage is an important aspect of the ecological integrity of a terrestrial ecosystem; many ecological processes and environmental variables affect it (drought, fire regime, herbivory, anthropomorphic disturbance). In addition, the impact of invasive non-native species on community function of native vegetation is well documented (Anable et al. 1992, Cable 1971, Cox et al. 1988). Livestock grazing can affect the structure and composition of semi-desert grasslands, as well as soil structure and water infiltration, and species diversity (USDA-USFS 2009). Plant species vary in their sensitivity to different stresses such as herbivory by native species, livestock grazing or lack of fire. This can alter the taxonomic composition of the terrestrial floral assemblage beyond its natural range of variation and strongly indicate the types and severities of stresses imposed on the ecosystem (Gori and Enquist 2003). High cover of native perennial grass and low cover of woody vegetation define this grassland CE.	Stressors to the taxonomic and functional composition of the plant assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, vegetation structure, and abiotic condition of the ecosystem; especially altered fire regime, improper livestock grazing management, and incursions of non-native species that alter the food web or directly compete with the native plants.

KEA Class: Name	Definition general	Rationale general	Stressors general
Biotic Condition: **Vegetation Structure**	An assessment of the overall structural complexity of the vegetation layers, including presence or cover of multiple strata, age and structural complexity of main canopy layer, and expected frequencies of successional or age classes.	Vegetation structure is an important reflection of dynamics and creates heterogeneity within the community. The distribution of total cover, crown diversity, stem size, and age classes or cohorts reflects natural disturbance regimes across the landscape and affects the maintenance of biological diversity, particularly of species dependent upon specific stages. For example, Gori and Enquist (2003) found grass cover declined with increased shrub cover in these mixed grasslands, which ranged from open grasslands with low shrub canopy cover (less than 10%) towards higher shrub cover and ultimately to convert (> 35% total shrub canopy cover or > 15% mesquite or juniper cover) to shrublands without frequent fire. High cover of native perennial grass and low cover of woody vegetation define this grassland CE.	Alteration of vegetation structure can come from a variety of stressors, including changes in fire regime (e.g. too frequent or too infrequent), removal of native woody species by herbicide, livestock grazing or concentrated native herbivory that removes native perennial herbaceous plants, climate change, and various kinds of mechanical disturbance that damages or removes vegetation.
Abiotic Condition: **Soil Condition**	Soil is basic to the proper functioning of a terrestrial ecosystem. Good soils will enhance the resilience and function of an ecosystem. Poor condition soil will limit the function of an ecosystem and if not addressed can permanently degrade a site. Soil condition includes indicators of multiple soil properties such as soil structure (particle and pore size, vertical profile, soil aggregates) and surface condition such as presence of soil crusts.	The condition of soil/surface substrate directly affects the functioning of the ecosystem. Soil/surface substrate condition of a site can be directly evaluated using indicators of soils disturbance such as evidence of erosion and disrupted soil processes and properties. The types of disturbances (stressors) can also be recorded to indicate condition such as livestock trampling and recreational vehicles. These disturbances can directly affect soil properties by disturbing soil crusts, compacting pore space that reduces water infiltration and percolation, changing other structural characteristics, and can expose soils to increased erosional forces.	Excessive livestock trampling, vehicle use (motorbikes, off-road vehicles, construction vehicles), filling and grading, plowing, other mechanical disturbance to the soil surface, excessive soil movement (erosion or deposition) as evidenced by gully, rill, or dune formation. Climate change and drought can also lead to increased potential for erosion.

KEA Class: Name	Definition general	Rationale general	Stressors general
Abiotic Condition: **Fire Regime**	Fire is a natural agent of disturbance in upland vegetation communities that maintains species composition, vegetation structure, and sustains ecological processes such as nutrient cycling.	Altered (uncharacteristic) fire regime greatly influences ecosystem processes and vegetation structure. For semi-desert grassland frequent fire (FRI of 2.5-10 years) is key to reducing shrub cover and preventing conversion from perennial grassland to shrubland or juniper woodland (Gori and Enquist 2003). Lack of fire can lead to increases in grass density and accumulated litter.	Fire exclusion in fire-maintained ecosystems results in increased woody species density and cover, vertical structure of the vegetation, changes in wildlife species assemblages, and increased fuel that ultimately produce high severity fire. Grazing can reduce fine fuels so that the landscape cannot carry a fire. Specific stresses include fire suppression with building roads that act as fire breaks, and active fire suppression by land owners and agency personnel.

D-2.1.7 Relationship of KEAs to Fundamentals of Rangeland Health

The key ecological attributes and indicators listed in Table D-10 also encompass the four fundamentals of rangeland health (USDI-BLM 2006), as shown in Table D-11. The KEA of Landscape Condition specifically refers to watershed conditions; all other KEAs refer specifically to Ecological Processes and Habitat. However, many of the indirect indicators for the KEAs for Abiotic Condition focus on stressors that arise as a result of modifications to the watershed or water quality, the fourth Fundamental. These relationships are also indicated in Table D-11. Further information about interpretation and assessment of these fundamentals of rangeland health can be found in Pellant et al. (2005).

Table D-11. Key Ecological Attributes (KEA) for the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe, and their relationship to fundamentals of rangeland health.

Indicator	Watershed	Ecological Processes	Water Quality	Habitat
Landscape Condition	X	X	X	X
Patch Size	X	X		X
Terrestrial Fauna				X
Vegetation Composition		X		X
Vegetation Structure				X
Soil Condition		X	X	X
Fire Regime	X	X		X

D-2.1.8 Conceptual Model Diagrams

See Figure D-10 and Figure D-11 above.

D-2.2 Ecological Status Assessment Results and Interpretation

This section of the appendix presents and discusses the results of the ecological status assessment for the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe CE. The presentation addresses each indicator separately, and then addresses the overall assessment, which integrates the results of all individual indicators. The results are presented using a common framework, in which the status of an indicator – or the combination of all indicators – is scored on a scale from 0.0 to 1.0, where 0.0 indicates a condition of complete replacement of reference ecological conditions due to the impacts of stressors, and 1.0 indicates a condition of no alteration of reference ecological conditions. The same color ramp is used for all results, yellow to dark blue, where yellow equals low scores, green moderate scores and dark blues high scores.

D-2.2.1 Current Ecological Status: Development, Fire Regime, Invasives

The maps below (Figure D-12) show the ecological status results for each of the three individual indicators – development, fire regime departure, and invasives – for the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe.

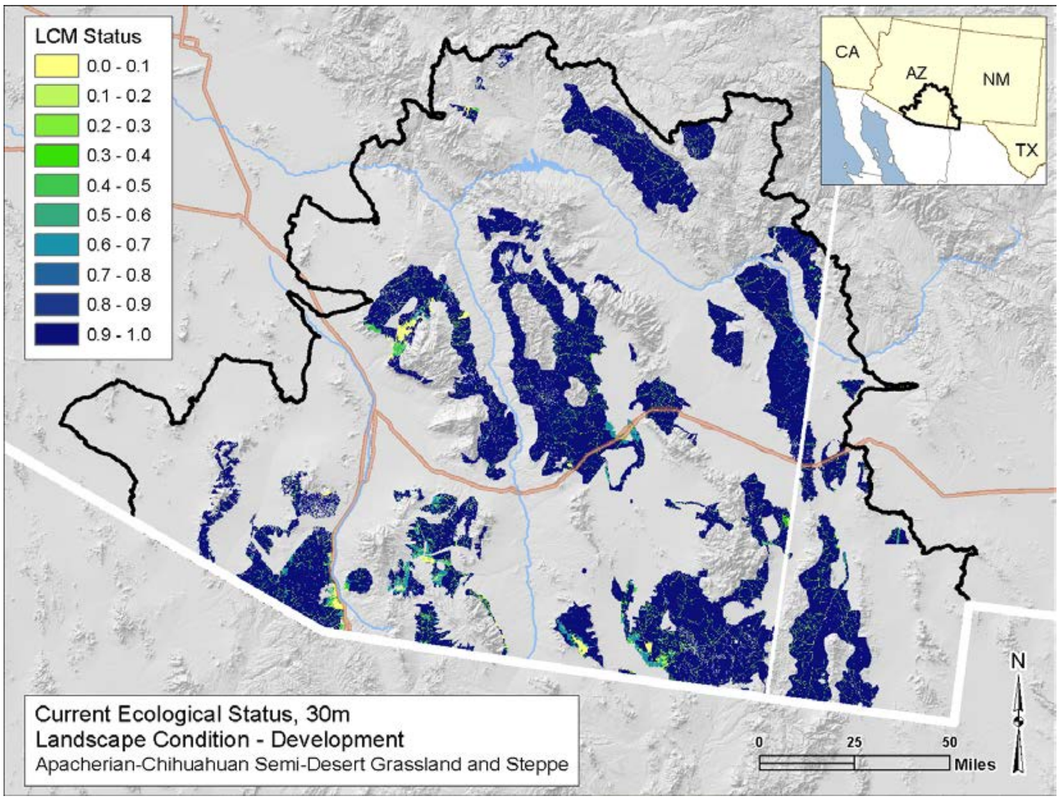
The development indicator is a stressor-based indicator of the spatial extent and intensity of human modifications to the land surface that alters ecosystems or habitat in the MAR ecoregion. The indicator takes into account the density of urban development; infrastructure such as above- and below-ground distribution corridors, communication towers, and border barriers; a wide range of transportation features; mines and landfills; recreational development; agriculture; and energy development. The scoring is on a continuous scale from 0 to 1, with the highest score of 1.0 indicating no ecologically relevant modifications, and the lowest score of 0.0 indicating modifications that essentially eliminate all natural cover and ecological functions.

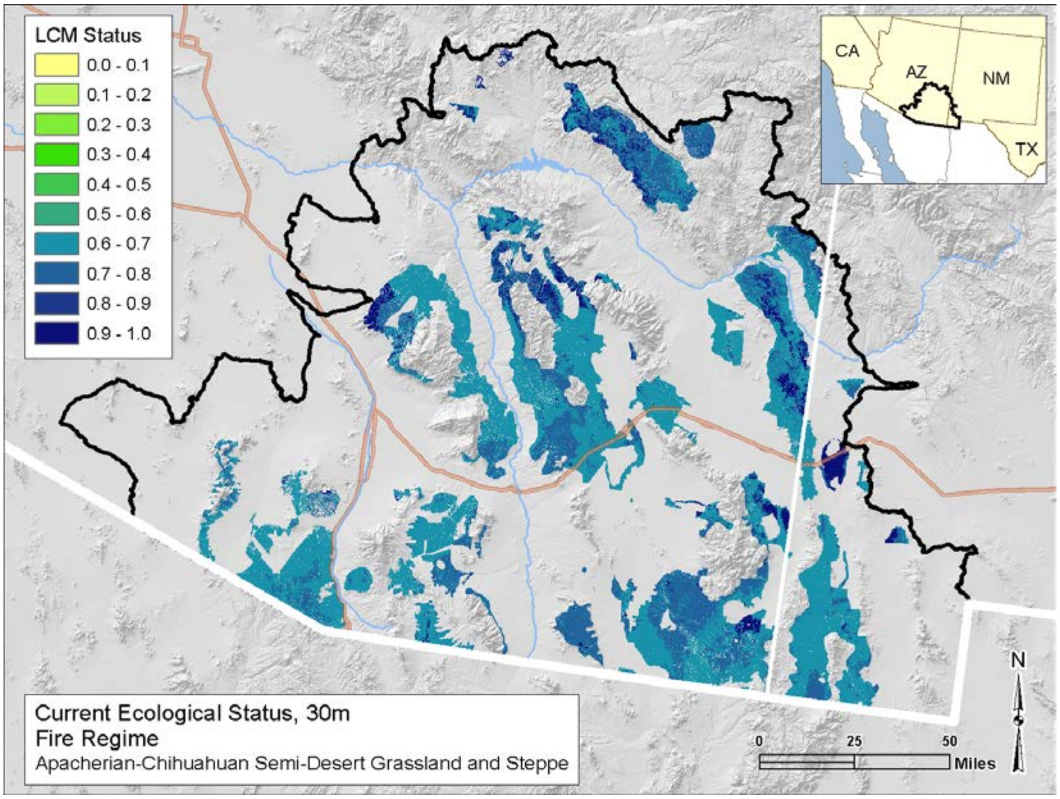
The development indicator results shown in the first map of Figure D-12 show several large areas and corridors of intense development throughout the ecoregion, representing areas of municipal and agricultural development. Development impacts are especially noticeable in and around residential communities in the ecoregion such as Portal, Douglas, Bisbee, Sonoita, Patagonia, Nogales, Tucson, and Willcox, Fort Huachuca, Oro Valley, and Rio Rico; and along corridors associated with interstate highways 10 and 19, and many other larger roads. At the scale of the ecoregion and a small map such as this, the dispersed effects of smaller development features such as dirt roads, transmission corridors, pipelines, cell towers, and the like are not noticeable. They nevertheless contribute to fragmentation of the grasslands, effects of dispersed recreation actitivites, and overall lead to increased impacts to the grasslands in general.

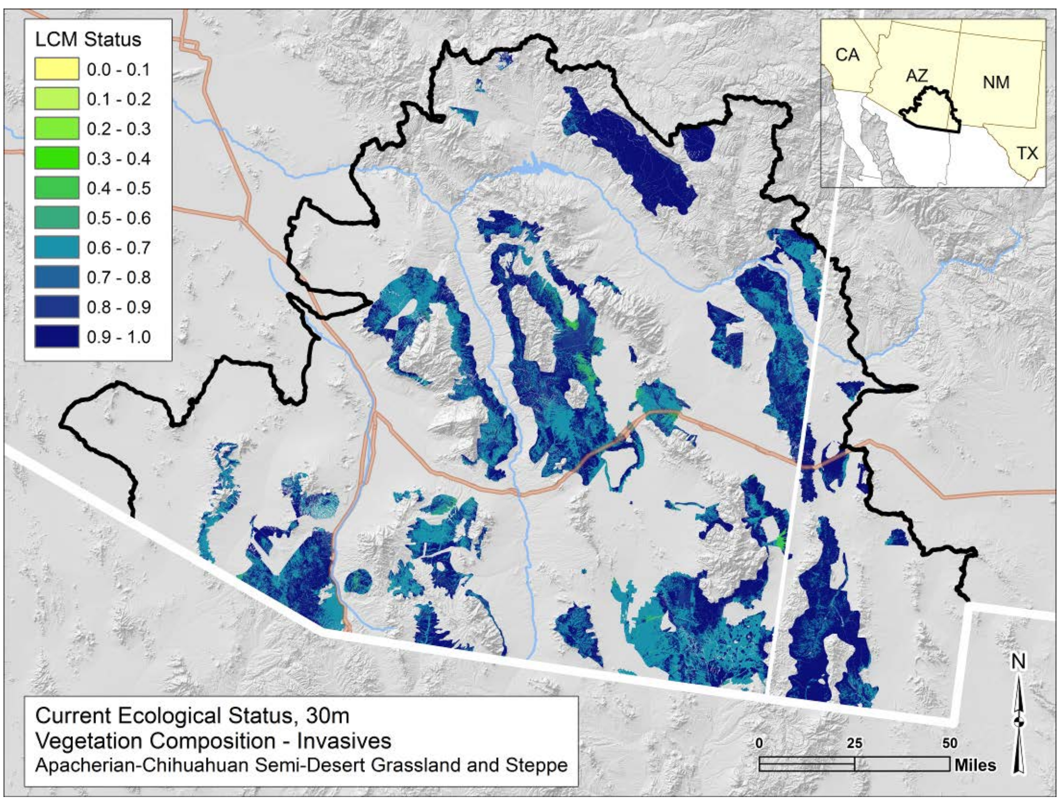
It is important to note that most development impacts are scored much lower than non-development change agents; for example, site intensity values for urbanization ranged from 0.05 to 0.6 for high to low density development, respectively. This is because development typically has a much stronger on-site impact than the other indicators. However, except for urban development, most development impacts occur at smaller scales than can be displayed in these maps, but still are pervasive throughout much of the ecoregion. In particular, effects of many of the very small, local areas of development, or small linear features (e.g. dirt roads) will not be obvious at the scale of the development indicator map.

The second indicator is an indirect measure of fire regime. It is based on the Vegetation Condition Class (VCC) dataset produced by Landfire, which was developed to compare historical reference conditions with current conditions for an individual ecological system type (see **Status Assessment Methods** above). The result of VCC is a ranking of departure from expected historical range of variability, which can be interpreted as “how has the disturbance regime [for the REA purposes and relevant to this ecoregion: fire regime] changed from its historical variability for this individual CE”. Only Severe Vegetation Departure (0.65) and Moderate Vegetation Departure (0.75) were used and are displayed in the map; no to minor departure was scored as 1 (dark blue in the map).

Figure D-12. Scores for three indicators for Apacherian-Chihuahuan Semi-Desert Grassland and Steppe: development indicator (first map), fire regime departure indicator (second map), and invasive species indicator (third map) for each 30m pixel. At the ecoregion scale, many development features are not readily visible (i.e. secondary roads or highways, railroads, small agricultural fields). Yellow (equivalent to 0) indicates high impacts from the CA, dark blue (equivalent to 1) indicates little to no impact from the CA. Only 3 classes of fire regime condition are scored: no to little departure (dark blue), moderate departure and severe departure (lighter blue). For the invasives indicator results, higher cover of mesquite or invasive exotics will score between .4 and .6 (light greens), while lower cover scores between .6 and .8 (light blues).




LCM Status
0.0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1.0
CA
AZ
NM
TX
N
0
25
50
Miles
Current Ecological Status, 30m
Fire Regime
Apacherian-Chihuahuan Semi-Desert Grassland and Steppe


LCM Status
0.0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1.0
CA
AZ
NM
TX
N
0
25
50
Miles
Current Ecological Status, 30m
Vegetation Composition - Invasives
Apacherian-Chihuahuan Semi-Desert Grassland and Steppe

As illustrated in the second map of Figure D-12, much of this CE's extent is in moderate (0.7-0.8) to severe (0.6-0.7) departure throughout much of the ecoregion. Areas with low departure are small patch and often restricted to higher elevation grasslands. These results are consistent with research documenting the results of fire exclusion in the MAR ecoregion. Historically, The Apacherian-Chihuahuan Semi-Desert Grassland and Steppe burned frequently; these grasslands were maintained as open grasslands with low shrub cover by fire return intervals of 2.5 to 10 years (Brown and Archer 1999, McPherson 1995, Robinett 1994, Wright 1980). Active and passive fire suppression over the last century has excluded fire from much of this ecological system (Gori and Enquist 2003, Schussman 2006a). Fire exclusion allows increased woody species cover and leads to an uncharacteristic fire regime in many stands (Barton 1999, Gori and Enquist 2003, Muldavin et al. 2002, Turner et al. 2003). This altered (uncharacteristic) fire regime greatly influences ecosystem processes, resulting in grasslands becoming dominated by woody vegetation and eventually converted to shrublands or woodlands. Conversion to juniper woodlands or mesquite or creosotebush shrublands is common when trees or mesquite exceed 15% cover (Gori and Enquist 2003).

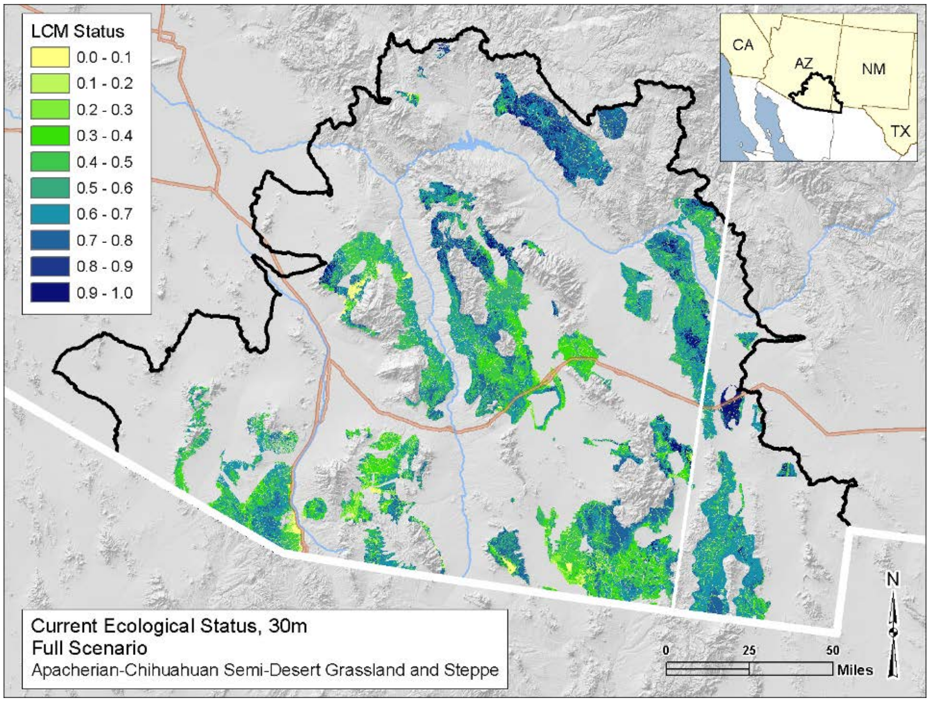
The invasive species indicator serves as an indirect measure of vegetation composition, by measuring the cover of invasive species. It includes a combination of non-native grass and forbs and native woody increasers (mesquite cover), as described previously in this appendix. The scoring is on a continuous scale from 0 to 1, with the highest score of 1.0 indicating no ecologically relevant cover of invasive species, and 0.0 indicating a conversion to non-native grasses and forbs and/or invasive mesquite. Table D-3 shows the cover classes used and the site intensity values for them, for this CE. The values range from 0.65 to 0.90. Either or both non-native invasive and native invasive woody cover may occur on in a single pixel. If both occur, then scores for that pixel are multiplied to create a new combined, lower indicator score.

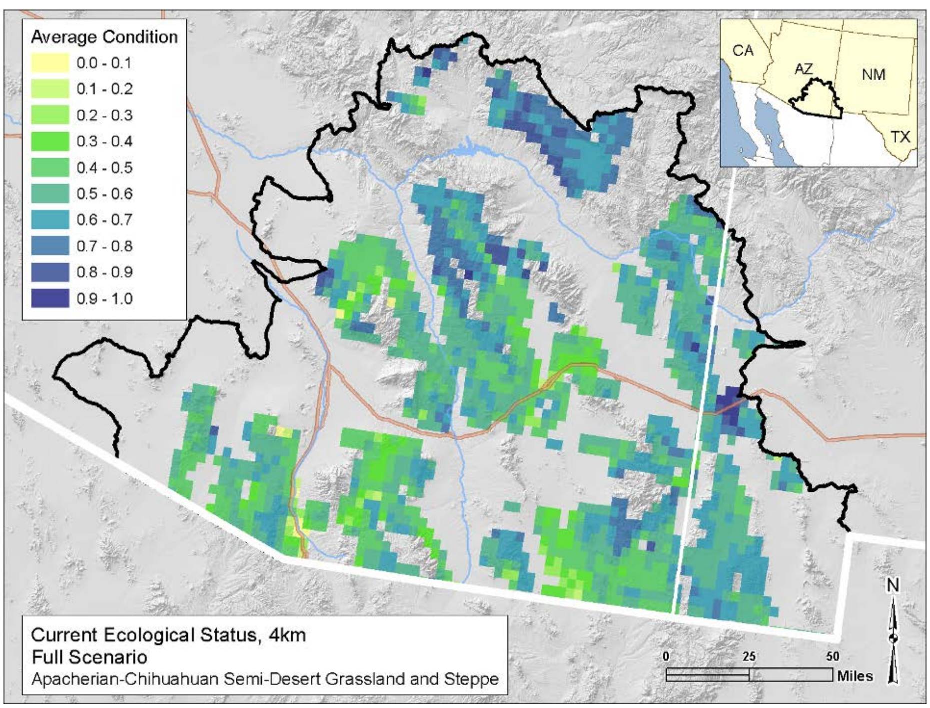
The third map of Figure D-12 indicates moderate (>10 -15%) to high (>25%) cover of exotic grasses and forbs or invasive mesquite in the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe CE for the ecoregion. There are significant areas with low or no cover of invasive species in small patches often at higher elevations, and in large patches in Natanes Plateau and ranges in the boot heel of New Mexico. Area with high cover of both non-native grasses and forbs and invasive mesquite are indicated in light green patches east of the Galliuro Mountains.

These results are also consistent with research documenting the results of fire exclusion in the REA. With fire exclusion, the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe CE is vulnerable to increases in native shrub cover, especially invasive mesquite and juniper (Gori and Enquist 2003). The introduction of two invasive non-native, perennial grasses, Lehmann and Boer lovegrasses (*Eragrostis lehmanniana* and *Eragrostis curvula*) has greatly impacted many semi-desert grasslands in this ecoregion (Anable et al. 1992, Cable 1971, Gori and Enquist 2003).

D-2.2.2 Current Ecological Status: Full Scenario

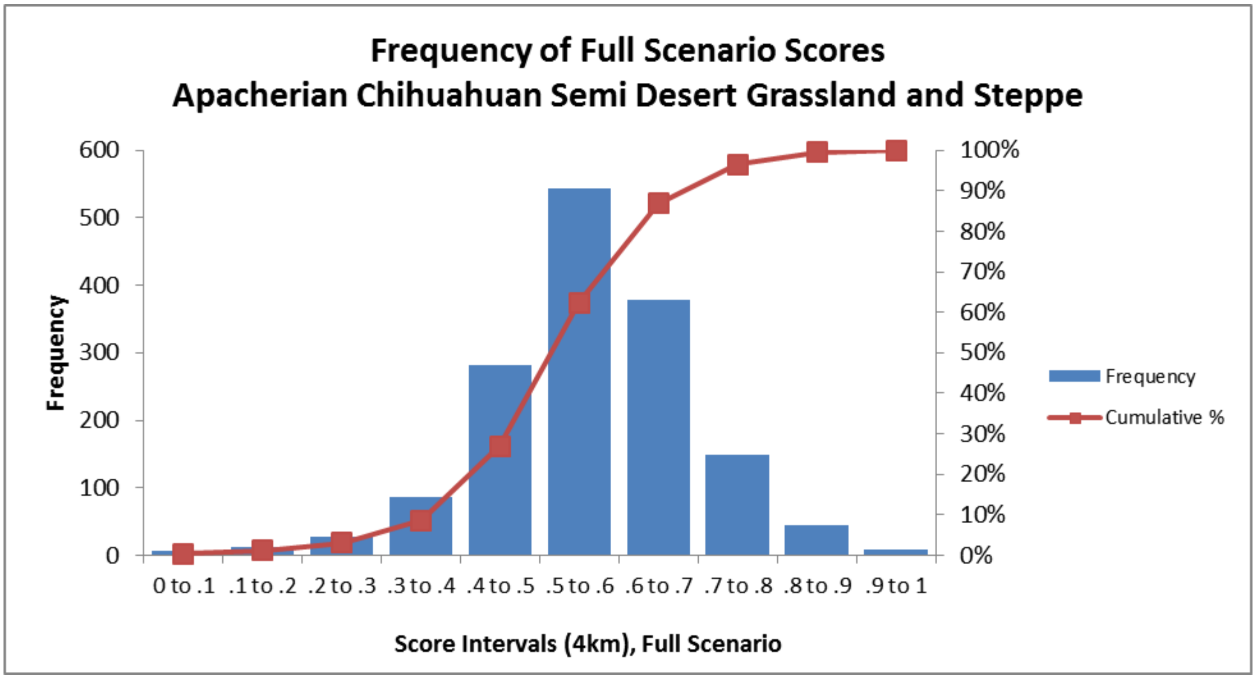
Figure D-13. Overall ecological status scores for Apacherian-Chihuahuan Semi-Desert Grassland and Steppe for all indicators combined (development, fire regime and invasives) for each 30m pixel (top) and 4km grid cells (bottom). The score for each 4km cell is an average of all 30m pixels that are scored for the CE. Yellow scores (equivalent to 0) indicate high impacts from the CAs, dark blue (equivalent to 1) indicate little to no impact from the CAs.





The first map in Figure D-13 illustrates all three of the indicators combined into a single ecological status score per pixel of the CE's distribution. The combined, per-pixel status scores are noticeably lower than the individual scores for each indicator. The combined status scores for each pixel were summarized to the reporting unit (e.g., 4km grid) by taking the average status score from all the pixels of the CE within the reporting unit. The results, shown in the second map of Figure D-13 and the frequency diagram in Figure D-14 indicate the widespread general degradation of the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe CE across its range in the ecoregion. Some 90% of the 4km grid cells fall at or below the 0.7 scores. There are a few local areas of better ecological condition, a result of low level of development, low or no cover of invasive species, and moderate fire regime departure.

Figure D-14. Frequency distribution of the 4km ecological status scores for the Apacherian-Chihuahuan Semi-Desert Grassland and Steppe, with cumulative percent. The x-axis represents the 0.1 increment scoring intervals, while the y-axis shows the number of grid cells in each interval (left) and the cumulative percentage of the grid cells for each interval (right). For this CE, most of the status scores fall in the range from 0.4 to 0.7.



D-2.3 References for the CE

Anable, M. E., M. P. McClaran, and G. B. Ruyle, 1992. Spread of introduced Lehmann lovegrass *Eragrostis lehmanniana* Nees. in southern Arizona, USA. Biological Conservation, 61, 181-188.

Anning, D.W., S.A. Thiros, L.M. Bexfield, T.S. McKinney, and J.M. Green. 2009. Southwest Principal Aquifers Regional Ground-Water Quality Assessment. U.S. Department of the Interior, U.S. Geological Survey Fact Sheet 2009-3015. http://water.usgs.gov/nawqa/studies/praq/swpa.

Bahre, C. J. 1985. Wildfire in southeastern Arizona between 1859 and 1890. Desert Plants, 7, 190-194.

Bahre, C.J. 1991. *A* legacy of change: historic human impact on vegetation of the Arizona borderlands. The University of Arizona Press, Tucson, AZ.

Barton, A.M. 1999. Pines versus oaks: effects of fire on the composition of Madrean forests in Arizona. Forest Ecology and Management, 120, 143-156.

Bock, C. E. and J. H. Bock. 2002. Numerical response of grassland birds to cattle ranching versus exurban development in southeastern Arizona. 87th Annual Meeting of the Ecological Society of America and the 14th Annual International Conference of the Society for Ecological Restoration.

Bock, J.H. and C.E. Bock. 1992. Short-term reduction in plant densities following prescribed fire in an ungrazed semidesert shrub-grassland. The Southwestern Naturalist **37:**49-53.

Brown, D. E., editor. 1982. Biotic communities of the American Southwest-United States and Mexico. Desert Plants Special Issue 4(1-4):1-342.

Brown, D.E. and E. Makings. 2014. A guide to North American grasslands. Desert Plants Vol. 29 No. 2. University of Arizona.

Brown, J. R. and S. Archer. 1999. Shrub invasion of grassland: Recruitment is continuous and not regulated by herbaceous biomass or density. *Ecology*, 80, 2386-2396.

Burgess, T. L. 1995. Desert grassland, mixed shrub savanna, shrub steppe, or semidesert scrub. Pages 31-67 in: M. P. McClaran and T. R. Van Devender, editors. The Desert Grassland. University of Arizona Press, Tucson.

Cable, D. R. 1971. Lehmann lovegrass on the Santa Rita Experimental Range, 1937-1968. Journal of Range Management, 24, 17-21.

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. Ecological systems of the United States: A working classification of U.S. terrestrial systems. NatureServe, Arlington, VA.

Comer, P. J., and J. Hak. 2009. NatureServe landscape condition model. Internal documentation for NatureServe Vista decision support software engineering, prepared by NatureServe, Boulder, CO.

Cooke, R.U. and R. W. Reeves. 1976. Arroyos and environmental change in the American southwest. Oxford, Clarendon Press.

Cox, J. R., G. B. Ruyle, J. H. Fourle, and C. Donaldson. 1988. Lehmann lovegrass--central South Africa and Arizona, USA. Rangelands. 10(2): 53-55.

Dick-Peddie, W. A. 1993. New Mexico vegetation: Past, present, and future. University of New Mexico Press, Albuquerque. 244 pp.

Faber-Langendoen, D., J. Rocchio, S. Thomas, M. Kost, C. Hedge, B. Nichols, K. Walz, G. Kittel, S. Menard, J. Drake, and E. Muldavin. 2012b. Assessment of wetland ecosystem condition across landscape regions: A multi-metric approach. Part B. Ecological Integrity Assessment protocols for rapid field methods (L2). EPA/600/R-12/021b. U.S. Environmental Protection Agency Office of Research and Development, Washington, DC.

Finch, D.M. editor. 2012. Climate change in grassslands, shrublands, and deserts of the interior American West: a review and needs assessment. Gen. Tech. Rep. RMRS-GTR-285. USDA Forest Service Service, Rocky Mountain Research Station, Fort Collins, CO.

Finch, D. M., editor. 2004. Assessment of Grassland Ecosystem Conditions in the Southwestern United States; Volumes 1 and 2. USDA Forest Service Gen. Tech. Rpt. RMRS-GTR-135. USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy. editors. 2013. Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment, A report by the Southwest Climate Alliance. Washington, DC: Island Press.

Gibbens, R. P., R. P. McNeely, K. M. Havstad, R. F. Beck, and B. Nolen. 2005. Vegetation change in the Jornada Basin from 1858 to 1998. Journal of Arid Environments 61(4):651-668.

Gori, D. F. and C. A. F. Enquist. 2003. An assessment of the spatial extent and condition of grasslands in central and southern Arizona, southwestern New Mexico and northern Mexico. The Nature Conservancy, Arizona Chapter. 29pp.

Gori, D., G. S. Bodner, K. Sartor, P. Warren, and S. Bassett. 2012. Sky Island Grassland Assessment: Identifying and Evaluating Priority Grassland Landscapes for Conservation and Restoration in the Borderlands. Report prepared by The Nature Conservancy in New Mexico and Arizona. 85 p.

Heinz Center. 2011. Managing and Monitoring Arizona's Wildlife in an Era of Climate Change: Strategies and Tools for Success Report and Workshop Summary. Prepared for: U.S. Department of Interior. Bureau of Land Management and The Arizona Game and Fish Department by the H. John Heinz III Center for Science Economics and the Environment. January 13, 2011. Washington, D. C. 67 pp. plus appendices.

Humphrey, R. R. 1949. Fire as a means of controlling velvet mesquite, burroweed, and cholla on southern Arizona ranges. Journal of Range Management, 2, 175-182.

Kaib, M., C.Baisan, H. D. Grissino-Mayer, and T. W. Swetnam. 1996. Fire history of the Gallery pine-oak forests and adjacent grasslands of the Chiracahua Mountains of Arizona. Pages 253-264 in: Folliott, P. F., D. F. DeBano, D. M. Baker, G. J. Gottfried, G. Solis-Garza, C. B. Edminster, D. G. Neary, L. S. Allen, and R. H. Hamre, eds. 1996. Effects of fire on Madrean province ecosystems-a symposium proceedings. Gen. Tech. Rep. RM-289; 1996 March 11-15; Tucson, AZ. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Experiment Station. 277 p.

Marshall, R.M., A.Turner, A. Gondor, D. Gori. C. Enquist, G. Luna, R. Paredes Aguilar, S. Anderson, S. Schwartz, C. Watts, E. Lopez, P. Comer. 2004. An ecological Analysis of Conservation Priorities in the Apache Highlands Ecoregion. Prepared by The Nature Conservancy of Arizona, Instituto del Medio Ambiente y el Desarrolla Sustentable del Estado de Sonora, agency and institutional partners. 152 pp.

Martin, S. C. 1983. Responses of semidesert grasses and shrubs to fall burning. Journal of Range Management, 36, 604-610.

McAuliffe, J. R. 1995. Landscape evolution, soil formation, and Arizona's desert grasslands. Pages 100-129 in: M. P. McClaran and T. R. Van Devender, editors. The Desert Grassland. University of Arizona Press, Tucson.

McKinney, T.S. and D.W. Anning. 2009. Geospatial data to support analysis of water-quality conditions in basin-fill aquifers in the southwestern United States. U.S. Geological Survey Scientific Investigations Report 2008-5239. http://pubs.er.usgs.gov/sir/2008/5239.

McPherson, G. R. 1995. The role of fire in the desert grasslands. Pages 130-151 in: M. P. McClaran and T. R. Van Devender, editors. The Desert Grassland. University of Arizona Press, Tucson.

McPherson, G.R. 1997. Ecology and management of North American savannas. The University of Arizona Press, Tucson, Arizona.

Milchunas, D.G. 2006. Responses of plant communities to grazing in the southwestern United States. Gen. Tech. Rep. RMRS-GTR-169. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 126 p.

Muldavin, E. H., P. Arbetan, E. B. Henderson, and M. Creutzburg. 2012. Modeling vegetation dynamics among Chihuahuan Semi-desert Grassland ecological groups as part of the Integrated Landscape Assessment Project (ILAP). Poster Presentation for Ecological Society of America. August 2012. August 5 -- 10, 2012

Muldavin, E., Y. Chauvin, and G. Harper. 2000b. The vegetation of White Sands Missile Range, New Mexico: Volume I. Handbook of vegetation communities. Final report to Environmental Directorate, White Sands Missile Range. New Mexico Natural Heritage Program, University of New Mexico, Albuquerque. 195 pp. plus appendices.

Muldavin, E, T. Neville, C. McGuire, P. Pearthree, and T. Biggs. 2002. Soils, geology and vegetation change in the Malpais Borderlands. Publication No. 05-GTR-228. Natural Heritage New Mexico, Museum of Southwestern Biology, University of New Mexico. 26 p. NatureServe. 2013. International Ecological Classification Standard: International Vegetation Classification. Central Databases. NatureServe, Arlington, VA.

NatureServe. 2013. International Ecological Classification Standard: International Vegetation Classification. Central Databases. NatureServe, Arlington, VA.

Ockenfels, R.A., C.L. Ticer, A., Alexander, and, J.A. Wennerlund. 1994. Home ranges, movement patterns, and habitat selection of pronghorn in central Arizona a final report. March 1994. Phoenix, Arizona, Arizona Game and Fish Department Research Branch.

Parmenter,R. R. and T. R.Van Devender. 1995. Diversity, Spatial Variability, and Functional Roles of Vertebrates in the Desert Grassland. Pages 196-229 in: M. P. McClaran and T. R. Van Devender, editors. The Desert Grassland. University of Arizona Press, Tucson.

Pellant, M., P. Shaver, D.A. Pyke, and J.E. Herrick. 2005. Interpreting indicators of rangeland health, version 4. Technical Reference 1734-6. U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center, Denver, CO. BLM/WO/ST-00/001+1734/REV05. 122 pp.

Pickett, S.T.A., and J.N. Thompson. 1978. Patch dynamics and the size of nature reserves. Biological Conservation 13: 27-37.

Robinett, D. 1994. Fire effects on southeastern Arizona plains grasslands. *Rangelands*, 16, 143-148.

Schussman, H. 2006a. Historical Range of Variation and State and Transition Modeling of Historical and Current Landscape Conditions for Semi-Desert Grassland of the Southwestern U.S. Prepared for the U.S.D.A. Forest Service, Southwestern Region by The Nature Conservancy, Tucson, AZ. 53 pp.

Swetnam, T.W. and C.H. Baisan. 1996. Fire histories of montane forests in the Madrean borderlands. Effects of fire on Madrean Province ecosystems: A symposium proceedings. RM-GTP-289. December 1996. USDA Forest Service.

Turner, R.M., R.H. Webb, J.E. Bowers, and J.R Hastings. 2003. The changing mile revisited An ecological study of vegetation change with time in the lower mile of an arid and semiarid region. University of Arizona Press, Tucson, Arizona.

USDI-BLM [U.S. Bureau of Land Management]. 2006. 43CFR4180.1 Fundamentals of Rangeland Health. Code of Federal Regulations and Federal Register, Accessed February 2013 http://federal.eregulations.us/cfr/section/2006/04/18/43-cfr-4180.1

USDI-BLM[U.S. Bureau of Land Management]. 2010. Instructional Memorandum No. AZ-2011-005. The BLM Sensitive Species List for Arizona. EMS TRANSMISSION 12/29/10

USDA-NRCS. 2014. Selected Approved Ecological Site Descriptions for Major Land Resource Area 041- Southeastern Arizona Basin and Range. US Department of Agriculture. Natural Resource Conservation Service. Website accessed September 2014. https://esis.sc.egov.usda.gov/Welcome/pgApprovedSelect.aspx?type=ESD

USDA-USFS [U.S. Forest Service]. 2009. Ecological sustainability report. Coronado National Forest. United States Department of Agriculture. Forest Service. Southwest Region. February 2009. Pp. 118.

Whitford, W. G., G. S. Forbes, and G. I. Kerley. 1995. Diversity, spatial variability, and functional roles of invertebrates in desert grassland ecosystems. Pages 151-195 in: M. P. McClaran and T. R. Van Devender, editors. The Desert Grassland. University of Arizona Press, Tucson.

Wright, H. A. The role and use of fire in the semidesert grass-shrub type. 1980. Ogden, UT, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station.

Yanoff, S., P. McCarthy, J. Bate, L.W. Miller, A. Bradley, and D. Gori. 2008. New Mexico rangeland ecological assessment. 73 p. The Nature Conservancy in New Mexico. Report available online: http://nmconservation.org/projects/rangeland_ecological_assessment/ [August 15, 2012].

Foothill Woodlands

D-3 Madrean Encinal Ecological System

D-3.1 Conceptual Model

D-3.1.1 Classification

The ecosystem conservation elements for the MAR REA were selected from NatureServe's classification of terrestrial ecological systems (Comer et al. 2003). Over three dozen ecological systems occur in the MAR, but only a select subset was chosen for the REA. The CE concept provided in this conceptual model includes this NatureServe ecological system type:

- Madrean Encinal (CES305.795)

There are other terrestrial ecological systems in the NatureServe classification that also occur in the MAR, or in adjacent ecoregions, which are similar to this CE concept but are not included in this conservation element. These are listed here to help the reader understand what is not included in this conceptual model; each of these other ecological systems has information that can be searched for and reviewed on NatureServe's on-line Explorer website (http://explorer.natureserve.org/servlet/NatureServe). The System Code beginning with CES (Community Ecological System) is an information rich database code that refers to the North American Ecological Division (305) where the system primarily occurs and the number used to identify the system (Comer et al. 2003).

- Madrean Juniper Savanna (CES305.730) - codominated by oak
- Madrean Pinyon-Juniper Woodland (CES305.797) - codominated by oak
- Apacherian-Chihuahuan Semi-Desert Grassland and Steppe (CES302.735) – with scattered oaks

D-3.1.2 Summary

Madrean Encinal occurs in foothills, canyons, alluvial fan piedmonts (bajadas) and plateaus in the Sierra Madre Occidentale and Sierra Madre Orientale in Mexico, extending north into Trans-Pecos Texas, southern New Mexico and sub-Mogollon Arizona. Stands occur down to 900 m elevation in southern Sonora, but generally range from around 1200-1350 m intermixed with semi-desert grasslands, and extend up to 1650-2200 m as pure oak patches within Madrean montane forests and woodlands (Brown 1982; Figure D-16). Soils are variable but generally thin and rocky. Where encinal occurs within grasslands, it generally occupies the rockier substrates or is restricted to drainages (Brown 1982).

Figure D-15. Distribution of Madrean Encinal at 30m resolution. The distribution was derived from the NatureServe (2013) terrestrial ecological systems map. Appendix G (ecological integrity) has a table listing the areal extent of this ecological system and its % of the assessment area.

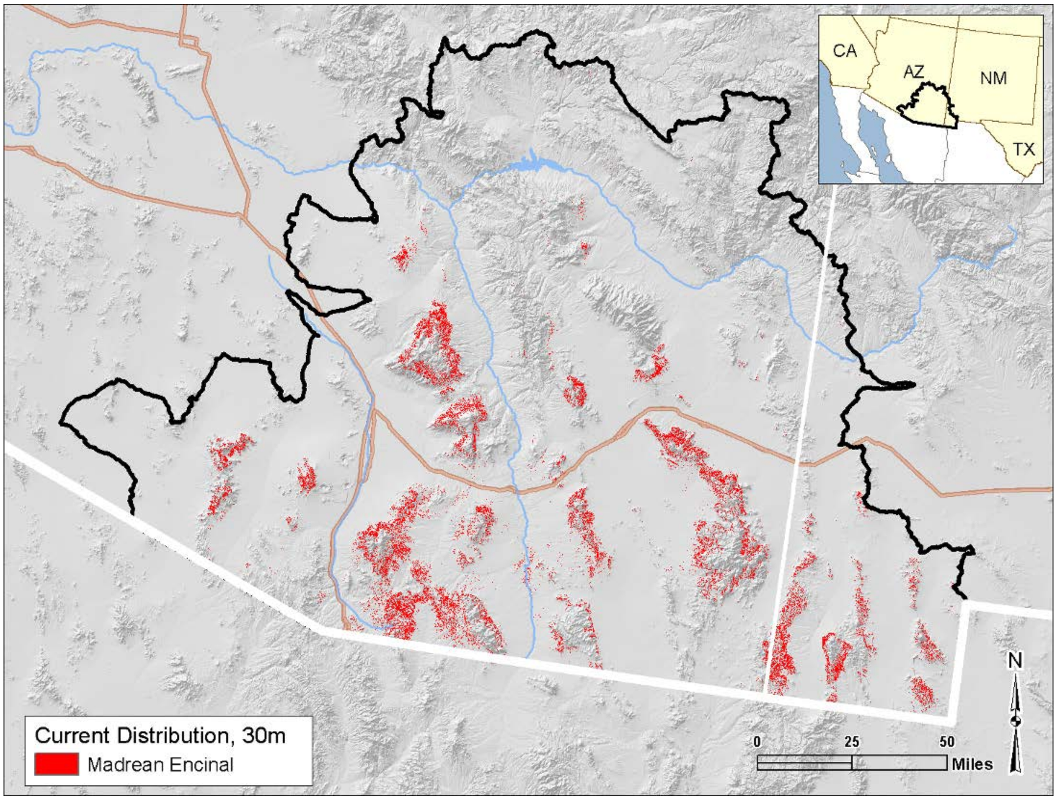


Figure D-16. Madrean Encinal steep west-facing slope above the pine-oak corridor of Rattlesnake Canyon (source http://azfirescape.org).

Adjacent ecosystems may include Madrean Pinyon-Juniper Woodland (CES305.797) and Madrean Lower Montane Pine-Oak Forest and Woodland [CES305.796] at higher elevations and Mogollon Chaparral (CES302.741), Madrean Juniper Savanna (CES305.730) and Apacherian-Chihuahuan Semi-Desert Grassland and Steppe CES302.735 at lower elevations. The environmental description is based on several references, including Brown (1982), Dick-Peddie (1993), Ffolliott (1999a), McAuliffe (1995), Muldavin et al. (1998), Muldavin et al. (2000b), NatureServe Explorer (2013), Schussman (2006b), and Stuever and Hayden (1997a).

Stands of this ecosystem are dominated by diagnostic Madrean evergreen oak tree species, including *Quercus arizonica, Quercus emoryi, Quercus grisea, Quercus oblongifolia* in the U.S. and northern Mexico, and *Quercus albocincta, Quercus chihuahuensis, Quercus chuchuichupensis*, and *Quercus santa-clarensis* further south in southern Chihuahua and Durango, Mexico. *Arbutus arizonica* or *Arbutus xalapensis* may be present with the evergreen oaks in some stands. Other evergreen tree species may be present with lower cover (not codominant), including *Pinus cembroides, Pinus discolor, Juniperus coahuilensis*, and *Juniperus deppeana* at lower elevations and *Pinus arizonica, Pinus engelmannii, Pinus leiophylla*, or *Pinus strobiformis* at montane elevations. Chaparral species such as *Arctostaphylos pungens, Cercocarpus montanus, Frangula betulifolia (= Rhamnus betulifolia)*, *Purshia* spp., *Garrya wrightii, Quercus intricata, Quercus toumeyi*, *Quercus turbinella,* or *Rhus* spp. are common in shrub layers, but do not dominate the vegetation. Other shrubs present may include rosette shrubs such as

Dasylirion wheeleri or *Yucca bacata;* and cacti*, Opuntia engelmannii, Opuntia imbricata,* or *Opuntia phaeacantha.* The herbaceous layer is usually prominent, especially in inter-spaces between trees in open woodlands. Dominant species are typically warm-season perennial grasses such as *Aristida* spp., *Bouteloua gracilis, Bouteloua curtipendula, Bouteloua radicosa, Bouteloua rothrockii, Digitaria californica, Eragrostis intermedia, Eragrostis mexicana, Hilaria belangeri, Leptochloa dubia, Muhlenbergia emersleyi, Muhlenbergia longiligula, Muhlenbergia pauciloba*, *Piptochaetium fimbriatum* or *Schizachyrium cirratum*, species typical of desert grasslands and steppe. This woodland group includes seral stands dominated by short (2-5 m tall) Madrean tree oaks, typically with a strong graminoid layer. In transition areas with drier chaparral, the stands of chaparral may have scattered Madrean tree oak species, but these oaks have sparse cover and do not form a layer. The vegetation description is based on several references, including Brown (1982), Dick-Peddie (1993), Ffolliott (1999), Muldavin et al. (2000b), NatureServe Explorer (2013), Schussman (2006b), and Stuever and Hayden (1997a).

A crosswalk of this system to USDA Natural Resource Conservation Service (NRCS) approved Ecological Site Descriptions (ESD) by Major Land Resource Areas (MLRA) is provided in Table D-12 (USDA-NRCS 2014). For complete list of ESDs for MLRA 41 see https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD.

Table D-12. Madrean Encinal ecosystem CE crosswalk with approved Ecological Site Descriptions (provisional cross-walk).

MLRA	Ecological Site Description Name	Site ID
041-Southeastern Arizona Basin and Range	Granitic Hills 16-20" p.z. - *Quercus emoryi* - *Quercus arizonica* / *Nolina microcarpa* - *Erythrina flabelliformis* / *Bouteloua curtipendula* - *Schizachyrium cirratum* (Emory oak - Arizona white oak / sacahuista - coralbean / sideoats grama - Texas bluestem)	R041XA102AZ
041-Southeastern Arizona Basin and Range	Volcanic Hills 16-20" p.z. - *Quercus emoryi* - *Juniperus deppeana* / *Eriogonum wrightii* - *Nolina microcarpa* / *Bouteloua curtipendula* - *Eragrostis intermedia* (Emory oak - alligator juniper / bastardsage - sacahuista / sideoats grama - plains lovegrass)	R041XA111AZ
041-Southeastern Arizona Basin and Range	Sandy Wash 16-20" p.z. (QUEM, QUAR) - *Quercus arizonica* / / *Bouteloua curtipendula* - *Leptochloa dubia* (Emory oak - Arizona white oak / / sideoats grama - green sprangletop)	R041XA112AZ
041-Southeastern Arizona Basin and Range	Granitic Upland 16-20" p.z. - *Quercus emoryi* / *Calliandra eriophylla* - *Fouquieria splendens* / *Bouteloua chondrosioides* - *Bouteloua hirsuta* (Emory oak / fairyduster - ocotillo / sprucetop grama - hairy grama)	R041XA117AZ
041-Southeastern Arizona Basin and Range	Sandy Loam Upland 16-20" p.z. Deep - *Quercus arizonica* / *Eriogonum wrightii* / *Bouteloua curtipendula* - *Bothriochloa barbinodis* (Arizona white oak / bastardsage / sideoats grama - cane bluestem)	R041XA127AZ

D-3.1.3 Species of Conservation or Management Concern

Below are listed some species of concern associated with this ecological system CE from the BLM Gila District (USDI-BLM 2010); typical species listed in Threaten-Endangered Species/Species of Concern/Species of Interest (TE/SOC/SOI) species associations in Madrean Encinal Woodland from Coronado National Forest Ecological Sustainability Report (USDA-USFS 2009); from the Arizona State Wildlife Action Plan (AZGFD 2012); and from the New Mexico Comprehensive Wildlife Conservation Strategy NMDGF (2006).

Amphibians: Tarahumara Frog (*Lithobates tarahumarae*); barking frog (*Craugastor augusti*)

Birds: Elegant Trogon (*Trogon elegans*); whiskered screech owl (*Otus trichopsis*); Gould's turkey, Montezuma quail, Mexican jay, bridled titmouse,

Mammals: Jaguar (*Panthera onca*); Black Bear (*Ursus americanus*); Arizona Gray Squirrel (*Sciurus arizonensis*)**;** Mexican long-nosed bat (*Leptonycteris nivalis*); lesser long-nosed bat (*Leptonycteris curasoae yerbabuenae*); southern pocket gopher (*Thomomys umbrinus*)

Reptiles: New Mexico Ridge-nosed Rattlesnake (*Crotalus willardi obscurus*); Arizona Ridge-nosed Rattlesnake (*Crotalus willardi*); Giant Spotted Whiptail (*Aspidoscelis burti stictogrammus*); brown vinesnake (*Oxybelis aeneus*)

Invertebrates: Huachuca Giant Skipper (*Agathymus evansi*), Pygmy Sonorella (*Sonorella micra*); Huachuca talussnail, Rosemont talussnail, (and many other talus snails)

Vascular Plants: Spreading Marina (*Marina diffusa*), Chiricahua Mock Pennyroyal (*Hedeoma costatum*), Rothrock's Grama (*Bouteloua rothrockii*)

D-3.1.4 Natural Dynamics

Under historical natural conditions (also called natural range of variability, NRV), the Madrean Encinal ecosystem varies considerably in tree density ranging from very open woodlands and treed savannas (5-15% cover) with a perennial grass-dominated understory in uplands, to moderately dense oak woodlands (20-40% tree cover) in drainages and on north-facing slopes. The understory of good condition stands generally has high cover of perennial grasses and low cover of shrubs such as *Mimosa* and this good condition of the stand is maintained with frequent fires. Turner et al. (2003) documented a trend from more open woodlands and savannas to denser woodlands with higher cover of species of *Juniperus* and *Prosopis* over the last 150 years. Regeneration of oaks following disturbance is from re-sprouting rather than acorns because of the dry conditions (Germaine and McPherson 1999).

Although there is not much encinal-specific information on fire return intervals (FRI) available, it is thought to be similar to adjacent ecosystems primarily the semi-desert grassland (FRI of 2.5 to 10 years) (Bahre 1985, Kaib et al. 1996, McPherson 1995, Wright 1980) and the pine-oak woodlands (FRI of 3- 7 years) (Bahre 1985, Kaib et al. 1996, McPherson 1995, Swetnam and Baisan 1996, Swetnam et al. 1992, Wright 1980). Fire season in encinal was probably similar to that of other Madrean woodlands and grasslands, occurring predominantly before the summer monsoon between April and June when vegetation is dry and ignition sources from dry lightning strikes are common (Swetnam and Betancourt 1990). Post disturbance regeneration (such as after stand-replacing fire) mostly occurs from re-sprouting from trees roots. Successful regeneration from acorns is related to annual precipitation (Germaine and McPherson 1999).

The understory of poor condition stands with less frequent fires or experiencing extended drought may have significant shrub invasion by species of *Arctostaphylos, Fouquieria, Mimosa, Prosopis,* and *Juniperus* and reduction of perennial grass cover (Schussman 2006a).

Over the last century, the woody component has increased in density over time in the absence of disturbance such as fire (Burgess 1995, Gori and Enquist 2003, Schussman 2006a, Turner et al. 2003). This is correlated to a decrease in fire frequency that is related to a reduction of fine fuels that carry fire because of extensive livestock grazing. Frequent, stand replacing fire was likely a key ecological attribute prior to 1890 (Bahre 1985, Kaib et al. 1996, McPherson 1995, Wright 1980).

Herbivory by native herbivores in the Madrean Encinal is likely very similar to semi-desert grasslands, at least for the more open stands, which range from invertebrates and rodents to pronghorn (Finch 2004, Paramenter and Vandevender 1995, Whitford et al. 1995). Encinal soils are also likely similar to grasslands with soil dwelling invertebrates, including tiny nematodes and larger termites and ants, which are important in nutrient cycling and effect soil properties, such as bulk density (Whitford et al. 1995). Above-ground invertebrates such as grasshoppers can significantly impact herbaceous cover when populations are high. Oak acorn and other fruit consumption and seed caching by birds such as jays and native mammals such as deer and bears also impacts encinal.

Herbivory from native small mammals such as burrowing rodents (e.g. ground squirrels) is significant in the semi-desert grassland ecosystem and likely also in encinal. These burrowing rodents have a substantial effect on vegetation composition, soil structure and nutrient cycling (Finch 2004, Parmenter and Van Devender 1995).

Invertebrate animals are also significant in encinal as they are in grasslands. They are both abundant and extremely diverse ranging from single celled protozoans, bacterial and soil nematodes and mites to larger arachnids, millipedes, cockroaches, crickets, grasshoppers, ants, beetles, butterflies, moths, flies, bees, wasps, and true bugs (Whitford et al. 1995). Invertebrates are important for nutrient cycling, pollination, and subterranean species of ants and termites can impact soil properties such as bulk density, infiltration permeability and storage (Whitford et al. 1995). Grasshoppers feed on grasses and forbs and can consume significant amounts of forage when their populations are high. Many species of butterflies, flies, bees, and moths are important for pollination. Some species such as Yucca moths (*Tegeticula yuccasella*) and *Yucca* species have obligate mutualistic relationships (Whitford et al. 1995). More study and review is needed to fully understand the many functional roles animals have within the Madrean Encinal ecosystem.

A good condition/proper functioning Madrean Encinal ecosystem is large and uninterrupted, the surrounding landscape is also in good condition; the biotic condition is within normal range of variation, the weeds are few, the native plants are robust, have expected abundance and reproduction; birds, mammals, reptiles, insects and amphibian species present are indicative of reference, un-molested conditions; the fire regime is functioning at near historical conditions with FRI (fire return interval) of surface fires every 2.5 to 10 years; soils have not been excessively eroded. The structure is that of open woodlands or savannas with an understory of native perennial grasses.

A poor condition/non-functioning ecosystem is highly fragmented, or much reduced in size from its historical extent; the surrounding landscape is in poor condition either with highly eroding soils, many non-native species or a large percentage of the surrounding landscape has been converted to pavement or highly maintained agriculture (row crops, irrigated crops, etc.); the biotic condition is at the limit or beyond natural range of variation, i.e. vegetation structure is converted from open woodlands or savannas with a native perennial grass understory to more dense woodlands with significant cover of non-native grasses such as Lehmann lovegrass (*Eragrostis lehmanniana*). Impacts from herbivory have significantly altered the vegetation structure of plant species composition, i.e. low cover of native grasses, high cover of seral species (such as *Aristida* spp.) or annuals. Characteristic birds, mammals, reptiles, and insect species are not present at expected abundances or the ratio of species shows an imbalance of predator to prey populations; abiotic condition is poor with evidence of high soil erosion, rill and gullies present or exposed soil sub-horizons. The fire regime is no longer a short-return interval, but has been altered by suppression, which in turn has lead to increasingly dense cover of the oaks.

D-3.1.4.1 Natural Dynamics Model

A conceptual state-and-transition model for the Historic Climax Plant Community (HCPC) was extracted directly from an Ecological Site Description (ESD) developed by staff from USDA Natural Resource Conservation Service (Figure D-17). The full conceptual state-and-transition model for the Granite Hills ESD was representative of the Madrean Encinal and is referred Granitic Hills 16-20" p.z, Q*uercus emoryi* -

Quercus arizonica / Nolina microcarpa - Erythrina flabelliformis / Bouteloua curtipendula - Schizachyrium cirratum from the 041-Southeastern Arizona Basin and Range MLRA at: https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD. Note fire and drought are the key ecological variables.

Figure D-17. Conceptual state and transition model of historical conditions for the Madrean Encinal CE. This model is the Historic Climax Plant Community (HCPC) portion of a larger model that was taken directly from NRCS ESD R041XA102A2Z Granitic Hills 16-20" p.z, *Quercus emoryi - Quercus arizonica / Nolina microcarpa - Erythrina flabelliformis / Bouteloua curtipendula - Schizachyrium cirratum.*

D-3.1.5 Change Agent Effects on the CE

This section of the conceptual model presents a narrative description of the primary change agents and current knowledge of their effects on Madrean Encinal ecosystem. The section contains two sub-sections: (1) A list of primary change agents identified for the CE; and (2) a discussion of altered dynamics caused by these agents.

D-3.1.5.1 List of Primary Change Agents

Occurrences of this grassland ecological system are directly affected by incompatible grazing by livestock, direct and indirect wildfire suppression, land development, non-native plant species invasion. Table D-13identifies the most likely impacts associated with each of these stressors.

Table D-13. Stressors and their likely impacts on the Madrean Encinal ecosystem in the Madrean Archipelago ecoregion.

Stressor	Impacts
Land Use	
Livestock grazing	Grazing of native vegetation by livestock at incompatible stocking rates, season of use, or duration can be detrimental to grass vigor resulting in decline of grass cover and shifts species composition to more grazing tolerant or less palatable species (Milchunas 2006). Over time this often results in increased woody cover or bare ground and erosion. Heavy grazing can indirectly decrease fire return intervals by removing fine fuels that carry fire (Kaib et al. 1996, Swetnam and Baisan 1996).
Over- harvesting of fuelwood	Fuel wood cutting has impacted stands in southeastern Arizona historically and is still common for domestic use (Bahre 1991, Bennet 1992). Change stands structure such as increased number of stems per acre, decreased crown volume and depth, decreased tree height and foliage volume (USDA-USFS 2009.)
Recreation	This mostly relates to off road vehicle use, which creates additional roads and trails that fragment encinal and contribute to increase soil erosion and compaction and non-native species dispersal (USDA-USFS 2009).
Development	
Transportation infrastructure Roadways/railways and transmission lines	Fragmentation from transportation infrastructure leads to disruptions in ecological processes such as fire, dispersal of invasive non-native species, and can alter hydrological processes when excessive runoff from roads creates gullies that can lower water tables. Additionally, destruction of wildlife habitat and disruption of wildlife migration patterns can also occur (Bahre 1991, Bock and Bock 2002, Finch 2004, Heinz Center 2011, Marshall et al. 2004, McPherson 1997, Ockenfels et al. 1994, Schussman 2006b).
Suburban/Rural (include Military), Mines/Landfill	This stress contributes to altered fire regimes, increased erosion, direct habitat loss/conversion, increased groundwater pumping, fragmentation, invasive non-native species dispersal and disruption of wildlife migration patterns. (Bahre 1991, Finch 2004, McPherson 1997).
Energy (Renewable wind/solar), Oil/Gas	This stress contributes to altered fire regimes, increased erosion, direct habitat loss/conversion, increased groundwater pumping, fragmentation, invasive non-native species dispersal and disruption of wildlife migration patterns.
Uncharacteristic Fire Regime	Fire suppression has increased woody species, changed woody species composition and lead to an uncharacteristic fire regime in many stands (Barton 1999, Gori and Enquist 2003, Muldavin et al. 2002, Turner et al. 2003).

Stressor	Impacts
Invasive non-native Species	Replacement of native vegetation with non-native grass species such as *Eragrostis lehmanniana* and *Eragrostis curvula*. These species are better adapted to frequent fire and increase in relative abundance over native grasses after burning (Anable et al. 1992, Cable 1971, Gori and Enquist 2003, Schussman 2006b).
Climate change	Alteration of precipitation and evapotranspiration rates and timing may result in more frequent drought periods and higher intensity precipitation events, which following drought can cause significant erosion of topsoil (Garfin et al. 2012).

D-3.1.5.2 Altered Dynamics

These oak woodlands and savannas are characterized by a strong perennial grass layer and are driven by many of the same ecological processes as semi-desert mixed grassland, primarily frequent fire and drought (USDA-USFS 2009.)

It is generally agreed that fire regime has been altered for encinal by passive fire suppression via removal of fine fuels through livestock grazing, as well as active suppression over the last 100 years. This has reduced the number of surface fires, permitting a buildup in woody fuels resulting in increased fire severity when fires occurs in encinal and adjacent vegetation types like semi-desert grasslands and pine-oak woodlands across much of the southwestern US and adjacent Mexico (Kaib et al. 1996, Swetnam and Baisan 1996). Reduced fire frequency is a disturbance of the natural fire regime and results in increased cover of woody plants (Barton 1999, Gori and Enquist 2003, Muldavin et al. 2002, Turner et al. 2003). The increase in woody species in the Madrean Encinal has changed species composition, in some areas, from oak dominated woodlands or savanna to mesquite and/or juniper dominated woodlands (Turner et al. 2003).

Livestock grazing in Madrean Encinal is currently a common practice in both the United States and Mexico with grazing occurring in virtually all of Mexico's and in roughly 75 % of the United States' oak woodlands (McPherson 1997). Livestock grazing can affect the structure and composition of Madrean oak woodlands, as well as soil structure and water infiltration (USDA-USFS 2009).

Other management practices that cause disturbance in Madrean Encinal woodland are road building, recreation management, fire management, and ecosystem restoration activities. As with livestock grazing, the direct, indirect and cumulative effects of these activities are analyzed and mitigated through site specific NEPA processes (USDA-USFS 2009).

The introduction of two invasive non-native, perennial grasses, Lehmann and Boer lovegrasses (*Eragrostis lehmanniana* and *Eragrostis curvula*) has greatly impacted many semi-desert grasslands and encinal in this ecoregion (Anable et al. 1992, Cable 1971, Gori and Enquist 2003). Anable et al. (1992) and Cable (1971) found Lehmann lovegrass is a particularly aggressive invader and alters ecosystem processes, vegetation composition, and species diversity.

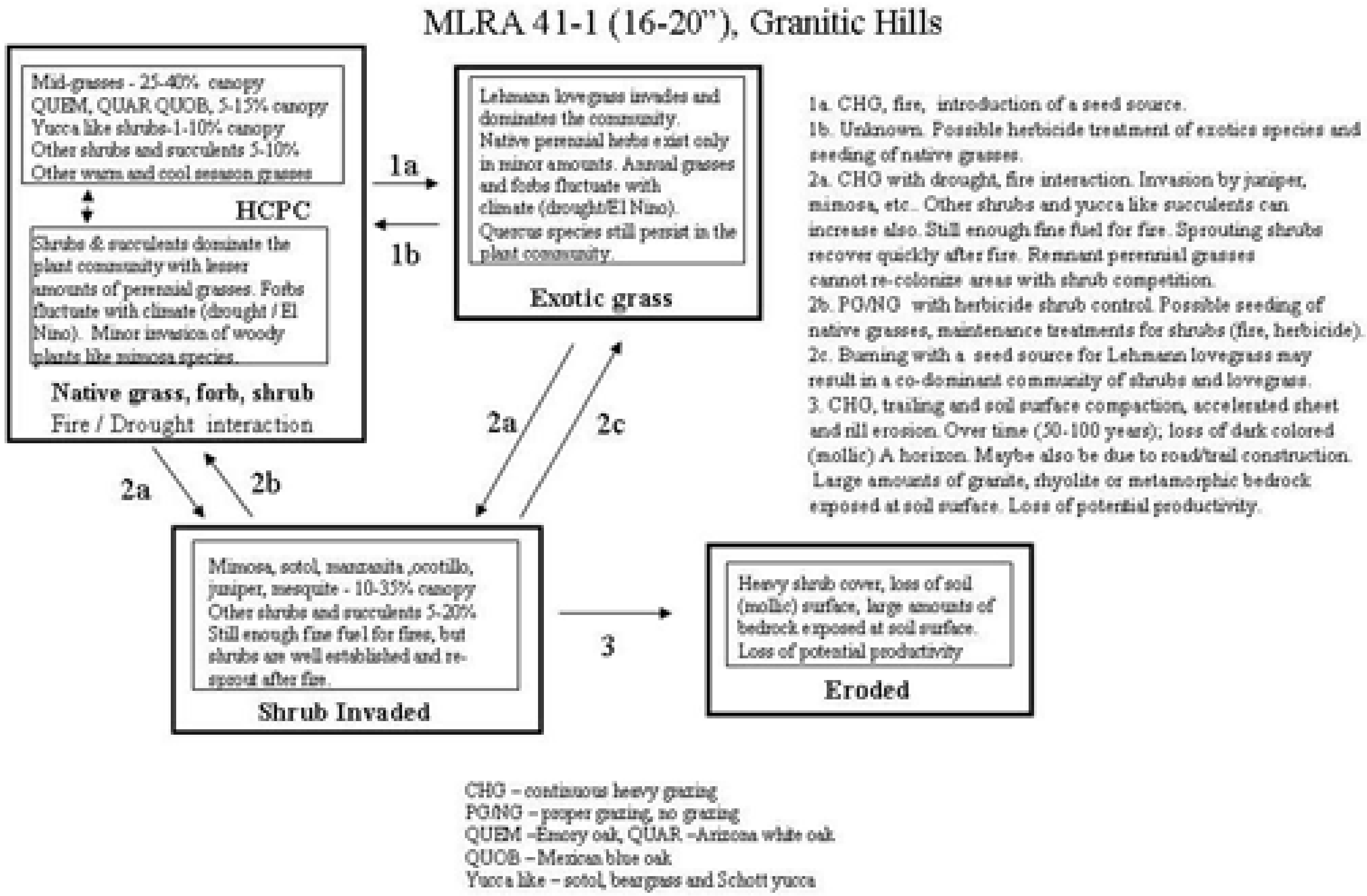
Historical fuel wood cutting for mining and domestic use in was common in Madrean Encinal in southeastern Arizona until the late 1800's, and is still common in Arizona and northern Mexico today (Bahre 1991, Bennet 1992). Although fuel wood harvesting had dramatic effects historically its consequence were generally local and short-lived (Turner et al. 2003).

Fragmentation of Madrean Encinal and closely associated semi-desert grasslands has a large impact especially around urban areas and has increased greatly in the last 70 years (Bahre 1991). Fragmentation has been well documented as an ecological stressor and threat in many assessments and reports (Bahre 1991, Bock and Bock 2002, Finch 2004, Heinz Center 2011, Marshall et al. 2004, McPherson 1997, Ockenfels et al. 1994, Schussman 2006b). Urban development has lead to the loss and fragmentation of grassland and encinal vegetation and the alteration of ecological processes, such as frequent low intensity surface fire, that used to maintain the vegetation with home, road and fence building (Bahre 1991, Finch 2004, McPherson 1997).

D-3.1.5.3 Altered Dynamics Model

A conceptual state-and-transition model representing current conditions was developed for the Granite Hills ESD *Quercus emoryi - Quercus arizonica / Nolina microcarpa - Erythrina flabelliformis / Bouteloua curtipendula - Schizachyrium cirratum* (R041XA102A2Z) from the 041-Southeastern Arizona Basin and Range MLRA by the staff from USDA Natural Resource Conservation Service at: https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD (Figure D-18). This model generally represents the Madrean Encinal ecosystem. It includes the Historic Climax Plant Communitiy (HCPC) as well as altered states (dominance of Lehman's lovegrass, increased cover of shrubs beyond acceptable ranges, a degraded eroded state after loss of ground cover) and changes in the transitions from the above NRV.

Figure D-18. Conceptual state and transition model of current conditions for the Madrean Encinal CE. This model was taken directly from NRCS ESD R041XA102A2Z Granitic Hills 16-20" p.z, *Quercus emoryi - Quercus arizonica / Nolina microcarpa - Erythrina flabelliformis / Bouteloua curtipendula - Schizachyrium cirratum* and includes the Historic Climax Plant Community (HCPC) portion with the larger model.



Model description was taken directly from ESD R041XA102AZ:

Description of State and Transition Model

The HCPC portion of this model represents this ecosystem under natural dynamic conditions. The Altered Dynamic portions of this community are shown with arrow indicating introduction of non-native forage grasses such as *Eragrostis lehmanniana* or *E. curvula*; increases in desert shrubs (*Prosopis* spp., *Fouquieria* sp., *Mimosa* spp.) and small trees cover (primarily species of *Juniperus* not characteristic of this community) resulting from extended periods of lack of fire; and an eroded surface with low grass cover (including reduction or loss of A soil horizon, reduced soil infiltration, soil organic material, ground cover, litter, and increased soil compaction, sheet and rill erosion).

This model description was excerpted directly from NRCS ESD R041XA102AZ:

"The potential plant community is a diverse mixture of warm and cool season perennial grasses, ferns, forbs, succulents and shrubs. A tree canopy of 5-15% Mexican live-oak species occurs on the site, giving it a savannah appearance. Most perennial herbaceous species are well dispersed throughout the plant community. A few species, however, occur only under the canopies of trees.

With continuous heavy grazing, mid-grasses like sideoats grama, plains lovegrass, crinkleawn and green sprangletop are removed and replaced by annual grasses and forbs. Naturally occurring wildfires in June-August are an important factor to shaping this plant community. Fire-free intervals range from 10-20 years. In the absence of fire, this site gets shrubby with increases in species like terpentine bush, mimosas, bricklebush, goldeneye, sotol and amole. Oak species on the site are very tolerant of fire. Well-developed covers of stones, cobbles, and gravel protect the soil from erosion after fire or heavy grazing. Trees per acre run from 5-30. Agave Palmeri plants average 5-60 per acre. Without periodic disturbance like fire or grazing, grass species can become decadent and annuals like goldeneye can become dominant, especially in the years with wet winter-spring seasons.

Periodic drought can occur in this land resource area and cause significant grass mortality. Droughts in the early 1930s and mid 1950s, 1975-76 and 1988-89, 1995-96 and 2002 resulted in the loss of much of the grass cover on this site. The site recovers rapidly, due to good covers of gravels and cobbles and the favorable climate prevailing in this common resource area."

D-3.1.6 Ecological Status: Key Ecological Attributes and Indicators

This section of the conceptual model addresses Key Ecological Attributes and their potential indicators. The ecological status is a way of describing current status via criteria, functionality, or levels of attributes and asks if they are within the normal range of variation.

D-3.1.6.1 Key Ecological Attributes

Table D-14 identifies the key ecological attributes for the CE within the Madrean Archipelago ecoregion. A **key ecological attribute** of a focal ecological resource is a characteristic of the resource's biology, ecology, or physical environment that is critical to the resource's persistence in the face of both natural and human-caused disturbance. Alteration of such a characteristic beyond some critical range of variation will lead to the degradation or loss of the resource within decades or less. The KEAs table lists the identified key ecological attributes, with a brief definition, a rationale for why it is important for the CE, and a listing of stressors or change agents that might be affecting the key attribute.

Table D-14. Key Ecological Attributes (KEA) Madrean Encinal ecosystem CE in the Madrean Archipelago ecoregion. Indicators for these KEAs can be used to determine the ecological status for this CE; see **Table D-2** for a list of the indicators assessed in this REA.

KEA Class: **Name**	**Definition general**	**Rationale general**	**Stressors general**
Landscape Context: **Landscape Condition**	This attribute is the amount of anthropogenic disturbance of the ecosystem that can be identified using a Land Condition Model Index (LCM). It incorporates a number of development features (including roads, urban/rural areas, agriculture, mines, transmission corridors, and energy development) that degrade the condition of the landscape.	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance (Comer and Hak 2009)	Stressors to landscape condition include multiple sources of fragmentation (reduces connectivity) that alter ecological processes (e.g., fire or surface hydrology), degrade wildlife habitat and disrupt wildlife migration patterns by creating barriers to species movement. Stressors include livestock grazing (reduces fine fuel that carry fire), urban and exurban development, and road building.
Size/Extent: **Patch Size Distribution**	The distribution of patch sizes (number and size class frequency) is a measure of fragmentation in this historically matrix or large patch ecosystem. Historical patch size/frequency is compared with current patch size/frequency.	This attribute is used to evaluate level of ecosystem fragmentation that interferes with landscape scale ecological processes. The current average patch size and total number of patches of the type are compared to earlier conditions where data are available.	Stressors include conversion to agriculture/pasture, commercial/industrial/residential use and construction of transportation infrastructure - roads, pipelines, transmission lines - that interfere with large-scale ecological processes such as fire or surface hydrology.

KEA Class: Name	Definition general	Rationale general	Stressors general
***Size/Extent:* Ecosystem "Occurrence" Extent**	This attribute assesses the current size (ha) of the occurrence or stand as affects its biodiversity richness, structural complexity, and "internal" ecological processes, especially landscape scale processes like fire. Patch Size is measured as percentage of the Minimum Dynamic Area (MDA) for the ecosystem. This CE is a Large Patch type that functions best when patches are large ranging from 20 to 2000 hectares (approximately 50 to 5000 acres).	The area necessary to maintain ecological processes and ensure persistence is an ecosystem's minimum dynamic area (Pickett and Thompson 1978). Ecosystems with patch sizes above the minimum dynamic area (MDA) tend to exhibit vegetation structure and composition, landscape scale ecological processes, and soil and hydrology that are functioning within the natural range of variation. However, the role of patch size in assessing ecological integrity is complex and related to the larger landscape context. Fragmentation from roads and subdivisions has reduced the size of many patches so that the fire regime cannot be restored to pre-1882 frequency without management action i.e., prescribed fire. The MDA to maintain the fire regime (or any natural disturbance regime) under the historical range of natural variation for this ecological system has not been determined. Little empirical study has been done in ecosystems outside of eastern forests to determine the MDA; Faber-Langendoen et al. (2012b) developed criteria for rating patch size based on the spatial patterning of the ecosystem (i.e., matrix, large patch, small patch, or linear) and provide a discussion of the protocol for assessing size/extent.	Stressors to ecosystem extent include actions such as development and fire exclusion that directly or indirectly convert the ecosystem to other land uses or cover types, or actions such as roads that fragment large patches into many small patches.

KEA Class: Name	Definition general	Rationale general	Stressors general
***Biotic Condition:* Terrestrial Fauna**	The taxonomic and functional (e.g., guild) composition of the native faunal assemblage of the ecosystem including birds, mammals, reptiles and amphibians, and invertebrates; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term). Monitoring populations of key native fauna will provide information on the condition of these important components of this ecosystem.	The taxonomic and functional composition of the faunal assemblage is an important aspect of the ecological integrity of an ecosystem. Many native species of birds, mammals, reptiles and amphibians, and invertebrates use this ecosystem as habitat for feeding, resting, breeding, and movement; and their patterns of use vary over time (seasonal, annual, longer-term) (Finch 2004, McClaran and McPherson 1999, McPherson 1997). These species vary in their sensitivity to different stresses such as alterations to vegetation composition, fire frequency, and water availability. Alterations in the taxonomic and functional composition of the terrestrial faunal assemblage beyond its natural ranges of variation therefore strongly indicate the types and severities of stresses imposed on the ecosystem.	Stressors to the taxonomic and functional composition of the faunal assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, floral composition, and abiotic condition of the ecosystem; and incursions of non-native species that alter the food web or directly compete with or prey on the native fauna.
***Biotic Condition:* Vegetation Composition**	The overall plant species composition and diversity of an ecosystem is an important aspect of its ecological integrity and largely defines it.	The taxonomic and functional composition of the plant species assemblage is an important aspect of the ecological integrity of a terrestrial ecosystem; many ecological processes and environmental variables affect it (drought, fire regime, anthropomorphic disturbance). In addition, the impact of invasive non-native species on community function of native vegetation is well documented (Anable et al. 1992, Cable 1971, Cox et al. 1988). Livestock grazing can affect the structure and composition of encinal, as well as soil structure and water infiltration, and species diversity (USDA-USFS 2009). Plant species vary in their sensitivity to different stresses such as grazing or lack of fire. This can alter the taxonomic composition of the terrestrial floral assemblage beyond its natural range of variation and strongly indicate the types and severities of stresses imposed on the ecosystem (Kaib et al. 1996; Swetnam and Baisan 1996).	Stressors to the taxonomic and functional composition of the plant assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, vegetation structure, and abiotic condition of the ecosystem; especially altered fire regime, improper livestock grazing management, and incursions of non-native species that alter the food web or directly compete with the native plants.

KEA Class: Name	Definition general	Rationale general	Stressors general
Biotic Condition: **Vegetation Structure**	An assessment of the overall structural complexity of the vegetation layers, including presence or cover of multiple strata, age and structural complexity of main canopy layer, and expected frequencies of successional or age classes.	Vegetation structure is an important reflection of dynamics and creates heterogeneity within the community. The distribution of total cover, crown diversity, stem size, and age classes or cohorts reflects natural disturbance regimes across the landscape and affects the maintenance of biological diversity, particularly of species dependent upon specific stages. An open to closed oak tree canopy with moderate to high cover of native perennial grass defines the Madrean Encinal CE.	Alteration of vegetation structure can come from a variety of stressors, including changes in fire regime (e.g. too frequent or too infrequent), logging/fire wood cutting or other removal of woody species, livestock grazing or concentrated native herbivory that removes native perennial herbaceous plants, climate change, and various kinds of mechanical disturbance that damages or removes vegetation.
Abiotic Condition: **Soil Condition**	Soil is basic to the proper functioning of a terrestrial ecosystem. Good soils will enhance the resilience and function of an ecosystem. Poor condition soil will limit the function of an ecosystem and if not addressed can permanently degrade a site. Soil condition includes indicators of multiple soil properties such as soil structure (particle and pore size, vertical profile, soil aggregates) and surface condition such as presence of soil crusts.	The condition of soil/surface substrate directly affects the functioning of the ecosystem. Soil/surface substrate condition of a site can be directly evaluated using indicators of soils disturbance such as evidence of erosion and disrupted soil processes and properties. The types of disturbances (stressors) can also be recorded to indicate condition such as livestock trampling and recreational vehicles. These disturbances can directly affect soil properties by disturbing soil crusts, compacting pore space that reduces water infiltration and percolation, changing other structural characteristics, and can expose soils to increased erosional forces.	Excessive livestock trampling, vehicle use (motorbikes, off-road vehicles, construction vehicles), filling and grading, plowing, other mechanical disturbance to the soil surface, excessive soil movement (erosion or deposition) as evidenced by gully, rill, or dune formation. Climate change and drought can also lead to increased potential for erosion.
Abiotic Condition: **Fire Regime**	Fire is a natural agent of disturbance in upland vegetation communities that maintains species composition, vegetation structure, and sustains ecological processes such as nutrient cycling.	Altered (uncharacteristic) fire regime greatly influences ecosystem processes. For Madrean Encinal frequent fire (FRI of 2.5-10 years) is key to maintaining an open oak canopy, maintaining a perennial grass understory (Bahre 1985, Kaib et al. 1996, McPherson 1995, Wright 1980) and the pine-oak woodlands (FRI of 3-7 years) (Bahre 1985, Kaib et al. 1996, McPherson 1995, Swetnam and Baisan 1996, Swetnam et al. 1992, Wright 1980).	Fire exclusion in fire-maintained ecosystems results in increased woody species density and cover, changes in wildlife species assemblages, and increased fuel that ultimately produce high severity fire. Specific stresses include fire suppression with building roads that act as fire breaks, and active fire suppression by land owners and agency personnel.

D-3.1.7 Relationship of KEAs to Fundamentals of Rangeland Health

The key ecological attributes and indicators listed in Table D-14 also encompass the four fundamentals of rangeland health (USDI-BLM 2006), as shown in Table D-15. The KEA of Landscape Condition specifically refers to watershed conditions; all other KEAs refer specifically to Ecological Processes and Habitat. However, many of the indirect indicators for the KEAs for Abiotic Condition focus on stressors that arise as a result of modifications to the watershed or water quality, the fourth Fundamental. These relationships are also indicated in Table D-15. Further information about interpretation and assessment of these fundamentals of rangeland health can be found in Pellant et al. (2005).

Table D-15. Key Ecological Attributes (KEA) for the Madrean Encinal and their relationship to fundamentals of rangeland health.

Indicator	Watershed	Ecological Processes	Water Quality	Habitat
Landscape Condition	X	X		X
Patch Size	X	X		X
Terrestrial Fauna				X
Vegetation Composition		X		X
Vegetation Structure				X
Soil Condition		X	X	X
Fire Regime	X	X		X

D-3.1.8 Conceptual Model Diagrams

See Figure D-17 and Figure D-18 above.

D-3.2 Ecological Status Assessment Results and Interpretation

This section of the appendix presents and discusses the results of the ecological status assessment for the Madrean Encinal CE. The presentation addresses each indicator separately, and then addresses the overall assessment, which integrates the results of all individual indicators. The results are presented using a common framework, in which the status of an indicator – or the combination of all indicators – is scored on a scale from 0.0 to 1.0, where 0.0 indicates a condition of complete replacement of reference ecological conditions due to the impacts of stressors, and 1.0 indicates a condition of no alteration of reference ecological conditions. The same color ramp is used for all results, yellow to dark blue, where yellow equals low scores, green moderate scores and dark blues high scores.

D-3.2.1 Current Ecological Status: Development, Fire Regime, Invasives

The maps below (Figure D-19) show the ecological status results for each of the three individual indicators – development, fire regime departure, and invasives – for the Madrean Encinal.

The development indicator is a stressor-based indicator of the spatial extent and intensity of human modifications to the land surface that alters ecosystems or habitat in the MAR ecoregion. The indicator takes into account the density of urban development; infrastructure such as above- and below-ground distribution corridors, communication towers, and border barriers; a wide range of transportation features; mines and landfills; recreational development; agriculture; and energy development. The scoring is on a continuous scale from 0 to 1, with the highest score of 1.0 indicating no ecologically relevant modifications, and the lowest score of 0.0 indicating modifications that essentially eliminate all natural cover and ecological functions.

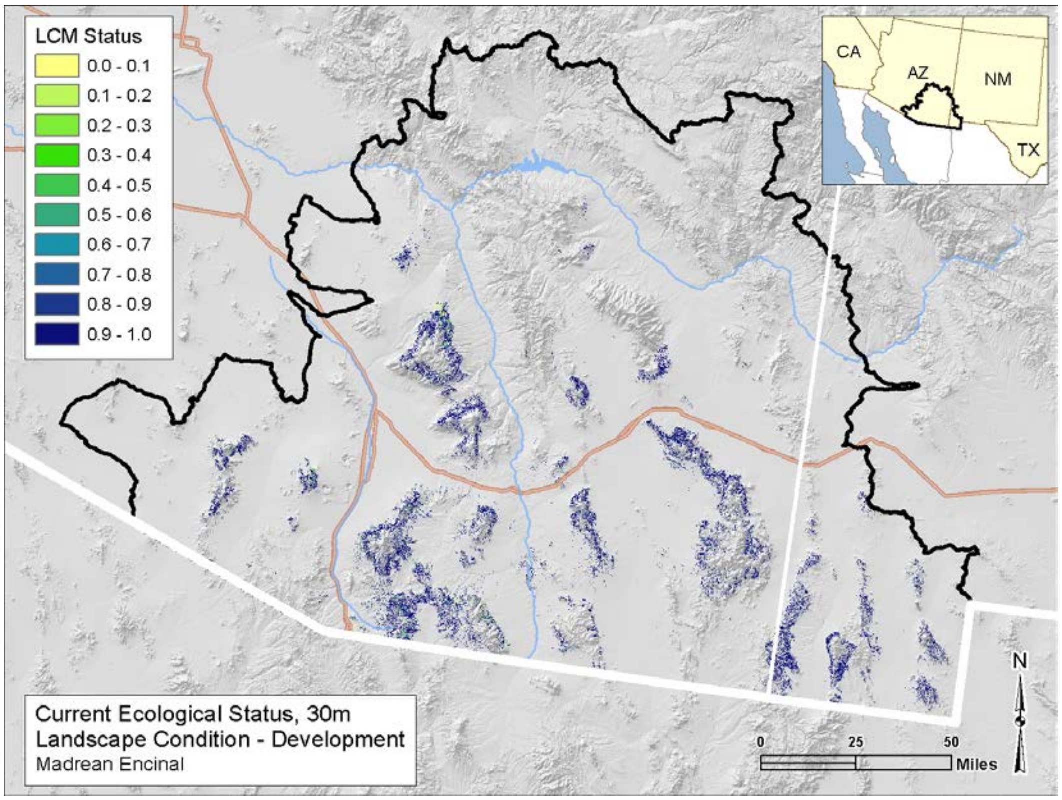
As illustrated in the first map of Figure D-19, this indicator reflects a relatively low amount of development for Madrean Encinal CE. However, this ecosystem occurs in the foothill zone, above much of the medium and high density development.

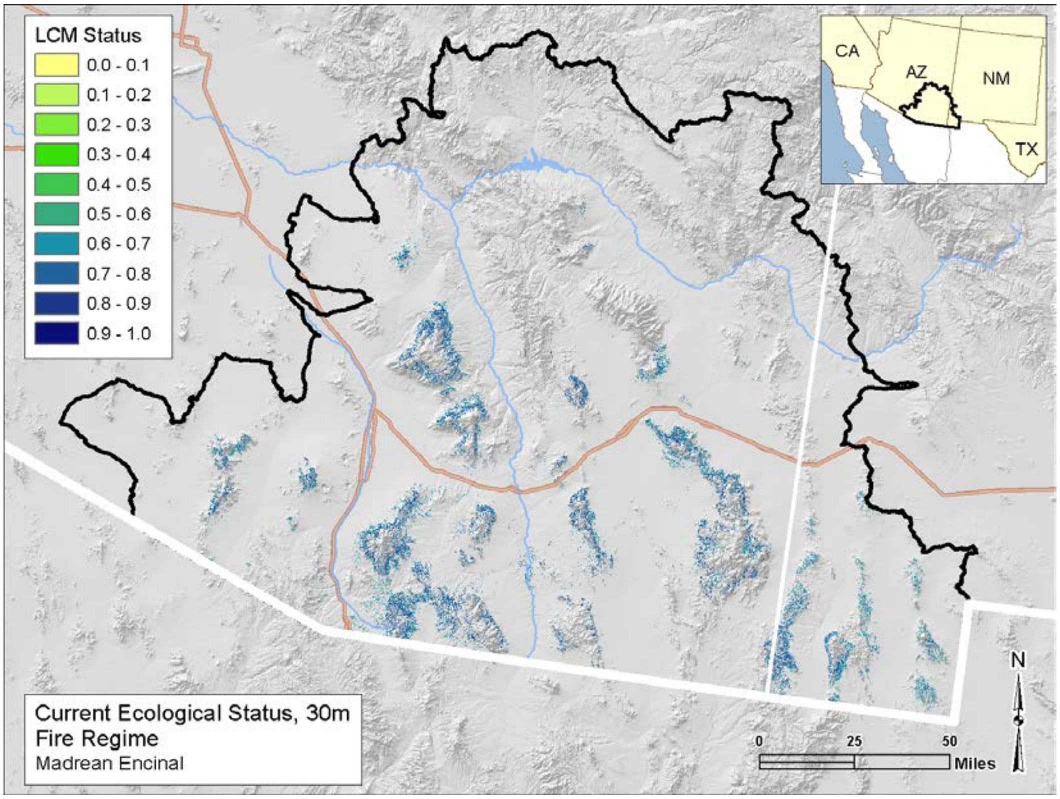
It is important to note that most development impacts are scored much lower than non-development change agents; for example, site intensity values for urbanization ranged from 0.05 to 0.6 for high to low density development, respectively. This is because development typically has a much stronger on-site impact than the other indicators. However, except for urban development, most development impacts occur at smaller scales than can be displayed in these maps, but still are pervasive throughout much of the ecoregion. In particular, effects of many of the very small, local areas of development, or small linear features (e.g. dirt roads) will not be obvious at the scale of the development indicator map.

The second indicator is an indirect measure of fire regime. It is based on the Vegetation Condition Class (VCC) dataset produced by Landfire, which was developed to compare historical reference conditions with current conditions for an individual ecological system type (see **Status Assessment Methods** above). The result of VCC is a ranking of departure from expected historical range of variability, which can be interpreted as "how has the disturbance regime [for the REA purposes and relevant to this ecoregion: fire regime] changed from its historical variability for this individual CE". Only Severe Vegetation Departure (0.65) and Moderate Vegetation Departure (0.75) were used and are displayed in the map; no to minor departure was scored as 1 (dark blue in the map).

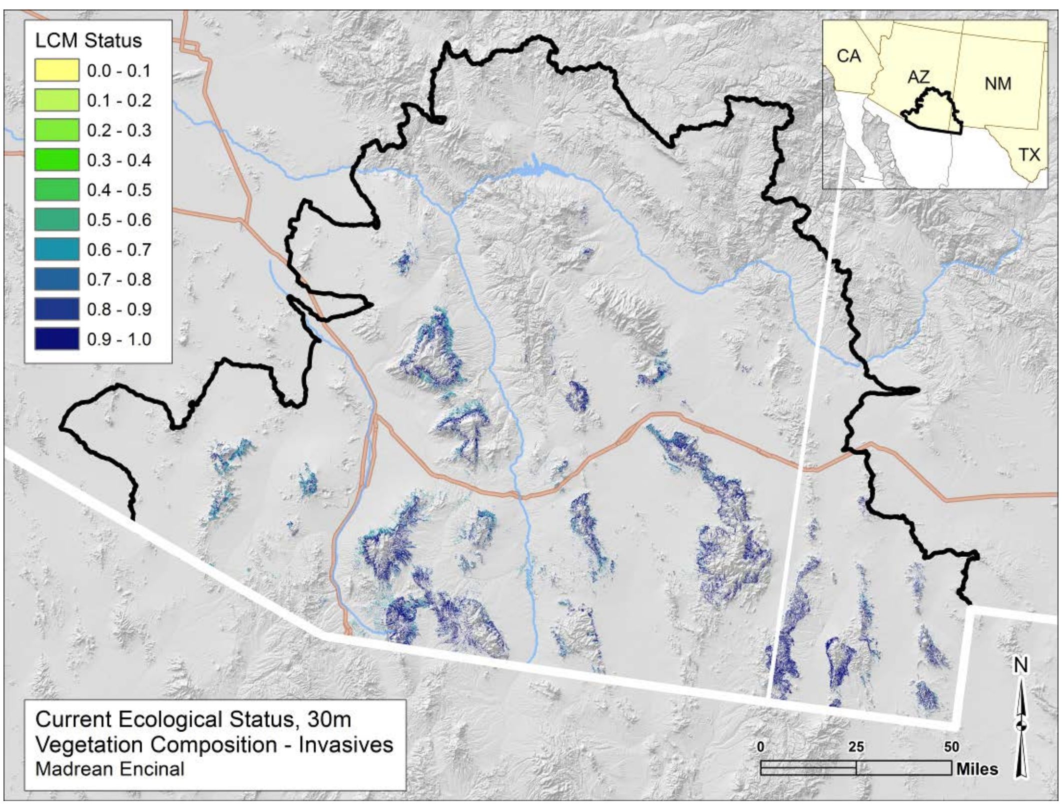
The second map in Figure D-19 shows severe departure (0.6-0.7) for much of the Madrean Encinal CE in the MAR ecoregion. Areas with moderate departure (0.7-0.8) are small patch and often restricted to higher elevations. This spatial result is supported by research documenting the results of fire exclusion in the REA. Although there is not much historical encinal-specific information on fire return intervals (FRI) available, it is thought to be similar to adjacent ecosystems primarily the semi-desert grassland (FRI of 2.5 to 10 years) (Bahre 1985, Kaib et al. 1996, McPherson 1995, Wright 1980) and the pine-oak woodlands (FRI of 3- 7 years) (Bahre 1985, Kaib et al. 1996, McPherson 1995, Swetnam and Baisan 1996, Swetnam et al. 1992, Wright 1980). Active and passive fire suppression over the last century has excluded fire from much of this ecological system (Schussman 2006a). In the absence of disturbance such as fire, the woody component has increased in density over time resulting in an uncharacteristic fire regime (Turner et al. 2003, Burgess 1995, Gori and Enquist 2003, Schussman 2006b).

Figure D-19. Scores for three indicators for Madrean Encinal: development indicator (first map), fire regime departure indicator (second map), and invasive species indicator (third map) for each 30m pixel. At the ecoregion scale, many development features are not readily visible (i.e. secondary roads or highways, railroads, small agricultural fields). Yellow (equivalent to 0) indicates high impacts from the CA, dark blue (equivalent to 1) indicates little to no impact from the CA. Only 3 classes of fire regime condition are scored: no to little departure (dark blue), moderate departure and severe departure (lighter blue). For the invasives indicator results, higher cover of mesquite or invasive exotics will score between .4 and .6 (light greens), while lower cover scores between .6 and .8 (light blues).





LCM Status
0.0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1.0
CA
AZ
NM
TX
Current Ecological Status, 30m
Fire Regime
Madrean Encinal
0
25
50
Miles
N



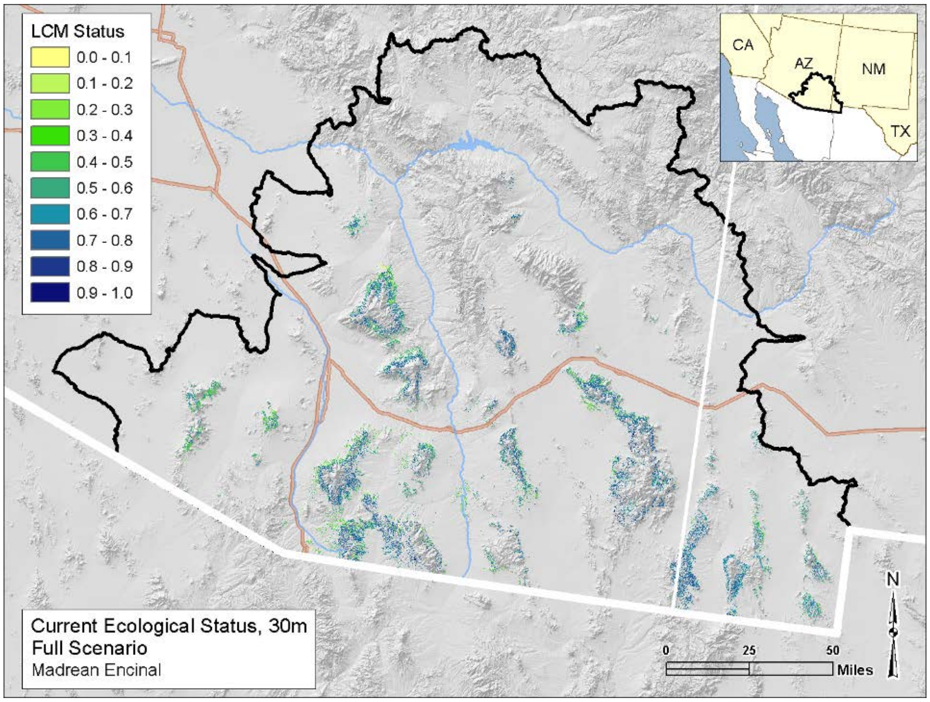
LCM Status
0.0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1.0
CA
AZ
NM
TX
Current Ecological Status, 30m
Vegetation Composition - Invasives
Madrean Encinal
0
25
50
Miles
N

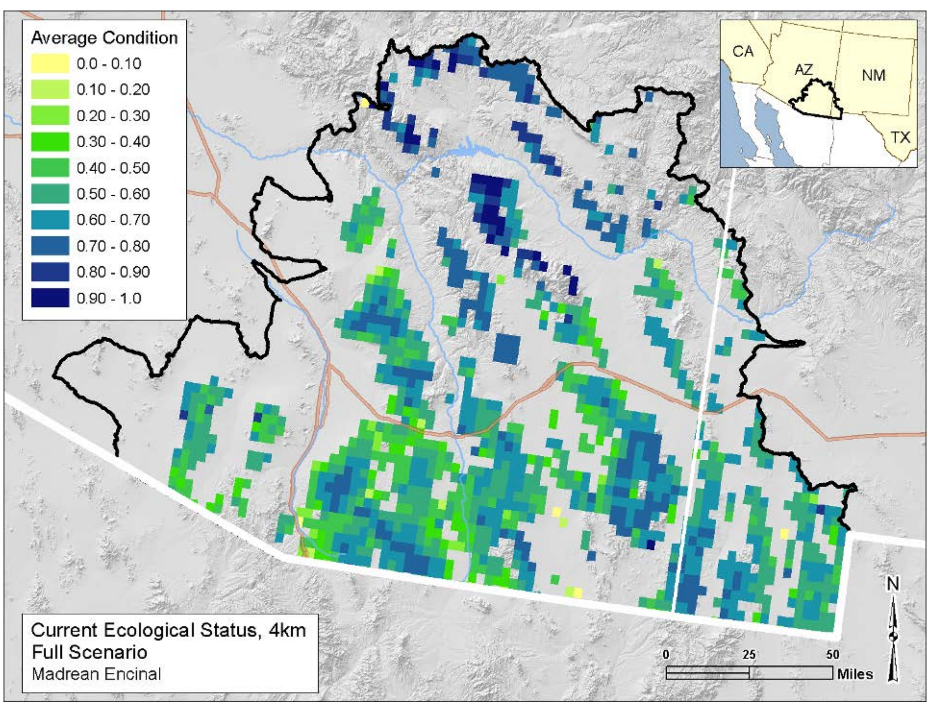
The invasive species indicator serves as an indirect measure of vegetation composition, by measuring the cover of invasive species. It includes a combination of non-native grass and forbs and native woody increasers (mesquite cover), as described previously in this appendix. The scoring is on a continuous scale from 0 to 1, with the highest score of 1.0 indicating no ecologically relevant cover of invasive species, and 0.0 indicating a conversion to non-native grasses and forbs and/or invasive mesquite. Table D-3 shows the cover classes used and the site intensity values for them, for this CE. The values range from 0.65 to 0.90. Either or both non-native invasive and native invasive woody cover may occur on in a single pixel. If both occur, then scores for that pixel are multiplied to create a new combined, lower indicator score.

The third map in Figure D-19 indicates moderate to high invasion of exotic grasses and forbs and/or invasive mesquite in the Madrean Encinal CE for much the ecoregion. This spatial result is supported by research documenting the results of fire exclusion in the REA. With fire exclusion, the Madrean Encinal CE is vulnerable to increases in native shrub cover, especially invasive mesquite and juniper (Gori and Enquist 2003, Schussman 2006b). Also, the introduction of two invasive non-native, perennial grasses, Lehmann and Boer lovegrasses (*Eragrostis lehmanniana* and *Eragrostis curvula*) has impacted many Madrean Encinal stands in this ecoregion (Anable et al. 1992, Cable 1971, Gori and Enquist 2003). Lehmann lovegrass is a particularly aggressive invader and alters ecosystem processes, vegetation composition, and species diversity (Anable et al. 1992, Cable 1971).

D-3.2.2 Current Ecological Status: Full Scenario

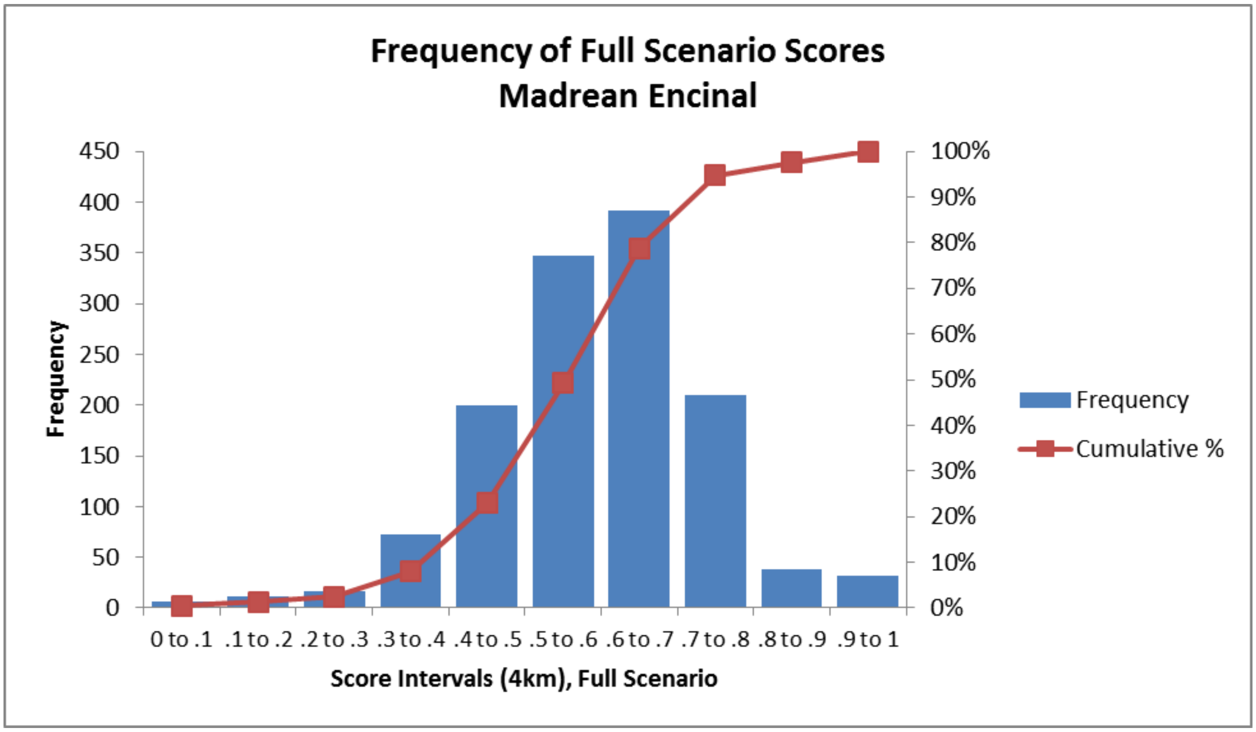
Figure D-20. Overall ecological status scores for Madrean Encinal for all indicators combined (development, fire regime and invasives) for each 30m pixel (top) and 4km grid cells (bottom). The score for each 4km cell is an average of all 30m pixels that are scored for the CE. Yellow scores (equivalent to 0) indicate high impacts from the CAs, dark blue (equivalent to 1) indicate little to no impact from the CAs.





The first map in Figure D-20 illustrates all three of the indicators combined into a single ecological status score per pixel of the CE's distribution. The combined, per pixel status scores are noticeably lower than the individual scores for each indicator. The combined status scores for each pixel were summarized to the reporting unit (e.g., 4km grid) by taking the average status score from all the pixels of the CE within the reporting unit. The results, shown in the second map in Figure D-20 and in the frequency diagram (Figure D-21) indicate the widespread general degradation of the Madrean Encinal CE across its range in the ecoregion. Approximately 80% of the 4km grid cells fall at or below the 0.7 score. There are a few local areas of better ecological conditions, a result of low level of development, low or no cover of invasive species, and moderate fire regime departure.

Figure D-21. Frequency distribution of the 4km ecological status scores for the Madrean Encinal, with cumulative percent. The x-axis represents the 0.1 increment scoring intervals, while the y-axis shows the number of grid cells in each interval (left) and the cumulative percentage of the grid cells for each interval (right). For this CE, most of the status scores fall in the range from 0.4 to 0.8.



D-3.3 References for the CE

Anable, M. E., M. P. McClaran, and G. B. Ruyle, 1992. Spread of introduced Lehmann lovegrass Eragrostis lehmanniana Nees. in southern Arizona, USA. Biological Conservation, 61, 181-188.

AZGFD [Arizona Game and Fish Department]. 2012. Arizona's State Wildlife Action Plan: 2012-2022. Arizona Game and Fish Department, Phoenix, Arizona.

Bahre, C. J. 1985. Wildfire in southeastern Arizona between 1859 and 1890. Desert Plants, 7, 190-194.

Bahre, C.J. 1991. *A* legacy of change: historic human impact on vegetation of the Arizona borderlands. The University of Arizona Press, Tucson, AZ.

Barton, A.M. 1999. Pines versus oaks: effects of fire on the composition of Madrean forests in Arizona. Forest Ecology and Management, 120, 143-156.

Bennet, D.A. 1992. Fuelwood extraction in southeastern Arizona. Pages 96-97 *in* P.F. Ffolliott, G.J. Gottfried, D.A. Bennett, V.M. Hernandez C., A. Ortega-Rubio, and R.H. Hamre (tech. coords.). Ecology and management of oak and associated woodlands: perspectives in the southwestern United States and northern Mexico. Proceedings; 1992 April 27-30; Sierra Vista, AZ. General Technical Report RM-218. Fort Collins, CO: USDA Forest Service, Rocky Mountain and Range Experiment Station.

Bock, C. E. and J. H. Bock. 2002. Numerical response of grassland birds to cattle ranching versus exurban development in southeastern Arizona. 87th Annual Meeting of the Ecological Society of America and the 14th Annual International Conference of the Society for Ecological Restoration.

Bock, C.E. and J.H. Bock. 1982. Numerical response of grassland birds to cattle ranching versus exurban development in southeastern Arizona. 87th Annual Meeting of the Ecological Society of America and the 14th Annual International Conference of the Society for Ecological Restoration. 2002.

Brown, D.E. 1982. Madrean Evergreen Woodland. Pages 59-65 in: Brown, D. E., editor. 1982. Biotic communities of the American Southwest-United States and Mexico. Desert Plants Special Issue 4(1-4):1-342.

Burgess, T. L. 1995. Desert grassland, mixed shrub savanna, shrub steppe, or semidesert scrub. Pages 31-67 in: M. P. McClaran and T. R. Van Devender, editors. The Desert Grassland. University of Arizona Press, Tucson.

Cable, D. R. 1971. Lehmann lovegrass on the Santa Rita Experimental Range, 1937-1968. Journal of Range Management, 24, 17-21.

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. Ecological systems of the United States: A working classification of U.S. terrestrial systems. NatureServe, Arlington, VA.

Comer, P. J., and J. Hak. 2009. NatureServe Landscape Condition Model. Technical documentation for NatureServe Vista decision support software engineering. NatureServe, Boulder, CO.

Cox, J. R., G. B. Ruyle, J. H. Fourle, and C. Donaldson. 1988. Lehmann lovegrass--central South Africa and Arizona, USA. Rangelands. 10(2): 53-55.

Dick-Peddie, W. A. 1993. New Mexico vegetation: Past, present, and future. University of New Mexico Press, Albuquerque. 244 pp.

Faber-Langendoen, D., J. Rocchio, S. Thomas, M. Kost, C. Hedge, B. Nichols, K. Walz, G. Kittel, S. Menard, J. Drake, and E. Muldavin. 2012b. Assessment of wetland ecosystem condition across landscape regions: A multi-metric approach. Part B. Ecological Integrity Assessment protocols for rapid field methods (L2). EPA/600/R-12/021b. U.S. Environmental Protection Agency Office of Research and Development, Washington, DC.

Ffolliott, P. F 1999a. Encinal Woodlands in the Southwestern United States. Chapter 6. Pages 69-81 in: P. F. Ffolliott and A. Ortega-Rubio, editors. Ecology and Management of Forests, Woodlands, and Shrublands in Dryland Regions of the United States and Mexico: Perspectives for the 21st Century. Co-edition number 1. University of Arizona-Centro de Investigacione.

Finch, D. M. 2004. Assessment of Grassland Ecosystem Conditions in the Southwestern United States. Fort Collins, Colorado, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. RMRS-GTR-135-vol.

Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy. editors. 2013. Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment, A report by the Southwest Climate Alliance. Washington, DC: Island Press.Germaine, H.L. and G.R. McPherson. 1998. Effects of timing of precipitation and acorn harvest date on emergence of Quercus emoryi. Journal of Vegetation Science, 9, 157-169.

Gibbens, R. P., R. P. McNeely, K. M. Havstad, R. F. Beck, and B. Nolen. 2005. Vegetation change in the Jornada Basin from 1858 to 1998. Journal of Arid Environments 61(4):651-668.

Gori, D., G. S. Bodner, K. Sartor, P. Warren, and S. Bassett. 2012. Sky Island Grassland Assessment: Identifying and Evaluating Priority Grassland Landscapes for Conservation and Restoration in the Borderlands. Report prepared by The Nature Conservancy in New Mexico and Arizona. 85 p.

Gori, D. F. and C. A. F. Enquist. 2003. An assessment of the spatial extent and condition of grasslands in central and southern Arizona, southwestern New Mexico and northern Mexico. The Nature Conservancy, Arizona Chapter. Pp29.

Heinz Center. 2011. Managing and Monitoring Arizona's Wildlife in an Era of Climate Change: Strategies and Tools for Success Report and Workshop Summary. Prepared for: U.S. Department of Interior. Bureau of Land Management and The Arizona Game and Fish Department by the H. John Heinz III Center for Science Economics and the Environment. January 13, 2011. Washington, D. C. 67 pp. plus appendices.

Kaib, M., C.Baisan, H. D. Grissino-Mayer, and T. W. Swetnam. 1996. Fire history of the Gallery pine-oak forests and adjacent grasslands of the Chiracahua Mountains of Arizona. Pages 253-264 in: Folliott, P. F., D. F. DeBano, D. M. Baker, G. J. Gottfried, G. Solis-Garza, C. B. Edminster, D. G. Neary, L. S. Allen, and R. H. Hamre, eds. 1996. Effects of fire on Madrean province ecosystems-a symposium proceedings. Gen. Tech. Rep. RM-289; 1996 March 11-15; Tucson, AZ. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Experiment Station.

Marshall, R.M., A.Turner, A. Gondor, D. Gori. C. Enquist, G. Luna, R. Paredes Aguilar, S. Anderson, S. Schwartz, C. Watts, E. Lopez, P. Comer. 2004. An ecological Analysis of Conservation Priorities in the Apache Highlands Ecoregion. Prepared by The Nature Conservancy of Arizona, Instituto del Medio Ambiente y el Desarrolla Sustentable del Estado de Sonora, agency and institutional partners. 152 pp.

McAuliffe, J. R. 1995. Landscape evolution, soil formation, and Arizona's desert grasslands. Pages 100-129 in: M. P. McClaran and T. R. Van Devender, editors. The Desert Grassland. University of Arizona Press, Tucson.

McClaran, M.P. and McPherson, G.R. 1999. Chapter 17, Oak Savanna in the American Southwest. Pages 275-287 in R.C. Anderson, J.S., Fralish and J.M. Baskin, editors. *Savannas, Barrens, and Rock Outcrop Plant Communities of North America*. Cambridge University Press, Cambridge, England.

McPherson, G. R. 1995. The role of fire in the desert grasslands. Pages 130-151 in: M. P. McClaran and T. R. Van Devender, editors. The Desert Grassland. University of Arizona Press, Tucson.

McPherson, G.R. 1997. Ecology and management of North American savannas. The University of Arizona Press, Tucson, Arizona.

Milchunas, D.G. 2006. Responses of plant communities to grazing in the southwestern United States. Gen. Tech. Rep. RMRS-GTR-169. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 126 p.

Muldavin, E., V. Archer, and P. Neville. 1998. A vegetation map of the Borderlands Ecosystem Management Area. Final report submitted to USDA Forest Service, Rocky Mountain Experiment Station, Flagstaff, AZ, by the New Mexico Natural Heritage Program, University of New Mexico, Albuquerque, NM. 58 pp.

Muldavin, E., Y. Chauvin, and G. Harper. 2000b. The vegetation of White Sands Missile Range, New Mexico: Volume I. Handbook of vegetation communities. Final report to Environmental Directorate, White Sands Missile Range. New Mexico Natural Heritage Program, University of New Mexico, Albuquerque. 195 pp. plus appendices.

Muldavin, E, T. Neville, C. McGuire, P. Pearthree, and T. Biggs. 2002. Soils, geology and vegetation change in the Malpais Borderlands. Publication No. 05-GTR-228. Natural Heritage New Mexico, Museum of Southwestern Biology, University of New Mexico. 26 p. NatureServe. 2013. International Ecological Classification Standard: International Vegetation Classification. Central Databases. NatureServe, Arlington, VA.

NatureServe. 2013. International Ecological Classification Standard: International Vegetation Classification. Central Databases. NatureServe, Arlington, VA.

NMDGF [New Mexico Department of Game and Fish]. 2006. Comprehensive Wildlife Conservation Strategy for New Mexico. New Mexico Department of Game and Fish. Santa Fe, NM. 526 pp + appendices.

Ockenfels, R.A., C.L. Ticer, A., Alexander, and, J.A. Wennerlund. 1994. Home ranges, movement patterns, and habitat selection of pronghorn in central Arizona a final report. March 1994. Phoenix, Arizona, Arizona Game and Fish Department Research Branch.

Parmenter,R. R. and T. R.Van Devender. 1995. Diversity, Spatial Variability, and Functional Roles of Vertebrates in the Desert Grassland. Pages 196-229 in: M. P. McClaran and T. R. Van Devender, editors. The Desert Grassland. University of Arizona Press, Tucson.

Pellant, M., P. Shaver, D.A. Pyke, and J.E. Herrick. 2005. Interpreting indicators of rangeland health, version 4. Technical Reference 1734-6. BLM/WO/ST-00/001+1734/REV05. U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center, Denver, CO. 122 pp.

Pickett, S.T.A., and J.N. Thompson. 1978. Patch dynamics and the size of nature reserves. Biological Conservation 13: 27-37.

Schussman, H. 2006a. Historical Range of Variation and State and Transition Modeling of Historical and Current Landscape Conditions for Semi-Desert Grassland of the Southwestern U.S. Prepared for the U.S.D.A. Forest Service, Southwestern Region by The Nature Conservancy, Tucson, AZ. 53 pp.

Schussman, H. 2006b. Historical Range of Variation for Madrean Encinal of the Southwestern U.S. Prepared for the U.S.D.A. Forest Service, Southwestern Region by The Nature Conservancy, Tucson, AZ. 16 pp.

Stuever, M. C., and J. S. Hayden. 1997a. Plant associations of Arizona and New Mexico. Edition 3. Volume 2: Woodlands. USDA Forest Service, Southwestern Region, Habitat Typing Guides. 196 pp

Swetnam, T.W. and C.H. Baisan. 1996. Fire histories of montane forests in the Madrean borderlands. Effects of fire on Madrean Province ecosystems: A symposium proceedings. RM-GTP-289. December 1996. USDA Forest Service.

Swetnam, T. W., C.H. Baisain, A.C. Caprio, and P.M. Brown. 1992. Fire history in a Mexican oak-pine woodland and adjacent montane conifer gallery forest in southeastern Arizona. Pages 165-173 *in* P.F. Ffolliott, G.J. Gottfried, D.A. Bennett, V.M. Hernandez C., A. Ortega-Rubio, and R.H. Hamre (tech. coords.). Ecology and management of oak and associated woodlands: perspectives in the southwestern United States and northern Mexico. Proceedings; 1992 April 27-30; Sierra Vista, AZ. General Technical Report RM-218. Fort Collins, CO: USDA Forest Service, Rocky Mountain and Range Experiment Station.

Swetnam, T.W. and J.L. Betancourt. 1990. Fire - Southern oscillation relations in the southwestern United States. Science, 1017-1020.

Turner, R.M., R.H. Webb, J.E. Bowers, and J.R Hastings. 2003. The changing mile revisited An ecological study of vegetation change with time in the lower mile of an arid and semiarid region. University of Arizona Press, Tucson, Arizona.

USDA-NRCS. 2014. Selected Approved Ecological Site Descriptions for Major Land Resource Area 041-Southeastern Arizona Basin and Range. US Department of Agriculture. Natural Resource Conservation Service. Website accessed September 2014. https://esis.sc.egov.usda.gov/Welcome/pgApprovedSelect.aspx?type=ESD

USDA-USFS [U.S. Forest Service]. 2009. Ecological sustainability report. Coronado National Forest. United States Department of Agriculture. Forest Service. Southwest Region. February 2009. Pp. 118.

USDI-BLM [U.S. Bureau of Land Management]. 2006. 43CFR4180.1 Fundamentals of Rangeland Health. Code of Federal Regulations and Federal Register, Accessed February 2013 http://federal.eregulations.us/cfr/section/2006/04/18/43-cfr-4180.1

Whitford, W. G., G. S. Forbes, and G. I. Kerley. 1995. Diversity, spatial variability, and functional roles of invertebrates in desert grassland ecosystems. Pages 151-195 in: M. P. McClaran and T. R. Van Devender, editors. The Desert Grassland. University of Arizona Press, Tucson.

Wright, H. A. The role and use of fire in the semidesert grass-shrub type. 1980. Ogden, UT, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. Montane Upland System

MONTANE UPLAND DIVISION

Lower Montane Woodlands

D-4 Madrean Pinyon-Juniper Woodland Ecological System

D-4.1 Conceptual Model

D-4.1.1 Classification

The ecosystem conservation elements for the MAR REA were selected from NatureServe's classification of terrestrial ecological systems (Comer et al. 2003). Over three dozen ecological systems occur in the MAR, but only a select subset were chosen for the REA. The CE concept provided in this conceptual model includes this NatureServe ecological system type:

- Madrean Pinyon-Juniper Woodland (CES305.797)

There are other terrestrial ecological systems in the NatureServe classification that also occur in the MAR, or in adjacent ecoregions, which are similar to this CE concept but are not included in this conservation element. These are listed here to help the reader understand what is not included in this conceptual model; each of these other ecological systems has information that can be searched for and reviewed on NatureServe's on-line Explorer website (http://explorer.natureserve.org/servlet/NatureServe). The System Code beginning with CES (Community Ecological System) is an information rich database code that refers to the North American Ecological Division (305) where the system primarily occurs and the number used to identify the system (Comer et al. 2003).

- Madrean Juniper Savanna (CES305.730)
- Madrean Encinal (CES305.795) with scattered PJ trees

D-4.1.2 Summary

This evergreen woodland ecosystem occurs on foothills, mountains and plateaus in the Sierra Madre Occidentale and Sierra Madre Orientale in Mexico, Trans-Pecos Texas, southern New Mexico and Arizona, generally south of the Mogollon Rim. Stands are generally restricted to foothill and lower montane elevations ranging from 1460-2225 m with high elevations stands restricted to warmer southern aspects and are found down to 760 m elevation in the Trans-Pecos of Texas (Figure D-23). Sites range from gentle to steep slopes. Substrates are variable, but soils tend to be dry and rocky. Adjacent ecosystems may include and Madrean Encinal (CES305.795) and Madrean Lower Montane Pine-Oak Forest and Woodland (CES305.796) at higher elevations and Mogollon Chaparral (CES302.741) and Madrean Juniper Savanna (CES305.730) at lower elevations. The environmental description is based on several references, including Brown (1982), Dick-Peddie (1993), Gori and Bate (2007), Gottfried (1992), Muldavin et al. (2000b), and NatureServe Explorer (2013).

Figure D-22. Distribution of Madrean Pinyon-Juniper Woodland at 30m resolution. The distribution was derived from the NatureServe (2013) terrestrial ecological systems map. Appendix G (ecological integrity) has a table listing the areal extent of this ecological system and its % of the assessment area.

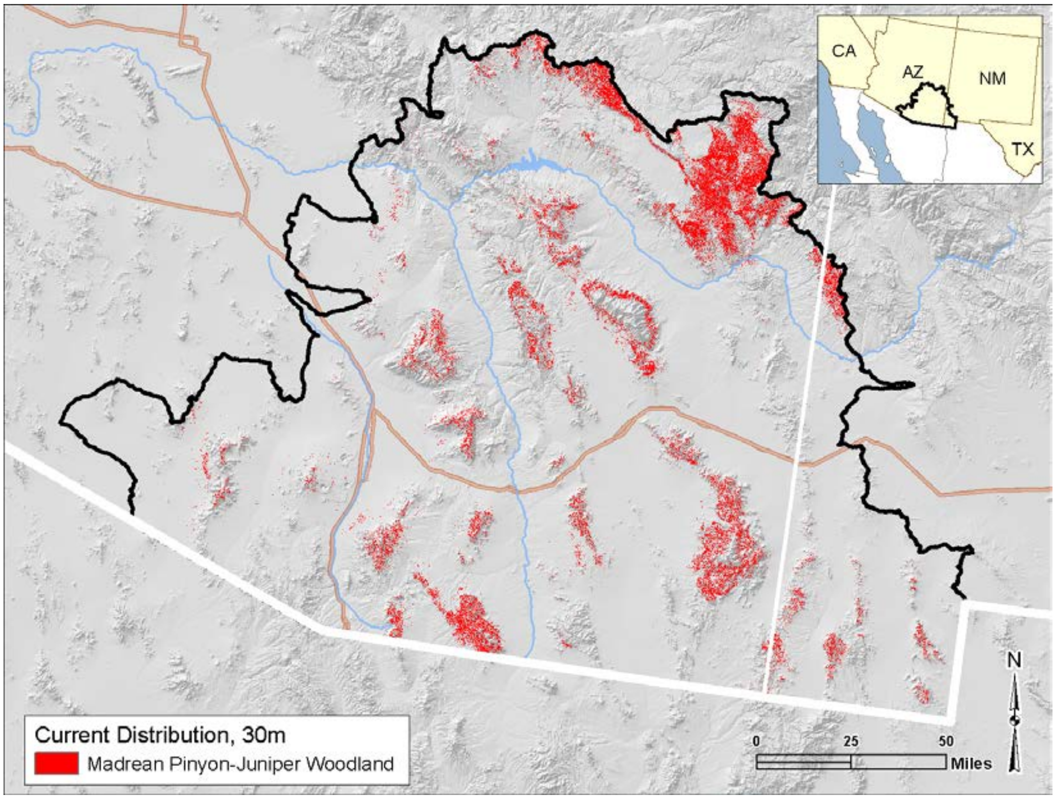


Figure D-23. Madrean Pinyon-Juniper Woodland in Arizona (source http://azfirescape.org)

Vegetation is characterized by an open to moderately dense tree canopy dominated by pinyon and juniper trees 2-5 m tall (Figure D-23). The presence of pinyons, *Pinus cembroides, Pinus discolor, Pinus remota,* or *Pinus edulis* with Madrean elements in the understory is diagnostic of this ecosystem. *Juniperus coahuilensis, Juniperus deppeana,* and *Juniperus pinchotii* are character species that are often present to dominant. *Pinus edulis* and *Juniperus monosperma* may be the dominants in the northern distribution in combination with Madrean shrub and/or graminoid elements. *Pinus ponderosa* is absent or scattered. Understory layers are variable, ranging from sparse to dense grass or shrub layers. If Madrean tree oak trees such as *Quercus arizonica, Quercus emoryi,* or *Quercus grisea* are present, then they do not dominate tree canopy. Common shrub species may include chaparral, desert scrub or lower montane shrubs such as *Arctostaphylos pungens, Canotia holacantha, Ceanothus greggii, Cercocarpus montanus, Quercus turbinella, Mimosa dysocarpa*, or *Rhus trilobata*. Perennial grasses such as *Bouteloua curtipendula, Bouteloua eriopoda, Bouteloua gracilis*, *Muhlenbergia emersleyi*, *Muhlenbergia pauciloba, Piptochaetium fimbriatum,* or *Piptochaetium pringlei* are present in many stands and may form an herbaceous layer. The vegetation description is based on several references, including Brown (1982), Dick-Peddie (1993), Gori and Bate (2007), Gottfried (1992), Muldavin et al. (2000b), and NatureServe Explorer (2013).

A crosswalk of this system to USDA Natural Resource Conservation Service (NRCS) approved Ecological Site Descriptions (ESD) by Major Land Resource Areas (MLRA) is provided in Table D-16 (USDA-NRCS

2014). For complete list of ESDs for MLRA 41 see https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD.)

Table D-16. Madrean Pinyon-Juniper Woodland ecological system CE crosswalk with approved Ecological Site Descriptions (provisional cross-walk).

MLRA	Ecological Site Description Name	Site ID
041-Southeastern Arizona Basin and Range	No Approved ESDs identified	

D-4.1.3 Species of Conservation or Management Concern

Below are listed some species of concern associated with this ecological system CE.

Listed below are from a list of typical Threaten-Endangered Species/Species of Concern/Species of Interest (TE/SOC/SOI) associations in Species Associations in Madrean Encinal Woodland from Coronado National Forest Ecological Sustainability Report (USDA-USFS 2009). Pinyon Juniper Woodlands were lumped into Madrean Encinal in this report so both MAR CEs have the same list of TE/SOC/SOI species. Some pinyon nut and juniper berry feeders were added to the list from the Natural Dynamics section below as they are important dispersers of these tree species.

Amphibians: Tarahumara Frog (*Lithobates tarahumarae*)

Birds: Elegant Trogon (*Trogon elegans*), pinyon seeds Scrub jays (*Aphelocoma californica*), pinyon jays (*Gymnorhinus cyanocephalus*), Steller's jays (*Cyanocitta stelleri*) and Clark's nutcrackers (*Nucifraga columbiana*)

Mammals: Jaguar (*Panthera onca*); Black Bear (***Ursus americanus*****);** Arizona Gray Squirrel (***Sciurus arizonensis*****),** cliff chipmunks (*Neotamias dorsalis*) and rock squirrels (*Spermophilus variegatus*),

Reptiles: New Mexico Ridge-nosed Rattlesnake (*Crotalus willardi obscurus*); Arizona Ridge-nosed Rattlesnake (*Crotalus willardi*); Giant Spotted Whiptail (*Aspidoscelis burti stictogrammus*);

Fish: Mexican Stoneroller (*Campostoma ornatum*), Qui chub (*Gila purpurea*) and Yaqui catfish (*Ictaluris pricei*)

Invertebrates: Huachuca Giant Skipper (*Agathymus evansi*), Pygmy Sonorella (*Sonorella micra*) (and many other talussnails)

Vascular Plants: Spreading Marina (*Marina diffusa*); Chiricahua Mock Pennyroyal (*Hedeoma costatum*)

D-4.1.4 Natural Dynamics

The Nature Conservancy did a review of the Historical Range of Variation for the broader Pinyon-Juniper Woodland (Gori and Bate 2007), however this CE for the MAR is restricted to the pinyon-juniper woodlands found in the Madrean Sky Island Archipelago ecoregion and is better represented by what Moir and Carleton (1987) classified as the High Sun Mild climate zone.

Romme et al. (2003) developed a pinyon-juniper classification with three types based on canopy structure, understory composition, and historical fire regime. All three types: pinyon-juniper grass savanna, pinyon-juniper shrub woodland, and pinyon-juniper forest occur within this ecoregion.

However the pinyon-juniper grass savanna and a new, ecologically similar type with tree canopy >10% cover (pinyon-juniper grass open woodland) best represents the Madrean Pinyon-Juniper Woodland ecosystem (Gori and Bate 2007, Landis and Bailey 2005). Other types are the pinyon-juniper shrub woodland, represented by pinyon-juniper trees with an understory of shrubs such as *Quercus turbinella,* and the pinyon-juniper forest type that has a typically sparse understory and is restricted to dry, rocky areas where it is protected from fire (Romme et al. 2003).

Fire dynamics for these types under historical natural conditions (also called natural range of variability, NRV; for pre 1900 time frame), are summarized below based on (Romme et al. 2003).

- The fire regime for the pinyon-juniper grass savanna/pinyon-juniper grass open woodland includes frequent, low-severity surface fires that are carried by the herbaceous layer. The low density of trees (5-20% cover) and high perennial grass cover is maintained by this fire regime. Mean fire interval is estimated to be 12-43 years (Gori and Bate 2007).
- The fire regime for the pinyon-juniper shrub woodland has moderately frequent, high-severity crown fires that are carried by the shrub and tree layers. After a stand replacing fire the site begins at early seral stage and returns to a moderately dense tree layer with a moderate to dense shrub layer. Succession happens relatively quickly if the shrub layer includes chaparral species that recover rapidly from fire by re-sprouting or from fire scarified seeds in a seed bank. Mixed-severity fires may alter this pattern by creating a mosaic of pinyon-juniper states (early, mid, and late seral). Mean fire interval is estimated to be 23-81 years (Gori and Bate 2007)
- The fire regime for the pinyon-juniper forest type has very infrequent, very high-severity fires that are carried by tree crowns. The stand dynamics are stable with multi-age tree canopy and with little change in shrub or herbaceous layers.

Other important ecological processes include climate, drought, insect infestations, pathogens, herbivory and seed dispersal by birds and small mammals.

Climate change has affected the distribution pinyon-juniper woodlands in the past and current climate change will likely shift the geographic and elevational distribution in the future (Betancourt et al. 1993, McAuliffe and Van Devender 1998, Van Devender 1977, Van Devender 1990). For example, after 500 BP, winter precipitation increased and caused a re-expansion of pinyon-juniper woodland that sharply increased after 1700 and again in the early 1900s (Davis and Turner 1986, Mehringer and Wigand 1990, as cited in Gori and Bate 2007). Shorter term variation in climate has important implications for this system. Regional droughts coupled with stress-induced insect outbreaks (pinyon Ips beetle) have caused widespread mortality of pinyons. This affects species dominance patterns, tree age structure, tree density, and canopy cover within pinyon-juniper woodlands and will shift dominance to juniper (Betancourt et al. 1993). Conversely, wet periods create conditions for tree recruitment and growth.

Juniper berries and pinyon nut crops are primarily utilized by birds and small mammals (Balda 1987, Gottfried et al. 1995, Johnsen 1962, McCulloch 1969, Salomonson 1978, Short et al. 1977). Large mammals, mule deer (*Odocoileus hemionus*), white-tailed deer (*Odocoileus virginianus*) and elk (*Cervus elaphus*) eat leaves and seeds of both species and they browse woodland grasses, forbs and shrubs including *Artemisia tridentata, Cercocarpus montanus, Quercus gambelii,* and *Purshia stansburiana* (Short and McCulloch 1977). The most important dispersers of juniper and pinyon seeds are birds. Juniper seeds that passed through the digestive tract of birds and other herbivores germinate faster than uneaten seeds (Johnsen 1962). The primary dispersers of pinyon seeds, Scrub jays (*Aphelocoma californica*), pinyon jays (*Gymnorhinus cyanocephalus*), Steller's jays (*Cyanocitta stelleri*) and Clark's nutcrackers (*Nucifraga columbiana*), during mast crop years cache hundreds of thousands of pinyon seeds, many of which are never recovered (Balda and Bateman 1971, Ligon 1978, Vander Wall and Balda

1977). In addition, small mammals, like cliff chipmunks (*Neotamias dorsalis*) and rock squirrels (*Spermophilus variegatus*), compete with birds (Christensen and Whitham 1993). There are many insects, pathogens, and plant parasites that attack pinyon and juniper trees (Gottfried et al. 1995, Rogers 1995, Weber et al. 1999). For pinyon, there are at least seven insects, plus a fungus and dwarf-mistletoe (black stain root disease (*Leptographium wageneri*), and pinyon dwarf mistletoe (*Arceuthobium divaricatum*)). These insects are normally present in these woodland stands, and during drought-induced water stress outbreaks may cause local to regional mortality (Gottfried et al 1995, Rogers 1995, Wilson and Tkacz 1992). Most insect-related pinyon mortality in the West is caused by pinyon Ips (*Ips confusus)* (Rogers 1993).

Most pinyon-juniper woodlands in the southwest have high soil erosion potential. Several studies have measured present-day erosion rates in pinyon-juniper woodlands, highlighting the importance of herbaceous cover and cryptogamic soil crusts (Belnap et al. 2001) in minimizing precipitation runoff and soil loss in pinyon-juniper woodlands.

A good condition/proper functioning Madrean Pinyon-Juniper Woodland stand is large and uninterrupted, the surrounding landscape is also in good condition; the biotic condition is within normal range of variation, the weeds are few, the native plants are robust, have expected abundance and reproduction; birds, mammals, reptiles, insects and amphibian species present are indicative of reference, un-molested conditions. Soils have not been excessively eroded, and cryptogamic soil crusts are present and undisturbed. The vegetation structure and fire regime that maintains it is functioning at near historical conditions depending on pinyon-juniper woodland types:

- with the pinyon-juniper grass savanna/pinyon-juniper grass open woodland type having frequent fires (FRI 12-43 years), low-severity surface fires that are carried by the abundant herbaceous layer. It has a low density of trees (5-20% cover) and high perennial grass cover is maintained by this fire regime.
- stands of the pinyon-juniper shrub woodland type have moderately frequent, high-severity crown fires that are carried by the shrub and tree layers. After a stand replacing fire the site begin at early seral stage and return to moderately dense tree layer with a moderate to dense shrub layer. Mean fire interval is estimated to be 23-81 years.
- stands of the pinyon-juniper forest type have very infrequent, very high-severity fires that are carried by tree crowns. The stand dynamics are stable with multi-age tree canopy and with little change in shrub or herbaceous layers.

A poor condition/non-functioning Madrean Pinyon-Juniper Woodland ecosystem is highly fragmented, or much reduced in size from its historical extent and the fire regime is functioning outside the historical range of variation. Density of tree canopy is too high and outside the historical range of variation. The surrounding landscape is in poor condition either with highly eroding soils, many non-native species or a large percentage of the surrounding landscape has been converted to pavement or highly maintained agriculture (row crops, irrigated crops, etc.); the biotic condition is at the limit or beyond natural range of variation. Characteristic birds, mammals, reptiles, and insect species are not present at expected abundances or the ratio of species shows an imbalance of predator to prey populations; abiotic condition is poor with evidence of high soil erosion, rill and gullies present or exposed soil sub horizons. Cryptogamic soil crusts, if present, have been disturbed or destroyed leading to increased soil erosion and loss of topsoil to both wind and water erosional processes.

D-4.1.4.1 Natural Dynamics Model

Conceptual historical state-and-transition models were developed by a team of ecologists (Gori and Bate 2007) using the Vegetation Dynamics Development Tool (VDDT) to model the Madrean Pinyon-Juniper

Woodland (for details on tool see http://essa.com/tools/vddt/). For methods on modeling please see Gori and Bate (2007). We were able to use their models for Madrean Pinyon-Juniper Woodland ecosystem CE because the two types represent the same vegetation. Models for both the pinyon-juniper grass savanna/open woodland and pinyon-juniper shrub woodland are shown (Romme et al. 2003; Figure D-24 and Figure D-25).

Figure D-24. Conceptual state and transition model of historical conditions for the Pinyon-Juniper Savanna vegetation type. This model was taken directly from Gori and Bate (2007). Frequency of transitions are noted when this information is supported by published sources; where no or conflicting information exists on the frequency of transitions, unknown is the notation (Gori and Bate 2007).

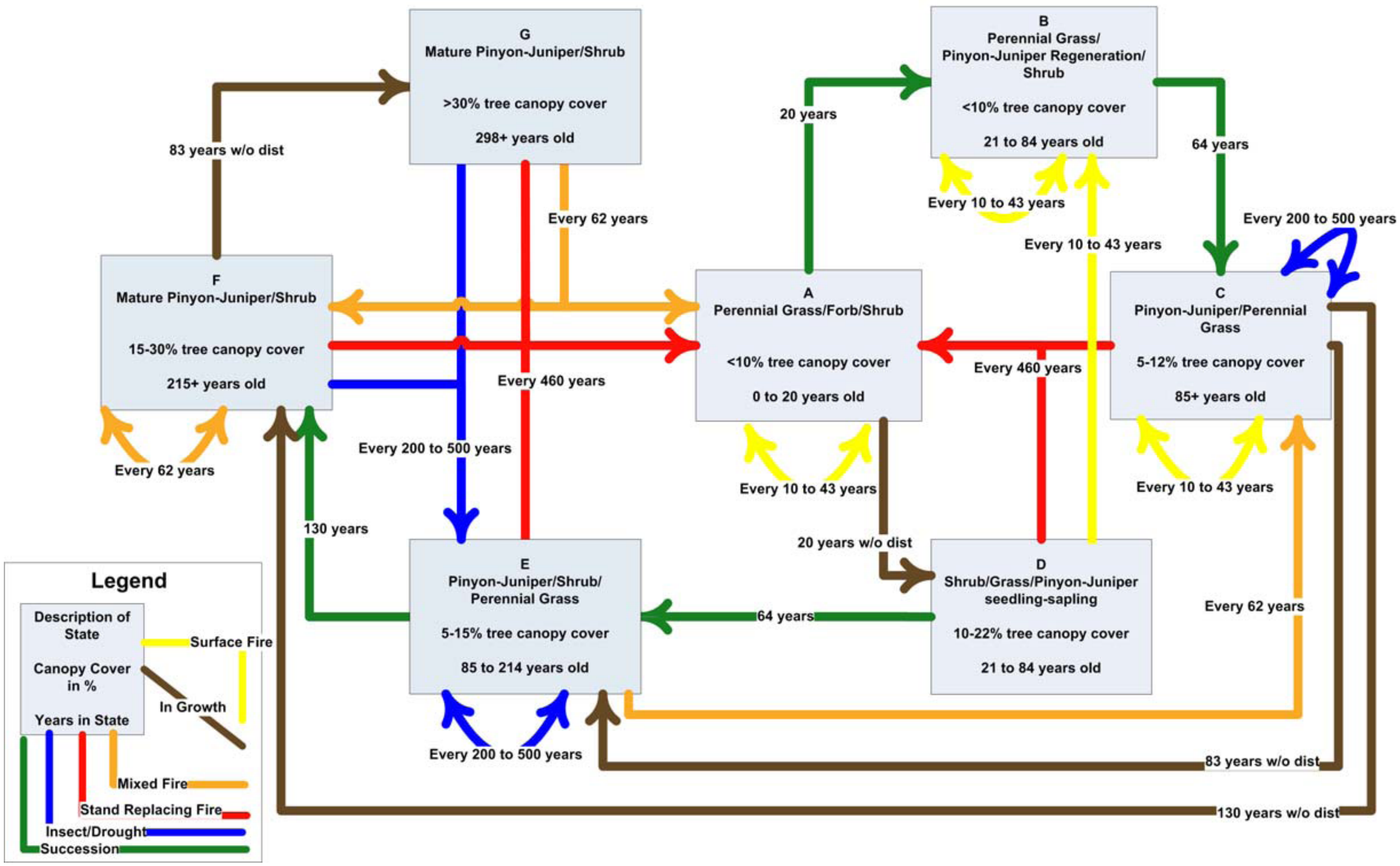
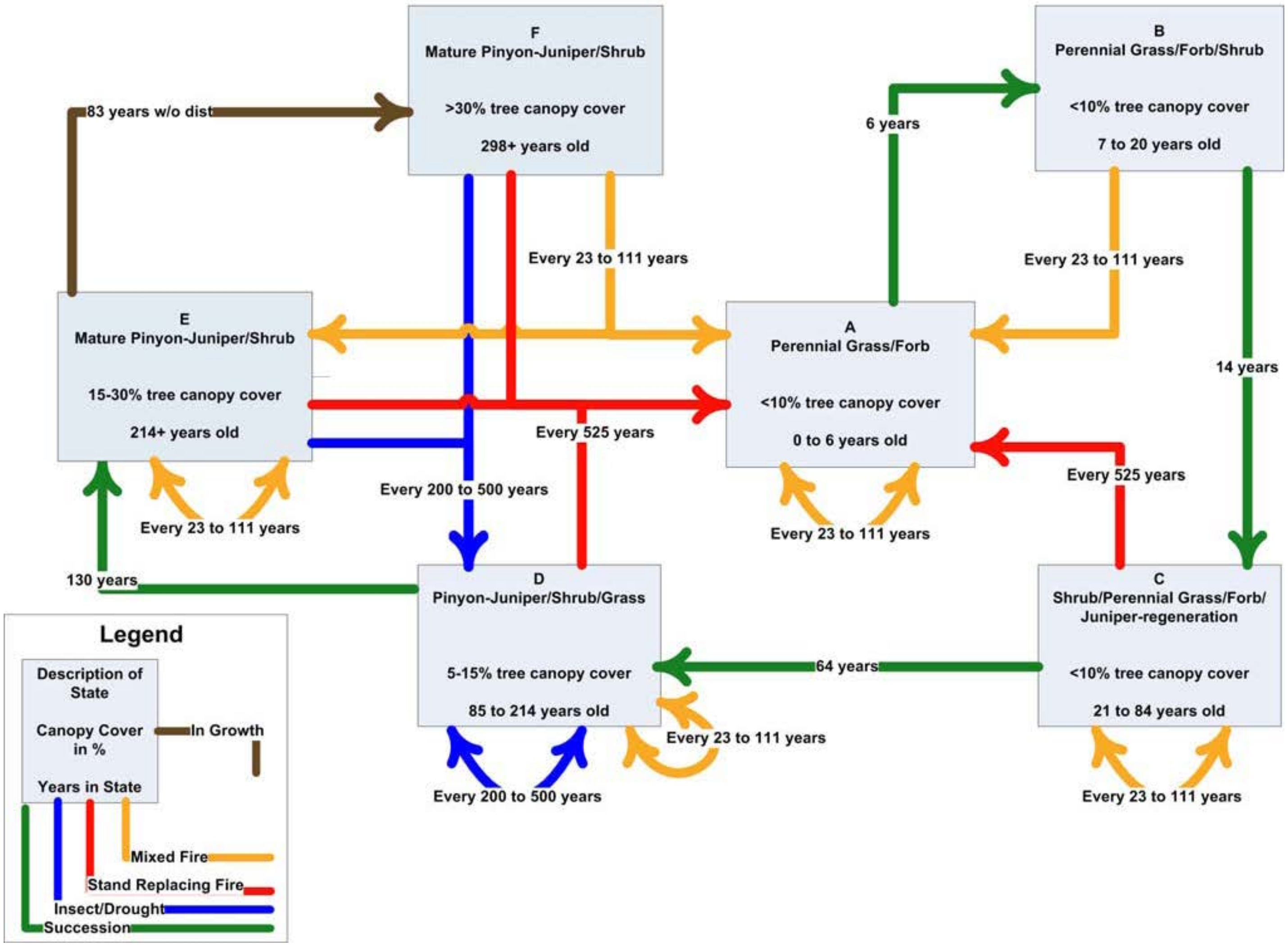


Figure D-25. Conceptual state and transition model of historical conditions for the Pinyon-Juniper Shrub Woodland vegetation type. This model was taken directly from Gori and Bate (2007). Frequency of transitions are noted when this information is supported by published sources; where no or conflicting information exists on the frequency of transitions, unknown is the notation.



D-4.1.5 Change Agent Effects on the CE

This section of the conceptual model presents a narrative description of the primary change agents and current knowledge of their effects on Madrean Pinyon-Juniper Woodland ecosystem. The section contains two sub-sections: (1) A list of primary change agents identified for the CE; and (2) a discussion of altered dynamics caused by these agents.

D-4.1.5.1 List of Primary Change Agents

Occurrences of this woodland ecological system are directly affected by livestock grazing, direct and indirect wildfire suppression, land development, non-native plant species invasion. Table D-17 identifies the most likely impacts associated with each of these stressors.

Table D-17. Stressors and their likely impacts on the Madrean Pinyon-Juniper Woodland ecosystem in the Madrean Archipelago ecoregion.

Stressor	Impacts
Land Use	
Livestock grazing	Grazing of native vegetation by livestock at incompatible stocking rates, season of use, or duration can be detrimental to grass vigor resulting in decline of grass cover and shifts species composition to more grazing tolerant or less palatable species (Milchunas 2006). Livestock will trample and destroy soil crusts, leading to soil erosion. Over time this often results in increased woody cover or bare ground and erosion. Heavy grazing can indirectly decrease fire return intervals by removing fine fuels that carry fire (Romme et al. 2003, Swetnam and Baisan 1996, Swetnam et al. 1999).
Harvesting fuelwood and forest management	Historical fuelwood and fencepost cutting, and, more recently, chemical and mechanical treatments such as chaining and roto-chopping, have impacted age structure, tree density and cover of many pinyon-juniper woodlands with current demand for these products continuing to increase (Dick-Peddie 1993a, Gottfried 1987, 1992, Gottfried and Severson 1993, Ffolliot et al 1979). Changes stand structure such as increased number of stems per acre, decreased crown volume and depth, decreased tree height and foliage volume (USDA-USFS 2009.)
Recreation	This mostly relates to off road vehicle use, which creates addition roads and trails that fragment woodlands and contribute to increase soil erosion and compaction and non-native species dispersal (USDA-USFS 2009).
Development	
Transportation infrastructure Roadways/railways and transmission lines	Fragmentation from transportation infrastructure leads to disruptions in ecological processes such as fire, dispersal of invasive non-native species, and can alter hydrological processes when excessive runoff from roads creates gullies. Additionally, destruction of wildlife habitat and disruption of wildlife migration patterns can also occur (Bahre 1991, Bock and Bock 2002, Gori and Bate 2007, Heinz Center 2011, Marshall et al. 2004, McPherson 1997).

Stressor	Impacts
Suburban/Rural (include Military), Mines/Landfill	This stress contributes to altered fire regimes, increased erosion, direct habitat loss/conversion, increased groundwater pumping, fragmentation, invasive non-native species dispersal and disruption of wildlife migration patterns. (Bahre 1991, Gori and Bate 2007).
Energy (Renewable wind/solar), Oil/Gas	This stress contributes to altered fire regimes (e.g. fire suppression activities to protect facilities), increased erosion, direct habitat loss/conversion, fragmentation, invasive non-native species dispersal and disruption of wildlife migration patterns.
Uncharacteristic Fire Regime	Fire suppression has increased woody species, lead to changes in woody species composition and lead to an uncharacteristic fire regime in many stands (Barton 1999, Gori and Bate 2007, Muldavin et al. 2002; Turner et al. 2003).
Invasive non-native Species	Replacement of native vegetation with non-native grass species such as *Eragrostis lehmanniana* and *Eragrostis curvula*, and annual Bromes (*Bromus* spp.). These species are better adapted to frequent fire and increase in relative abundance over native grasses after burning (Anable et al. 1992, Cable 1971, Gori and Bate 2007). Post-fire succession may be altered if invasive non-native species colonize and prevent native grasses and forbs from establishing (Floyd et al. 2006).
Climate change	Alteration of precipitation and evapotranspiration rates and timing, may result in more frequent drought periods and higher intensity precipitation events, which following drought can cause significant erosion of topsoil (Garfin et al. 2012).

D-4.1.5.2 Altered Dynamics

The Madrean Pinyon-Juniper Woodland ecological system CE has been impacted by human activities over the last century. Historical fire regimes were disrupted followed the introduction of livestock (and the 1890’s drought). Grazing passively suppresses fire by removing fine fuels needed to carry surface and mixed-severity fires that likely maintained the structure and composition of pinyon-juniper savannas and pinyon-juniper shrub woodlands historically. Active fire suppression was also practiced by the federal government during the last 100 years (Swetnam and Baisan 1996). As fire became less frequent, pinyon and juniper trees became denser and subsequent fires became more severe (Gori and Bate 2007). These impacts altered stand dynamics differently depending on stand structure. Fire dynamics under current conditions are summarized below for the three major pinyon-juniper types (pinyon-juniper grass savanna/open woodland, pinyon-juniper shrub woodland, and pinyon-juniper forest) developed by Romme et al. (2003) using canopy structure, understory composition, and historical fire regime and adapted for our use below.

- The fire regime for the pinyon-juniper grass savanna/ open woodland has a fire frequency that is significantly reduced and fire severity has greatly increased from pre-1900, from low severity surface fires towards high severity and stand-replacing crown fires. Tree density has increased and herbaceous biomass has decreased from historical conditions with active fire suppression and livestock grazing. Currently stands have some very old trees (> 300 years) present but not numerous, but are typically dominated by many young trees (<150 years). This type may also occur on sites with more rock soil and less grasses. This type is outside Historical Range of Variation (HRV) for disturbance regime, structure and composition (Gori and Bate 2007).

- The fire regime for the pinyon-juniper shrub woodland has a fire frequency that is reduced and fire severity is somewhat increased from pre-1900, from low to moderately frequent, high-severity stand replacing fires and moderately frequent mixed severity fires that likely maintain this type, toward less frequent, higher severity fires (Gori and Bate 2007). Tree density has increased and herbaceous biomass has decreased from historical conditions with active fire suppression and livestock grazing. Currently most stands have are a variable mix of tree and shrubs with few or no very old trees (> 300 years) present. With fire suppression, this type may be outside HRV for disturbance regime, and possibly for structure and composition as recent fires are likely more severe than historical fire in late 1800's (Romme et al. 2003).
- The fire regime for the pinyon-juniper forest type still has infrequent, high-severity fires that are carried by tree crowns. The stand dynamics remain relatively stable with little change in density of tree or shrub and herbaceous layers. Currently stands have numerous very old trees (> 300 years) present with a multi-aged structure. Active fire suppression and livestock grazing are thought to have had little impact on fire frequency and severity and the overstory structure and composition with this type remaining within HRV for disturbance regime (Gori and Bate 2007).

Additionally, historical fuelwood and fencepost cutting, and more recently, chemical and mechanical treatments such as chaining and rotochopping, have impacted age structure, tree density and cover of many pinyon-juniper woodlands with current demand for these products continuing to increase (Dick-Peddie 1993a, Gottfried 1987, Gottfried and Severson 1993, Ffolliot et al. 1979).

Fragmentation from a variety of sources such as construction of roads and secondary homes has occurred in many areas of pinyon-juniper woodlands (Gori and Bate 2007). The introduction of non-native species as a threat to Madrean Pinyon-Juniper Woodland ecosystem needs to be further investigated (Gori and Bate 2007). Non-native species invasion is an important issue in the Great Basin pinyon-juniper woodlands which has lead to increased fire frequency and size in this type (Miller and Tausch 2001). In Mesa Verde National Park, invasive non-native species dominate pinyon-juniper woodland areas post-fire (Romme et al. 2003). Post-fire succession may be altered if invasive non-native species colonize and prevent native grasses and forbs from establishing (Floyd et al. 2006).

D-4.1.5.3 Altered Dynamics Model

A conceptual state-and-transition model representing current conditions was developed by a team of ecologists (Gori and Bate (2007) using the Vegetation Dynamics Development Tool (VDDT) to model the Madrean Pinyon-Juniper Woodland vegetation type (for details on tool see http://essa.com/tools/vddt/). For methods on modeling please see Gori and Bate (2007). We were able to use their models for Madrean Pinyon-Juniper Woodland ecosystem CE because the two types represent the same vegetation. Models for both the pinyon-juniper grass savanna/open woodland and pinyon-juniper shrub woodland are shown (Romme et al. 2003; Figure D-26 and Figure D-27).

Figure D-26. Conceptual state and transition model of current conditions for the Pinyon-Juniper Savanna/Open Woodland vegetation type. This model was taken directly from Gori and Bate (2007). Frequency of transitions are noted when this information is supported by published sources; where no or conflicting information exists on the frequency of transitions, unknown is the notation (Gori and Bate 2007).

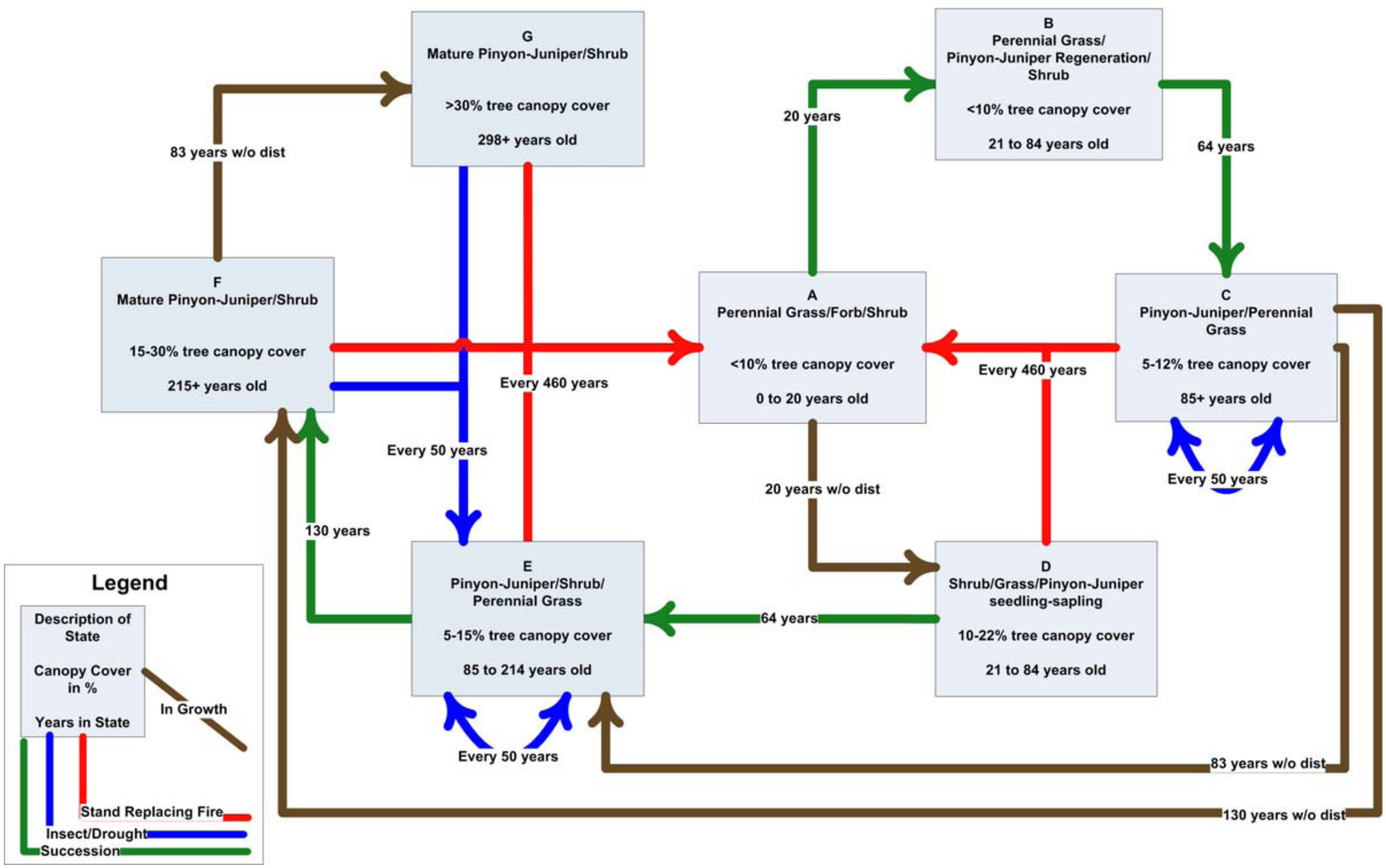
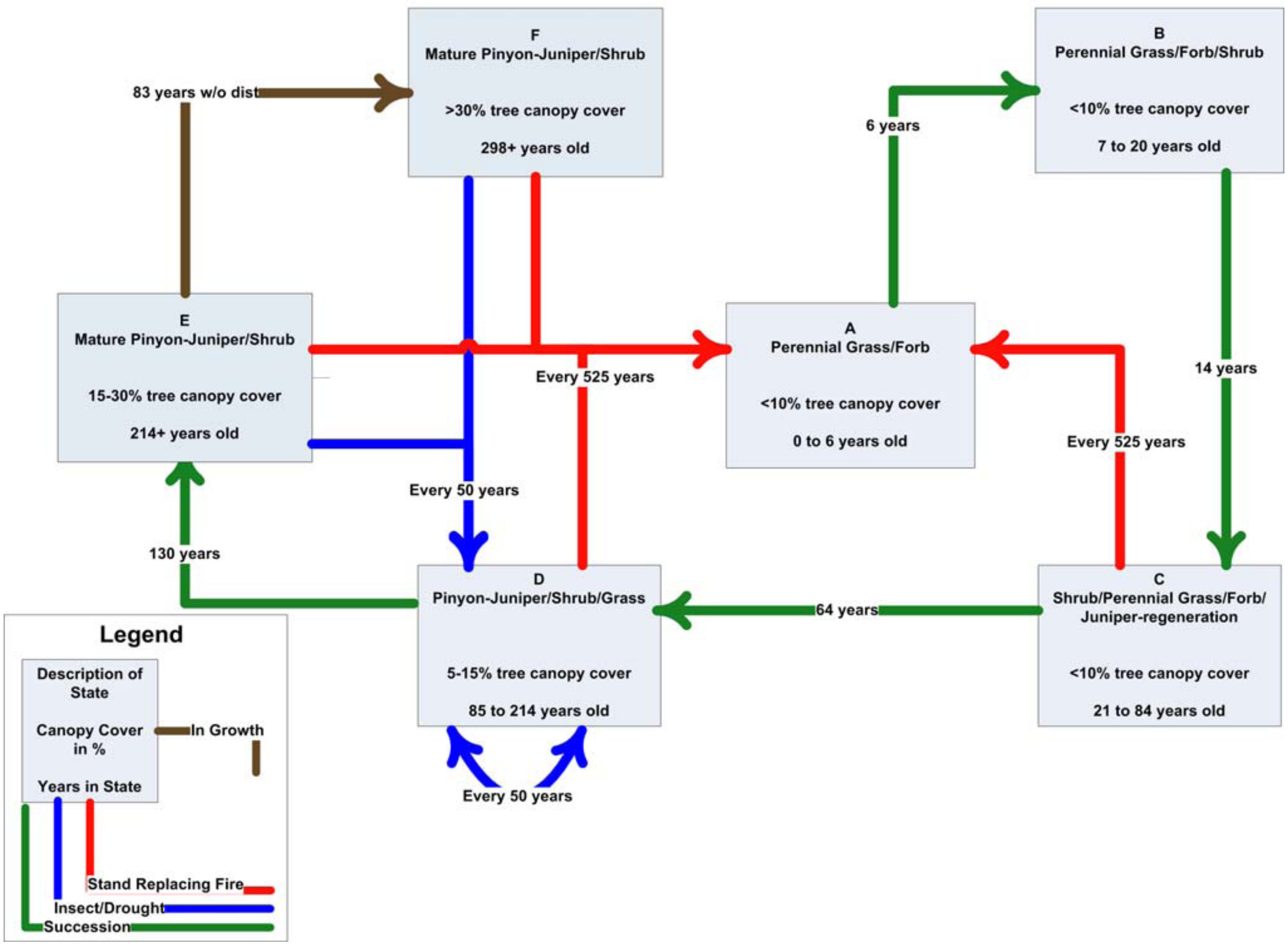


Figure D-27. Conceptual state and transition model of current conditions for the Pinyon-Juniper Shrub Woodland vegetation type. This model was taken directly from Gori and Bate (2007). Frequency of transitions are noted when this information is supported by published sources; where no or conflicting information exists on the frequency of transitions, unknown is the notation (Gori and Bate 2007).



D-4.1.6 Ecological Status: Key Ecological Attributes and Indicators

This section of the conceptual model addresses Key Ecological Attributes and their potential indicators. The ecological status is a way of describing current status via criteria, functionality, or levels of attributes and asks if they are within the normal range of variation.

D-4.1.6.1 Key Ecological Attributes

Table D-18 identifies the key ecological attributes for the CE within the Madrean Archipelago ecoregion. A **key ecological attribute** of a focal ecological resource is a characteristic of the resource's biology, ecology, or physical environment that is critical to the resource's persistence in the face of both natural and human-caused disturbance. Alteration of such a characteristic beyond some critical range of variation will lead to the degradation or loss of the resource within decades or less. The KEAs table lists the identified key ecological attributes, with a brief definition, a rationale for why it is important for the CE, and a listing of stressors or change agents that might be affecting the key attribute.

Table D-18. Key Ecological Attributes (KEAs) of Madrean Pinyon-Juniper Woodland ecosystem CE in the Madrean Archipelago ecoregion. Indicators for these KEAs can be used to determine the ecological status for this CE; see **Table D-2** for a list of the indicators assessed in this REA.

KEA Class: Name	Definition general	Rationale general	Stressors general
Landscape Context: **Landscape Condition**	This attribute is the amount of anthropogenic disturbance of the ecosystem that can be identified using a Land Condition Model Index (LCM). It incorporates a number of development features (including roads, urban/rural areas, agriculture, mines, transmission corridors, and energy development) that degrade the condition of the landscape.	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance (Comer and Hak 2009)	Stressors to landscape condition include multiple sources of fragmentation (reduces connectivity) that alter ecological processes (e.g., fire or surface hydrology), degrade wildlife habitat and disrupt wildlife migration patterns by creating barriers to species movement. Stressors include livestock grazing (reduces fine fuel that carry fire), urban and exurban development, and road building.
Size/Extent: **Patch Size Distribution**	The distribution of patch sizes (number and size class frequency) is a measure of fragmentation in this historically matrix or large patch ecosystem. Historical patch size/frequency is compared with current patch size/frequency.	This attribute is used to evaluate level of ecosystem fragmentation that interferes with landscape scale ecological processes. The current average patch size and total number of patches of the type are compared to earlier conditions where data are available.	Stressors include conversion to agriculture/pasture, commercial/industrial/residential use and construction of transportation infrastructure - roads, pipelines, transmission lines - that interfere with large-scale ecological processes such as fire or surface hydrology.

KEA Class: Name	Definition general	Rationale general	Stressors general
Ecosystem “Occurrence” Extent	This attribute assesses the current size (ha) of the occurrence or stand as affects its biodiversity richness, structural complexity, and “internal” ecological processes, especially landscape scale processes like fire. Patch Size is measured as percentage of the Minimum Dynamic Area (MDA) for the ecosystem. This CE is a Large Patch type that functions best when patches are large ranging from 20 to 2000 hectares (approximately 50 to 5000 acres).	The area necessary to maintain ecological processes and ensure persistence is an ecosystem’s minimum dynamic area (Pickett and Thompson 1978). Ecosystems with patch sizes above the minimum dynamic area (MDA) tend to exhibit vegetation structure and composition, landscape scale ecological processes, and soil and hydrology that are functioning within the natural range of variation. However, the role of patch size in assessing ecological integrity is complex and related to the larger landscape context. Fragmentation from roads and subdivisions has reduced the size of many patches so that the fire regime cannot be restored to pre-1882 frequency without management action i.e., prescribed fire. The MDA to maintain the fire regime (or any natural disturbance regime) under the historical range of natural variation for this ecological system has not been determined. Little empirical study has been done in ecosystems outside of eastern forests to determine the MDA; Faber-Langendoen et al. (2012b) developed criteria for rating patch size based on the spatial patterning of the ecosystem (i.e., matrix, large patch, small patch, or linear) and provide a discussion of the protocol for assessing size/extent.	Stressors to ecosystem extent include actions such as development and fire exclusion that directly or indirectly convert the ecosystem to other land uses or cover types, or actions such as roads that fragment large patches into many small patches.

KEA Class: Name	Definition general	Rationale general	Stressors general
Biotic Condition: **Terrestrial Fauna**	The taxonomic and functional (e.g., guild) composition of the native faunal assemblage of the ecosystem including birds, mammals, reptiles and amphibians, and invertebrates; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term). Monitoring populations of key native fauna will provide information on the condition of these important components of this ecosystem.	The taxonomic and functional composition of the faunal assemblage is an important aspect of the ecological integrity of an ecosystem. Many native species of birds, mammals, reptiles and amphibians, and invertebrates use this ecosystem as habitat for feeding, resting, breeding, and movement; and their patterns of use vary over time (seasonal, annual, longer-term) (Finch 2004, McClaran and McPherson 1999, McPherson 1997). These species vary in their sensitivity to different stresses such as alterations to vegetation composition, fire frequency, and water availability. Alterations in the taxonomic and functional composition of the terrestrial faunal assemblage beyond its natural ranges of variation therefore strongly indicate the types and severities of stresses imposed on the ecosystem.	Stressors to the taxonomic and functional composition of the faunal assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, floral composition, and abiotic condition of the ecosystem; and incursions of non-native species that alter the food web or directly compete with or prey on the native fauna.
Biotic Condition: **Vegetation Composition**	The overall plant species composition and diversity of an ecosystem is an important aspect of its ecological integrity and largely defines it.	The taxonomic and functional composition of the plant species assemblage is an important aspect of the ecological integrity of a terrestrial ecosystem; many ecological processes and environmental variables affect it (drought, fire regime, anthropomorphic disturbance). In addition, the impact of invasive non-native species on community function of native vegetation is well documented (Anable et al. 1992, Cable 1971, Cox et al. 1988). Livestock grazing can affect the structure and composition of shrub or grass understory, soil structure and water infiltration, as well as species diversity. Some plant species vary in their sensitivity to different stresses such as grazing or lack of fire. This can alter the taxonomic composition of the terrestrial floral assemblage beyond its natural range of variation and strongly indicate the types and severities of stresses imposed on the ecosystem. An open tree canopy defines most examples of this CE.	Stressors to the taxonomic and functional composition of the plant assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, vegetation structure, and abiotic condition of the ecosystem; especially altered fire regime, improper livestock grazing management, and incursions of non-native species that alter the food web or directly compete with the native plants.

KEA Class: Name	Definition general	Rationale general	Stressors general
Biotic Condition: **Vegetation Structure**	An assessment of the overall structural complexity of the vegetation layers, including presence or cover of multiple strata, age and structural complexity of main canopy layer, and expected frequencies of successional or age classes.	Vegetation structure is an important reflection of dynamics and creates heterogeneity within the community. The distribution of total cover, crown diversity, stem size, and age classes or cohorts reflects natural disturbance regimes across the landscape and affects the maintenance of biological diversity, particularly of species dependent upon specific stages. For example, Gori and Bate (2007) reported increased tree cover and declines in grass cover in these tree savannas and open woodlands with fire suppression. An open tree canopy defines most examples of this CE.	Alteration of vegetation structure can come from a variety of stressors, including changes in fire regime (e.g. too frequent or too infrequent), logging/fire wood cutting or other removal of woody species, livestock grazing or concentrated native herbivory that removes native perennial herbaceous plants, climate change, and various kinds of mechanical disturbance that damages or removes vegetation.
Abiotic Condition: **Soil Condition**	Soil is basic to the proper functioning of a terrestrial ecosystem. Good soils will enhance the resilience and function of an ecosystem. Poor condition soil will limit the function of an ecosystem and if not addressed can permanently degrade a site. Soil condition includes indicators of multiple soil properties such as soil structure (particle and pore size, vertical profile, soil aggregates) and surface condition such as presence of soil crusts.	The condition of soil/surface substrate directly affects the functioning of the ecosystem. Soil/surface substrate condition of a site can be directly evaluated using indicators of soils disturbance such as evidence of erosion and disrupted soil processes and properties. The types of disturbances (stressors) can also be recorded to indicate condition such as livestock trampling and recreational vehicles. These disturbances can directly affect soil properties by disturbing soil crusts, compacting pore space that reduces water infiltration and percolation, changing other structural characteristics, and can expose soils to increased erosional forces.	Excessive livestock trampling, vehicle use (motorbikes, off-road vehicles, construction vehicles), filling and grading, plowing, other mechanical disturbance to the soil surface, excessive soil movement (erosion or deposition) as evidenced by gully, rill, or dune formation. Climate change and drought can also lead to increased potential for erosion.
Abiotic Condition: **Fire Regime**	Fire is a natural agent of disturbance in upland vegetation communities that maintains species composition, vegetation structure, and sustains ecological processes such as nutrient cycling.	Altered (uncharacteristic) fire regime greatly influences ecosystem processes. Two of the three types described by Romme et al. (2003) have relatively frequent fires (mean FRI of 12-43 years for the tree savanna – open woodland type with grass understory and mean FRI of 23-81 years for the open woodland with shrub understory (Gori and Bate 2007)). Fire suppression has changed stand structure, and resulted in increased woody cover (tree and shrub) and decreased grass cover. This has lead to very infrequent, very high-severity, stand replacing fires that expose soil to erosion and disrupt other ecological processes (Gori and Bate 2007)	Fire exclusion in fire-maintained ecosystems results in increased woody species density and cover, changes in wildlife species assemblages, and increased fuel that ultimately produce high severity fire. Specific stresses include fire suppression with building roads that act as fire breaks, and active fire suppression by land owners and agency personnel.

D-4.1.7 Relationship of KEAs to Fundamentals of Rangeland Health

The key ecological attributes and indicators listed in Table D-18 also encompass the four fundamentals of rangeland health (USDI-BLM 2006), as shown in Table D-19. The KEA of Landscape Condition specifically refers to watershed conditions; all other KEAs refer specifically to Ecological Processes and Habitat. However, many of the indirect indicators for the KEAs for Abiotic Condition focus on stressors that arise as a result of modifications to the watershed or water quality, the fourth Fundamental. These relationships are also indicated in Table D-19. Further information about interpretation and assessment of these fundamentals of rangeland health can be found in Pellant et al. (2005).

Table D-19. Key Ecological Attributes (KEA) for the Madrean Pinyon-Juniper Woodland ecosystem and their relationship to fundamentals of rangeland health.

Indicator	Watershed	Ecological Processes	Water Quality	Habitat
Landscape Condition	X	X		X
Patch Size	X	X		X
Terrestrial Fauna				X
Vegetation Composition		X		X
Vegetation Structure				X
Soil Condition		X	X	X
Fire Regime	X	X		X

D-4.1.8 Conceptual Model Diagrams

See Figure D-24, Figure D-25, Figure D-26, and Figure D-27.

D-4.2 Ecological Status Assessment Results and Interpretation

This section of the appendix presents and discusses the results of the ecological status assessment for the Madrean Pinyon-Juniper Woodland CE. The presentation addresses each indicator separately, and then addresses the overall assessment, which integrates the results of all individual indicators. The results are presented using a common framework, in which the status of an indicator – or the combination of all indicators – is scored on a scale from 0.0 to 1.0, where 0.0 indicates a condition of complete replacement of reference ecological conditions due to the impacts of stressors, and 1.0 indicates a condition of no alteration of reference ecological conditions. The same color ramp is used for all results, yellow to dark blue, where yellow equals low scores, green moderate scores and dark blues high scores.

D-4.2.1 Current Ecological Status: Development, Fire Regime, Invasives

The maps below show the ecological status results for each of the three individual indicators – development, fire regime departure, and invasives – for the Madrean Pinyon-Juniper Woodland.

The development indicator is a stressor-based indicator of the spatial extent and intensity of human modifications to the land surface that alters ecosystems or habitat in the MAR ecoregion. The indicator takes into account the density of urban development; infrastructure such as above- and below-ground distribution corridors, communication towers, and border barriers; a wide range of transportation features; mines and landfills; recreational development; agriculture; and energy development. The scoring is on a continuous scale from 0 to 1, with the highest score of 1.0 indicating no ecologically relevant modifications, and the lowest score of 0.0 indicating modifications that essentially eliminate all natural cover and ecological functions.

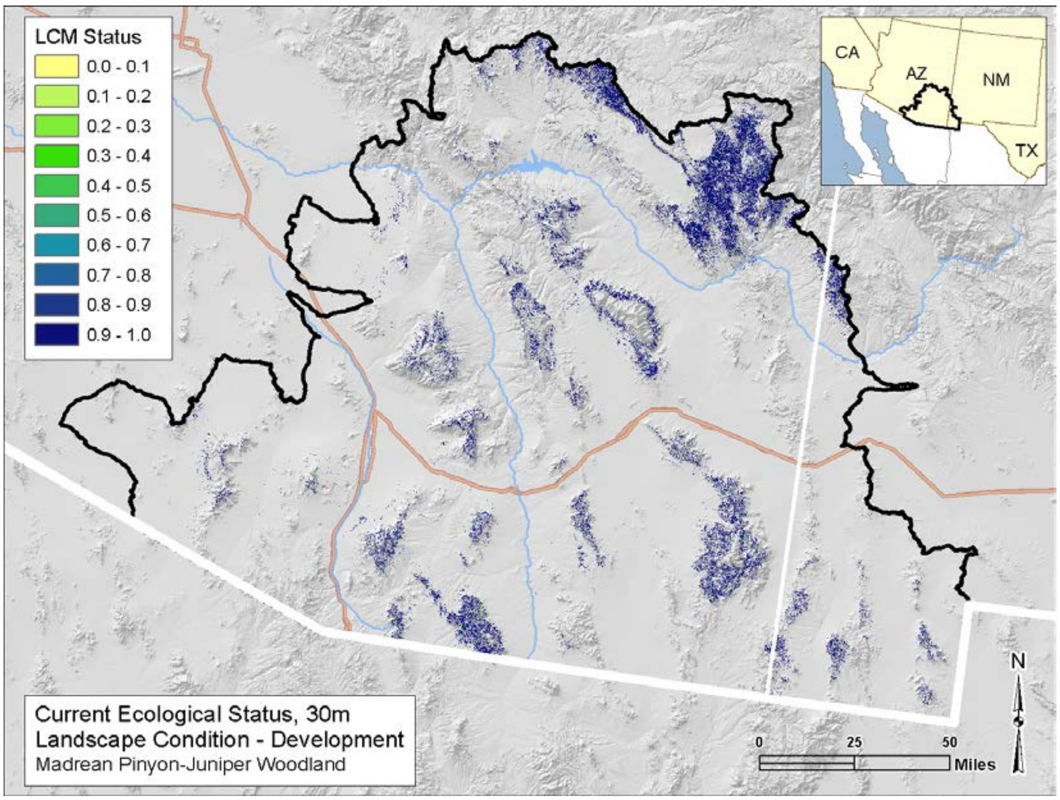
The first map in Figure D-28 indicates that there is generally low density of development within or adjacent to Madrean Pinyon-Juniper Woodland CE. This ecosystem occurs in the foothill to lower montane zone above much of the medium and high density development. There are some small patch areas of moderate development mixed in some stands, especially in the southern portion of the MAR ecoregion such as in the foothills of the Huachuca Mountains adjacent to Sierra Vista and on Fort Huachuca.

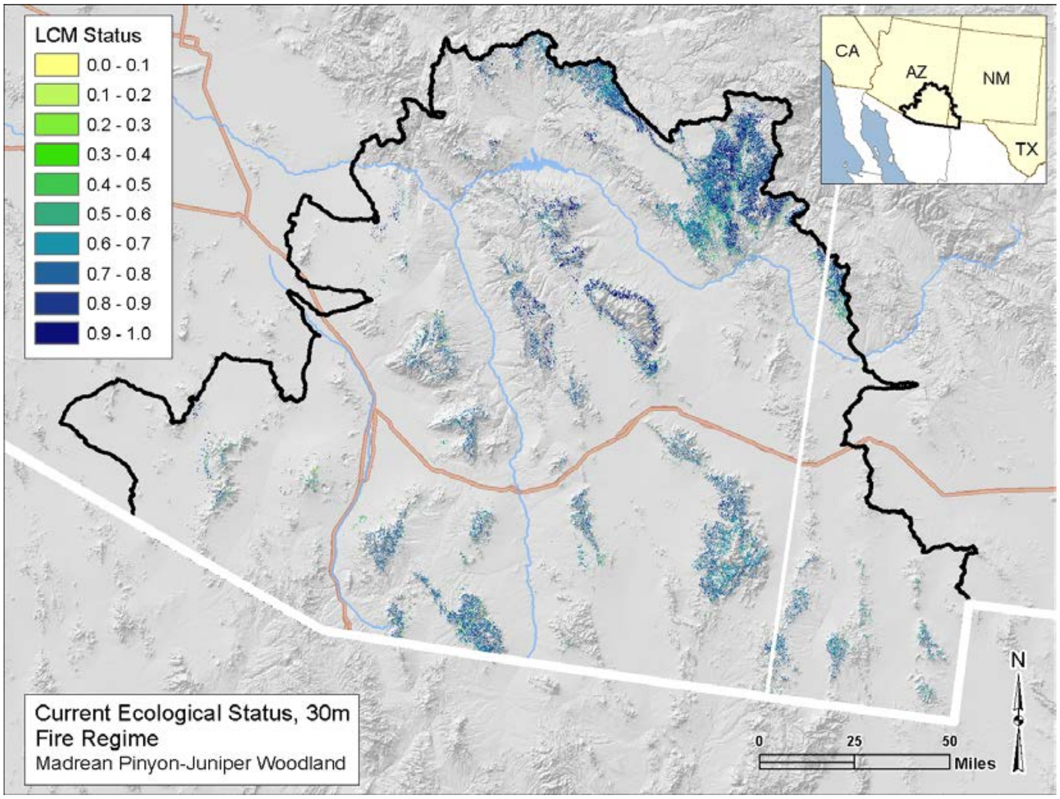
It is important to note that most development impacts are scored much lower than non-development change agents; for example, site intensity values for urbanization ranged from 0.05 to 0.6 for high to low density development, respectively. This is because development typically has a much stronger on-site impact than the other indicators. However, except for urban development, most development impacts occur at smaller scales than can be displayed in these maps, but still are pervasive throughout much of the ecoregion. In particular, effects of many of the very small, local areas of development, or small linear features (e.g. dirt roads) will not be obvious at the scale of the development indicator map.

The second indicator is an indirect measure of fire regime. It is based on the Vegetation Condition Class (VCC) dataset produced by Landfire, which was developed to compare historical reference conditions with current conditions for an individual ecological system type (see **Status Assessment Methods** above). The result of VCC is a ranking of departure from expected historical range of variability, which can be interpreted as “how has the disturbance regime [for the REA purposes and relevant to this ecoregion: fire regime] changed from its historical variability for this individual CE”. Only Severe Vegetation Departure (0.65) and Moderate Vegetation Departure (0.75) were used and are displayed in the map; no to minor departure was scored as 1 (dark blue in the map).

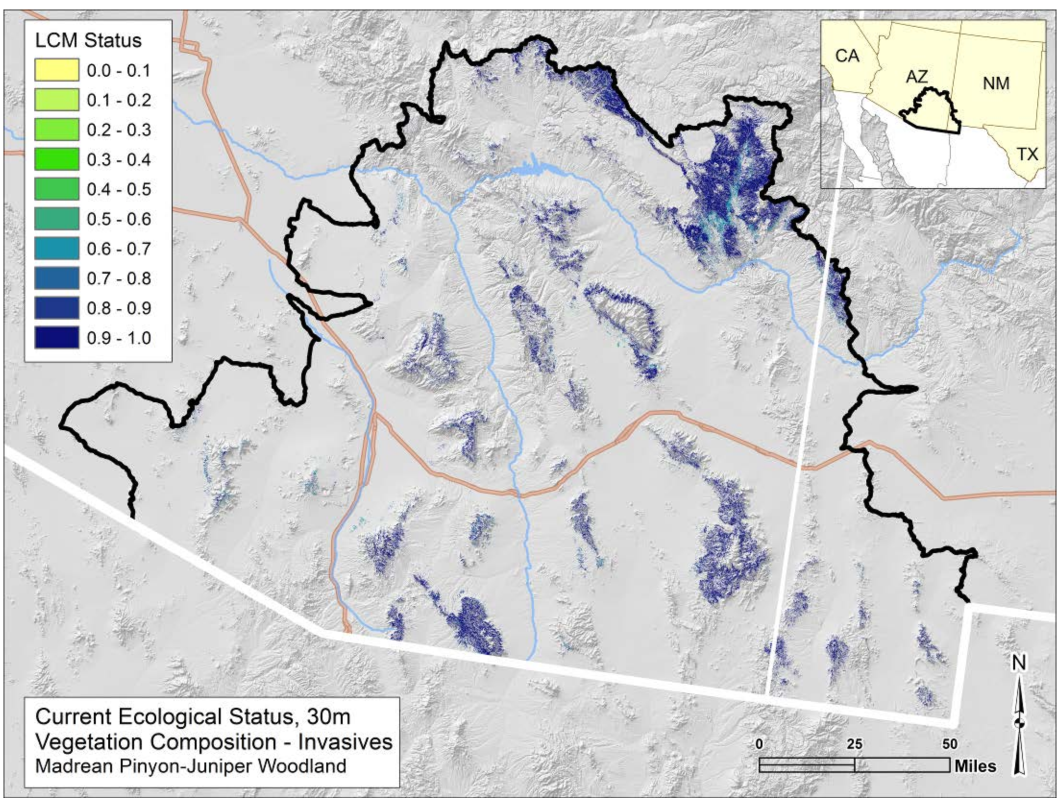
The second map in Figure D-19 shows severe departure (0.6-0.7) for much of the extent of the Madrean Pinyon-Juniper Woodland CE across the southern part of the MAR ecoregion, such as in the Baboquivari and Sierrita mountains with moderate departure (0.7-0.8) in the northern portion of the MAR ecoregion. This spatial result is supported by research documenting the results of fire exclusion in the MAR ecoregion. Active and passive fire suppression over the last century has excluded fire from much of this woodland (Gori and Bate 2007). In the absence of disturbance such as fire, the woody component increased in density over time resulting in an uncharacteristic fire regime (Gori and Bate 2007, Swetnam and Baisan 1996, Turner et al. 2003). As fire became less frequent, pinyon and juniper trees became denser and subsequent fires became more severe (Gori and Bate 2007).

Figure D-28. Scores for three indicators for Madrean Pinyon-Juniper Woodland: development indicator (first map), fire regime departure indicator (second map), and invasive species indicator (third map) for each 30m pixel. At the ecoregion scale, many development features are not readily visible (i.e. secondary roads or highways, railroads, small agricultural fields). Yellow (equivalent to 0) indicates high impacts from the CA, dark blue (equivalent to 1) indicates little to no impact from the CA. Only 3 classes of fire regime condition are scored: no to little departure (dark blue), moderate departure and severe departure (lighter blue). For the invasives indicator results, higher cover of mesquite or invasive exotics will score between .4 and .6 (light greens), while lower cover scores between .6 and .8 (light blues).





Current Ecological Status, 30m
Fire Regime
Madrean Pinyon-Juniper Woodland



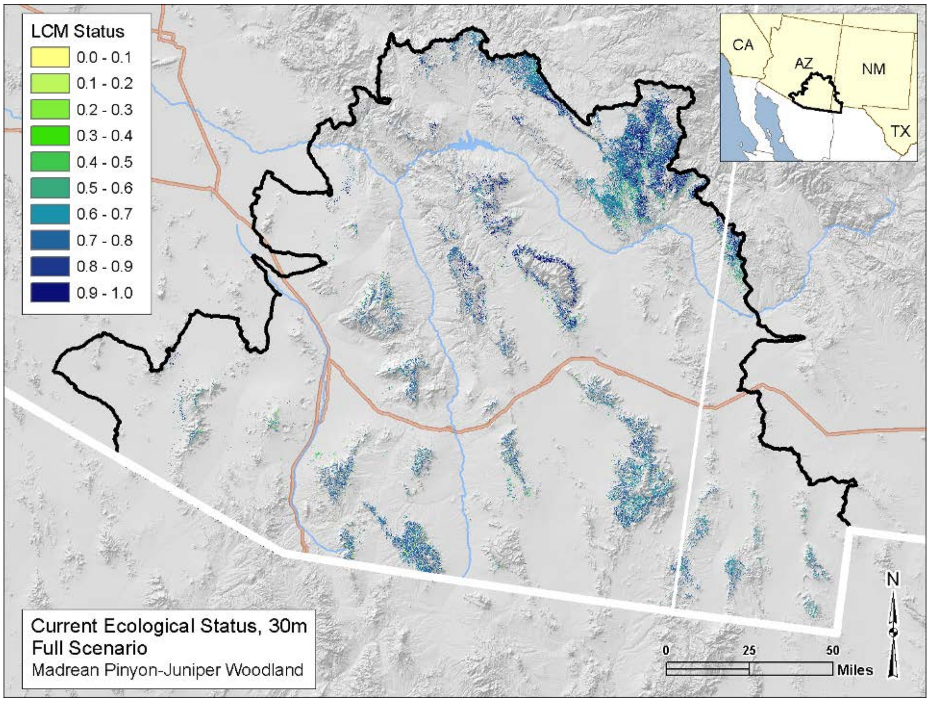
Current Ecological Status, 30m
Vegetation Composition - Invasives
Madrean Pinyon-Juniper Woodland

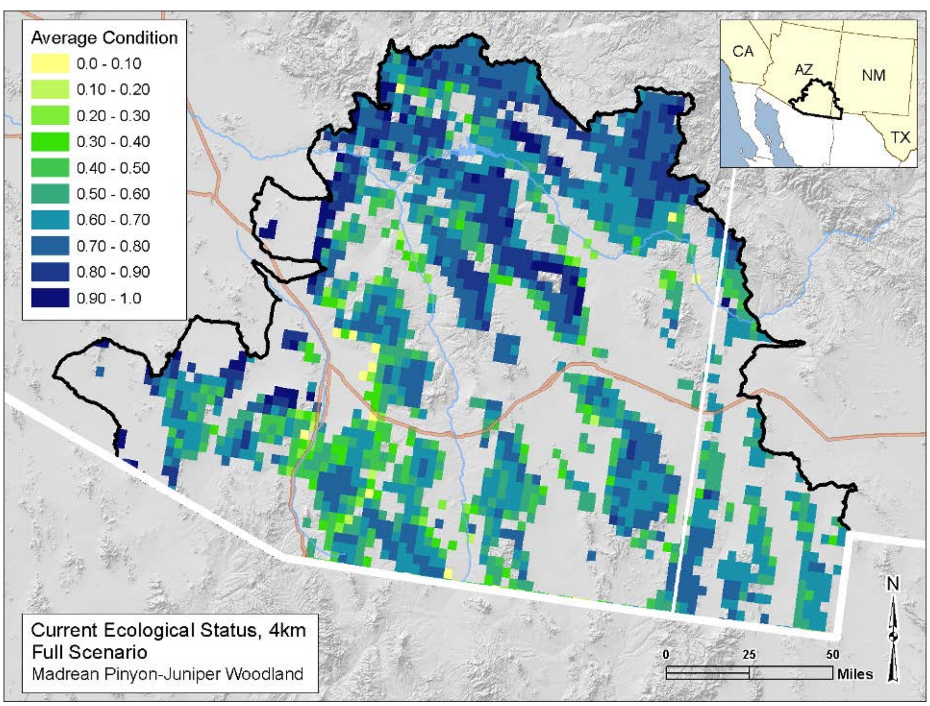
The invasive species indicator serves as an indirect measure of vegetation composition, by measuring the cover of invasive species. It includes a combination of non-native grass and forbs and native woody increasers (mesquite cover), as described previously in this appendix. The scoring is on a continuous scale from 0 to 1, with the highest score of 1.0 indicating no ecologically relevant cover of invasive species, and 0.0 indicating a conversion to non-native grasses and forbs and/or invasive mesquite. Table D-3 shows the cover classes used and the site intensity values for them, for this CE. The values range from 0.65 to 0.90. Either or both non-native invasive and native invasive woody cover may occur on in a single pixel. If both occur, then scores for that pixel are multiplied to create a new combined, lower indicator score.

The third map in Figure D-19 shows relatively moderate to high invasion of exotic grasses and forbs, and/or invasive mesquite in scattered areas of Madrean Pinyon-Juniper Woodland CE in the southern portion of the ecoregion. The northern portion has low cover of invasive species. This spatial result is supported by research documenting the results of fire exclusion in the MAR ecoregion. Active and passive fire suppression over the last century has excluded fire from much of this woodland (Gori and Bate 2007). In the absence of disturbance such as fire, the woody component increased in density over time and subsequent fires became more severe (Gori and Bate 2007, Swetnam and Baisan 1996, Turner et al. 2003). Although the effects of non-native species as a threat to Madrean Pinyon-Juniper Woodland ecosystem needs to be further investigated (Gori and Bate 2007), replacement of native vegetation with non-native grasses such as *Eragrostis lehmanniana, Eragrostis curvula*, and annual Bromes (*Bromus* spp.) may increase with burning as these species are better adapted to frequent fire and increase in relative abundance over native grasses after burning (Anable et al. 1992, Cable 1971, Gori and Bate 2007).

D-4.2.2 Current Ecological Status: Full Scenario

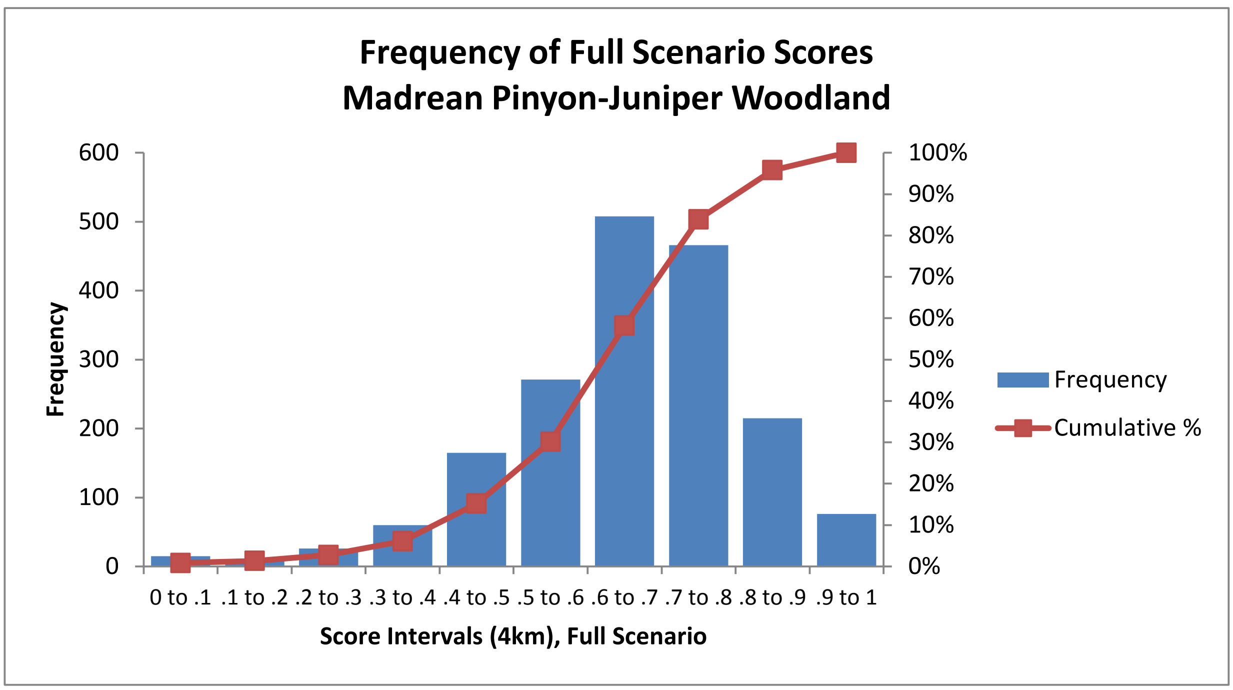
Figure D-29. Overall ecological status scores for Madrean Pinyon-Juniper Woodland for all indicators combined (development, fire regime and invasives) for each 30m pixel (top) and 4km grid cells (bottom). The score for each 4km cell is an average of all 30m pixels that are scored for the CE. Yellow scores (equivalent to 0) indicate high impacts from the CAs, dark blue (equivalent to 1) indicate little to no impact from the CAs.





The first map in Figure D-29 illustrates all three of the indicators combined into a single ecological status score per pixel of the CE's distribution. The combined, per-pixel status scores are noticeably lower than the individual scores for each indicator pixel indicator. The combined status scores for each pixel were summarized to the reporting unit (e.g., 4km grid) by taking the average status score from all the pixels of the CE within the reporting unit. The results, shown in the second map in Figure D-29 and in the frequency diagram (Figure D-30) indicate the widespread general degradation of the Madrean Pinyon-Juniper Woodland CE across its range in the ecoregion. The results are driven by severe departure in fire regime for the Madrean Pinyon-Juniper Woodland CE across the southern part of the MAR ecoregion. There are a few local areas of better ecological condition; a result low level of development, low or no cover of invasive species, and moderate fire regime departure. The map clearly shows better condition areas in the northern portion of the MAR ecoregion. However, because of these stands are generally at slightly higher elevation and occur on more publically owned lands, the cumulative percent of grid cells by scoring intervals (Figure D-30) is shifted towards slightly more cells in better condition; about 60% of the grid cells fall at or below the 0.7 score interval.

Figure D-30. Frequency distribution of the 4km ecological status scores for the Madrean Pinyon-Juniper Woodland, with cumulative percent. The x-axis represents the 0.1 increment scoring intervals, while the y-axis shows the number of grid cells in each interval (left) and the cumulative percentage of the grid cells for each interval (right). For this CE, most of the status scores fall in the range from 0.5 to 0.8.



D-4.3 References for the CE

Anable, M. E., M. P. McClaran, and G. B. Ruyle, 1992. Spread of introduced Lehmann lovegrass *Eragrostis lehmanniana* Nees. in southern Arizona, USA. Biological Conservation, 61, 181-188.

Bahre, C.J. 1991. A legacy of change: historic human impact on vegetation of the Arizona borderlands. The University of Arizona Press, Tucson, AZ.

Balda, R.P. 1987. Avian impacts on pinyon-juniper woodlands. In: Everett, R.L., compiler. Proceedings, pinyon-juniper conference; 1986 January 13-16; Reno, NV. General Technical Report INT-215. Ogden, UT: USDA Forest Service, Intermountain Research Station. Pp. 525-533.

Balda, R.P. and Bateman, G.C. 1971. Flocking and annual cycle of the Piñon jay *Gymnorhinus cyanocephalus*. Condor 73:287-302.

Barton, A.M. 1999. Pines versus oaks: effects of fire on the composition of Madrean forests in Arizona. Forest Ecology and Management, 120, 143-156

Belnap, J., J. Kaltenecker, R. Rosentreter, J. Williams, S. Leonard, and D. Eldridge. 2001. Biological soil crusts: Ecology and management. Technical Report 1730-2, United States Department of the Interior. 110 pp.

Betancourt, J.L., Peirson, E.A., Rylander, K.A., Fairchild-Parks, J.A., and Dean, J.S. 1993. Influence of history and climate on New Mexico pinyon-juniper woodlands. In: Aldon, E.F. and Shaw, D.W., eds. Managing Piñon-Juniper Ecosystems for Sustainability and Social Needs: Proceedings of the Symposium April 26-30, Santa Fe, New Mexico. Gen. Tech. Rep. RM-236, Fort Collins, CO: USDA Forest Service, Rocky Mountain & Range Experiment Station, p. 42-62.

Bock, C. E. and J. H. Bock 2002.Numerical response of grassland birds to cattle ranching versus exurban development in southeastern Arizona. 87th Annual Meeting of the Ecological Society of America and the 14th Annual International Conference of the Society for Ecological Restoration.

Bock, C.E. and J.H. Bock. 1982. Numerical response of grassland birds to cattle ranching versus exurban development in southeastern Arizona. 87th Annual Meeting of the Ecological Society of America and the 14th Annual International Conference of the Society for Ecological Restoration. 2002.

Brown, D. E., editor. 1982. Biotic communities of the American Southwest-United States and Mexico. Desert Plants Special Issue 4(1-4):1-342.

Cable, D. R. 1971. Lehmann lovegrass on the Santa Rita Experimental Range, 1937-1968. Journal of Range Management. 24: 17-21.

Christensen, K.M. and Whitham, T.G. 1993. Impact of insect herbivores on competition between birds and mammals for pinyon pine seeds. Ecology 74: 8:2270-2278.

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. Ecological systems of the United States: A working classification of U.S. terrestrial systems. NatureServe, Arlington, VA.

Comer, P. J., and J. Hak. 2009. NatureServe Landscape Condition Model. Technical documentation for NatureServe Vista decision support software engineering. NatureServe, Boulder, CO.

Comer, P., and J. Hak. 2012. Landscape condition model of the western United States. NatureServe, Boulder, CO. In preparation.

Cox, J. R., G. B. Ruyle, J. H. Fourle, and C. Donaldson. 1988. Lehmann lovegrass--central South Africa and Arizona, USA. Rangelands. 10(2): 53-55.

Davis, O.K. and R.M. Turner. 1986. Palynological evidence for the historic expansion of juniper and desert shrubs in Arizona. Review of Palaeobotany and Palynology. 49: 177-193.

Dick-Peddie, W. A. 1993. New Mexico vegetation: Past, present, and future. University of New Mexico Press, Albuquerque. 244 pp.

Faber-Langendoen, D., J. Rocchio, S. Thomas, M. Kost, C. Hedge, B. Nichols, K. Walz, G. Kittel, S. Menard, J. Drake, and E. Muldavin. 2012b. Assessment of wetland ecosystem condition across landscape regions: A multi-metric approach. Part B. Ecological Integrity Assessment protocols for rapid field methods (L2). EPA/600/R-12/021b. U.S. Environmental Protection Agency Office of Research and Development, Washington, DC.

Ffolliott, P.F., Rasmussen, W.O., Warfield, T.K., and Borland, D.S. 1979. Supply, demand, and economics of fuelwood markets in selected population centers of Arizona. Arizona Land Marks. 9(2): 1-74

Finch, D. M., editor. 2004. Assessment of Grassland Ecosystem Conditions in the Southwestern United States; Volumes 1 and 2. USDA Forest Service Gen. Tech. Rpt. RMRS-GTR-135. USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Floyd, M.L., D.D. Hanna, W.H. Romme, and T.E. Crews. 2006. Predicting and mitigating weed invasions to restore natural post-fire succession in Mesa Verde National Park, Colorado, USA. International Journal of Wildland Fire 15:247-259.

Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy. editors. 2013. Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment, A report by the Southwest Climate Alliance. Washington, DC: Island Press.

Gori, D. and J. Bate. 2007. Historical Range of Variation and State and Transition Modeling of Historical and Current Landscape Conditions for Pinyon-Juniper of the Southwestern U.S. Prepared for the U.S.D.A. Forest Service, Southwestern Region by The Nature Conservancy, Tucson, AZ. 141 pp.

Gori, D. F. and C. A. F. Enquist. 2003. An assessment of the spatial extent and condition of grasslands in central and southern Arizona, southwestern New Mexico and northern Mexico. The Nature Conservancy, Arizona Chapter. Pp29.

Gottfried, G.J. 1987. Regeneration of Pinyon. Everett, R. L., Compiler. Proceedings - Pinyon Juniper Conference. General Technical Report INT. 215. Ogden, UT: U.S. Dept. of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station: 249-254.

Gottfried, G.J. 1992. Pinyon-juniper woodlands in the southwestern United States. Pages 53-67 in: P. F. Ffolliott and A. Ortega-Rubio, editors. Ecology and Management of Forests, Woodlands, and Shrublands in Dryland Regions of the United States and Mexico: Perspectives for the 21st Century. Co-edition number 1. University of Arizona-Centro de Investigacione.

Gottfried, G.J. and Severson, K.E. 1993. Distribution and multi-resource management of pinon-juniper woodlands in the southwestern United States. In: Aldon, Earl F.; Shaw, Douglas W., tech. coords. Managing pinon-juniper ecosystems for sustainability and social needs; Santa Fe, NM. GTR-RM-236. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 108-116.

Gottfried, G.J., Swetnam, T.W., Allen, C.D., Betancourt, J.L., and Chung-MacCoubrey, A.L. 1995. Pinyon-Juniper Woodlands. In: Finch, D. M. and J. A. Tainter, eds. Ecology, diversity, and sustainability of the middle Rio Grande Basin. General Technical Report RM. 268. Ft. Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station: 95-132.

Heinz Center. 2011. Managing and Monitoring Arizona's Wildlife in an Era of Climate Change: Strategies and Tools for Success Report and Workshop Summary. Prepared for: U.S. Department of Interior. Bureau of Land Management and The Arizona Game and Fish Department by the H. John Heinz III Center for Science Economics and the Environment. January 13, 2011. Washington, D. C. 67 pp. plus appendices.

Johnsen, T.N. 1962. One-seed juniper invasion of northern Arizona grasslands. Ecological Monographs. The Ecological Society of America. 32(3): 187-207

Landis, A.G. and J.D. Bailey. 2005. Reconstruction of age structure and spatial arrangement of pinyon-juniper woodlands and savannas of Anderson Mesa, Arizona. Forest Ecology and Management. 204:221-236.

Ligon, J.D. 1978. Reproductive interdependence of pinon jays and pinon pines. Ecological Monographs. 48(2): 111-126.

Marshall, R.M., A.Turner, A. Gondor, D. Gori. C. Enquist, G. Luna, R. Paredes Aguilar, S. Anderson, S. Schwartz, C. Watts, E. Lopez, P. Comer. 2004. An ecological Analysis of Conservation Priorities in the Apache Highlands Ecoregion. Prepared by The Nature Conservancy of Arizona, Instituto del Medio Ambiente y el Desarrolla Sustentable del Estado de Sonora, agency and institutional partners. 152 pp.

McAuliffe, J. R., and T. R. Van Devender. 1998. A 22,000-Year Record of vegetation and climate change in the north-central Sonoran Desert. Palaeogeography, Paelaeoclimatology, Palaeobotany 141:253-275.

McClaran, M.P. and G.R. McPherson. 1999. Chapter 17, Oak Savanna in the American Southwest. Pages 275-287 in R.C. Anderson, J.S., Fralish and J.M. Baskin, editors. *Savannas, Barrens, and Rock Outcrop Plant Communities of North America*. Cambridge University Press, Cambridge, England.

McCulloch, C.Y. 1969. Some effects of wildfire on deer habitat in pinyon-juniper woodland. Journal of Wildlife Management. 33(4): 778-784.

McPherson, G.R. 1997. Ecology and management of North American savannas. The University of Arizona Press, Tucson, Arizona.

Mehringer, P.J., Jr. and P.E. Wigand. 1990. Comparison of late Holocene environments from woodrat middens and pollen: Diamond Craters, Oregon. In: Betancourt, J.L., Van Devender, T.R. and Martin, P.S., eds. Packrat middens: the last 40,000 years of biotic change, University of Arizona Press, Tucson. Pg. 13-16.

Milchunas, D.G. 2006. Responses of plant communities to grazing in the southwestern United States. Gen. Tech. Rep. RMRS-GTR-169. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 126 p.

Miller, R.F. and R.J. Tausch. 2001. The role of fire in juniper and pinyon woodlands: a descriptive analysis. Pages 15-30 in, K.E.M. Galley and T. P. Wilson, eds. Proceedings of the invasive species workshop: the role of fire in the control and spread of invasive species. Fire Conference. Miscellaneous Publication Number 11. Tallahassee, FL: Tall Timbers Research Station.

Moir, W. H., and J. O. Carleton. 1987. Classification of pinyon-juniper (P-J) sites on national forests in the Southwest. Pages 216-226 in: R. L. Everett, editor. Proceedings of the Pinyon-Juniper Conference, Reno, NV, 13-16 January 1986. General Technical Report. USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, UT. 581 pp.

Muldavin E., G. Bell, et al. 2002. Draft ecoregional conservation assessment of the Chihuahuan Desert. Pronatura Noreste. 87 pp.

Muldavin, E., Y. Chauvin, and G. Harper. 2000b. The vegetation of White Sands Missile Range, New Mexico: Volume I. Handbook of vegetation communities. Final report to Environmental Directorate, White Sands Missile Range. New Mexico Natural Heritage Program, University of New Mexico, Albuquerque. 195 pp. plus appendices.

NatureServe. 2013. International Ecological Classification Standard: International Vegetation Classification. Central Databases. NatureServe, Arlington, VA.

Pellant, M., P. Shaver, D.A. Pyke, and J.E. Herrick. 2005. Interpreting indicators of rangeland health, version 4. Technical Reference 1734-6. BLM/WO/ST-00/001+1734/REV05. U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center, Denver, CO. 122 pp.

Pickett, S.T.A., and J.N. Thompson. 1978. Patch dynamics and the size of nature reserves. Biological Conservation 13: 27-37.

Rogers T.J. 1993. Insect and disease associates of the pinyon-juniper woodlands. In Preceedings: Managing pinyon-juniper ecosystems for sustainability and social needs. Comps Aldon E.F., Shaw D.W., 124-125. USDA Forest Service, Rocky Mountain Research Station, General Technical Report RM -236. Fort Collins, CO

Rogers, T.J. 1995. Insect and disease associates of the pinon-juniper woodlands. Pages 107-108 in D.W. Shaw, E.F. Aldon, and C. LoSapio, tech. coords., Desired future conditions for pińon-juniper ecosystems; Flagstaff, AZ. GTR-RM-258. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station:

Romme, W.H., L. Floyd-Hanna, and D.D. Hanna. 2003. Ancient pinon-juniper forests of Mesa Verde and the west: a cautionary note for forest restoration programs. Pages 335-350 in, P.N. Omi and L.A Joyce, tech. eds., Fire, fuel treatments, and ecological restoration: Conference proceedings; Fort Collins, CO. RMRS-P-29. Fort Collins, CO: USDA Forest Service, RMRS.

Salomonson, M.G. 1978. Adaptations for animal dispersal of one-seed juniper seeds. Oecologia 32:333-339.

Short, H.L., W. Evans, and E.L. Boeker. 1977. The use of natural and modified pinyon-juniper woodlands by deer and elk. Journal of Wildlife Management 41:543-559.

Short, H.L. and C.Y. McCulloch. 1997. Managing pinyon-juniper ranges for wildlife. General Technical Report RM-47. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. 10 p.

Swetnam, T.W., C.D. Allen, J.L. Betancourt. 1999. Applied historical ecology: using the past to manage for the future. Ecological Applications 9(4):1189-1206.

Swetnam, T. W. and C.W. Baisan. 1996. Historical fire regime patterns in the southwestern United States since AD 1700. Pages 11-32 in, C.D. Allen, ed. Fire effects in Southwestern Forests: Proceedings, 2nd La Mesa fire symposium. March 29-311994: Los Alamos, NM. General Technical Report RM-GTR-286. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station.

Turner, R.M., R.H. Webb, J.E. Bowers, and J.R Hastings. 2003. The changing mile revisited An ecological study of vegetation change with time in the lower mile of an arid and semiarid region. University of Arizona Press, Tucson, Arizona.

Unnasch, R.S., D. P. Braun, P. J. Comer, G. E. Eckert. 2009. The Ecological Integrity Assessment Framework: A Framework for Assessing the Ecological Integrity of Biological and Ecological Resources of the National Park System**.** Report to the National Park Service. 46 pp.

USDA-NRCS. 2014. Selected Approved Ecological Site Descriptions for Major Land Resource Area 041-Southeastern Arizona Basin and Range. US Department of Agriculture. Natural Resource Conservation Service. Website accessed September 2014. https://esis.sc.egov.usda.gov/Welcome/pgApprovedSelect.aspx?type=ESD

USDA-USFS [U.S. Forest Service]. 2009. Ecological sustainability report. Coronado National Forest. United States Department of Agriculture. Forest Service. Southwest Region. February 2009. Pp. 118.

USDI-BLM [U.S. Bureau of Land Management]. 2006. 43CFR4180.1 Fundamentals of Rangeland Health. Code of Federal Regulations and Federal Register, Accessed February 2013 http://federal.eregulations.us/cfr/section/2006/04/18/43-cfr-4180.1

Van Devender, T.R. 1977. Holocene woodlands in the southwestern deserts. Science. 198(4313): 189-192.

Van Devender, T.R. 1990. Late Quaternary vegetation and climate of the Chihuahuan Desert, United States and Mexico. In: Betancourt, J.L., Van Devender, T.R. and Martin, P.S., eds. Packrat middens: the last 40,000 years of biotic change, University of Arizona Press, Tucson, AZ. Pp. 104-133.

Vander Wall, S.B. and R.P. Balda. 1977. Coadaptations of the Clark's Nutcracker and the Pinon Pine for efficient seed harvest and dispersal. Ecological Monographs. The Ecological Society of America. 47(1): 89-111.

Weber, D.J., E.D. Bunderson, J.N. Davis, D.L. Nelson, and A. Hreha. 1999. Diseases and environmental factors of the pinyon-juniper communities. In: S.B. Monsen, and R. Stevens, eds. Proceedings: ecology and management of pinyon juniper communities within the interior West; Provo, UT. RMRS-P-9. Ogden, UT: United States Department of Agriculture Forest Service RMRS: 118-120.

Wilson, J.L. and B.M. Tkacz. 1992. Pinyon ips outbreak in pinyon juniper woodlands in northern Arizona: a case study. Pages 187-190 I in: Ffolliott, P.F. G.J. Gottfried, and D.A. Bennett and others, tech. coords. Ecology and management of oak and associated woodlands: perspectives in the southwestern United States and northern Mexico. Proceedings; 1992 April 27-30; Sierra Vista, AZ. General Technical Report RM-218. Fort Collins, CO: USDA Forest Service, Rocky Mountain and Range Experiment Station.

Montane Shrublands

D-5 Mogollon Chaparral Ecological System

D-5.1 Conceptual Model

D-5.1.1 Classification

The ecosystem conservation elements for the MAR REA were selected from NatureServe's classification of terrestrial ecological systems (Comer et al. 2003). Over three dozen ecological systems occur in the MAR, but only a select subset were chosen for the REA. The CE concept provided in this conceptual model includes this NatureServe ecological system type:

- Mogollon Chaparral (CES302.741)

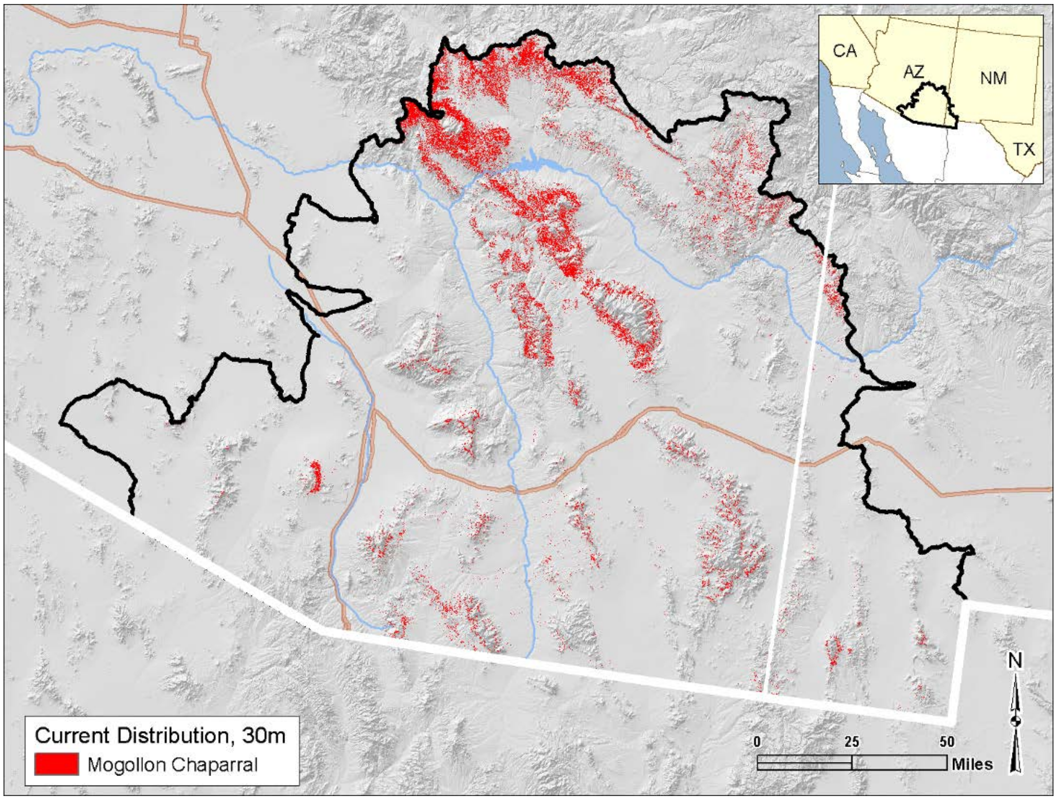
There are other terrestrial ecological systems in the NatureServe classification that also occur in the MAR, or in adjacent ecoregions, which are similar to this CE concept but are not included in this conservation element. These are listed here to help the reader understand what is not included in this conceptual model; each of these other ecological systems has information that can be searched for and reviewed on NatureServe's on-line Explorer website (http://explorer.natureserve.org/servlet/NatureServe). The System Code beginning with CES (Community Ecological System) is an information rich database code that refers to the North American Ecological Division (302) where the system primarily occurs and the number used to identify the system (Comer et al. 2003).

- Rocky Mountain Gambel Oak-Mixed Montane Shrubland (CES306.818); possibly in northern extent of MAR
- Rocky Mountain Lower Montane-Foothill Shrubland (CES306.822); possibly in northern extent of MAR
- Apacherian-Chihuahuan Semi-Desert Grassland and Steppe (CES302.735); heavily managed, degraded or seral chaparral might be similar to the grassland system

D-5.1.2 Summary

This chaparral ecosystem occurs across central Arizona (the Mogollon Rim), western New Mexico, and southern Utah and Nevada (Figure D-31). It often dominates along the mid-elevation transition from the Mojave, Sonoran, and northern Chihuahuan deserts into the mountains (1000-2200 m elevation). It occurs on foothills, mountain slopes and canyons in hotter and drier habitats below the oak woodlands (encinal) and *Pinus ponderosa* woodlands. Sites are often associated with more xeric and coarse-textured substrates and are often steep and rocky. Parent materials are varied and include basalt, diabases, gneiss, schist, shales, slates, sandstones and, more commonly, limestone and coarse-textured granitic substrates.

Figure D-31. Distribution of Mogollon Chaparral at 30m resolution. The distribution was derived from the NatureServe (2013) terrestrial ecological systems map. Appendix G (ecological integrity) has a table listing the areal extent of this ecological system and its % of the assessment area.



Adjacent ecosystems may include Madrean Pinyon-Juniper Woodland (CES305.797), Madrean Encinal (CES305.795), and Madrean Lower Montane Pine-Oak Forest and Woodland (CES305.796) at higher elevations and Apacherian-Chihuahuan Semi-Desert Grassland and Steppe (CES302.735), Chihuahuan Mixed Desert and Thornscrub (CES302.734), Apacherian-Chihuahuan Mesquite Upland Scrub (CES302.733), and Madrean Juniper Savanna (CES305.730), at lower elevations. The environmental description is based on several references, including Carmichael et al. 1978, DeBano (1999), Dick-Peddie (1993), Muldavin et al. (2000b), Pase and Brown (1982), Schussman (2006c), and NatureServe Explorer (2013).

The vegetation in this ecosystem (Figure D-32) is characterized by a moderately to highly dense, evergreen shrub canopy frequently of *Quercus turbinella,* or can be dominated or co-dominated by *Quercus toumeyi, Cercocarpus montanus, Canotia holacantha, Ceanothus greggii, Eriodictyon angustifolium, Garrya flavescens, Garrya wrightii, Mortonia scabrella, Purshia stansburiana, Arctostaphylos pungens* and at higher elevations *Arctostaphylos pringlei*. Additional short shrubs may form a subcanopy such as *Amelanchier utahensis, Coleogyne ramosissima, Ephedra viridis, Dasylirion wheeleri, Rhus ovata,* or *Rhus trilobata* (Pase and Brown 1982, Carmichael et al. 1978). Scattered remnant pinyon and juniper trees may be present. Occasional desert scrub species may be present in drier, rockier, or more open transition sites. Canopy density varies widely depending on time since last fire, soil depth and soil moisture (DeBano 1999). The herbaceous cover is often low or absent because of shading and other factors, but can form a layer composed of *Bouteloua curtipendula, Bouteloua eriopoda,* or *Muhlenbergia pauciflora* especially in the spaces between shrubs in more open stands. Most chaparral species are fire-adapted, resprouting vigorously after burning or producing abundant fire-resistant seeds Stands occurring within montane woodlands are seral and a result of recent fires. The vegetation description is based on several references, including Carmichael et al. (1978), DeBano (1999), Dick-Peddie (1993), Muldavin et al. (2000b), Pase and Brown (1982), Schussman (2006c), and NatureServe Explorer (2013).

Figure D-32. Mogollon Chaparral ecosystem (source http://www.azfirescape.org)

A crosswalk of this system to USDA Natural Resource Conservation Service (NRCS) approved Ecological Site Descriptions (ESD) by Major Land Resource Areas (MLRA) is provided in Table D-20 (USDA-NRCS 2014). For complete list of ESDs for MLRA 41 see https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD.)

Table D-20. Mogollon Chaparral ecosystem CE crosswalk with approved Ecological Site Descriptions (provisional cross-walk).

MLRA	Ecological Site Description Name	Site ID
041-Southeastern Arizona Basin and Range	Limestone Hills 16-20" p.z. / *Vauquelinia californica* / *Agave palmeri* - *Cercocarpus montanus* / *Bouteloua curtipendula* - *Tridens muticus* (Arizona rosewood / Palmer's century plant - alderleaf mountain mahogany / sideoats grama - slim tridens)	R041XA 103AZ

D-5.1.3 Species of Conservation or Management Concern

According to Arizona's State Wildlife Action Plan: 2012-2022 (AGFD 2012), "Most wildlife species that occur in chaparral are widespread and common, and Species of Greatest Conservation Need (SGCN) that occupy chaparral also occur in woodland or grassland habitats where chaparral meets those communities at its upper elevation limits, or in desertscrub at lower elevations; examples include Arizona night lizard *(Xantusia arizonae)*, western red-tailed skink (*Plestiodon gilberti rubricaudata)*, and black-chinned sparrow (*Spizella atrogularis*)."

Reynolds and Johnson (1964) listed 83 species of vertebrates from the chaparral type in Sierra Ancha Experimental Forest, which is the northern extent of the Sky Island Archipelago ecoregion. Below is a short list of vertebrate species from the state wildlife action plan Species of Greatest Conservation Need that Reynolds and Johnson (1964) reported as occurring in chaparral on the Sierra Ancha Experimental Forest in the 1960's. Additionally, the Coronado National Forest Ecological Sustainability Report (USDA-USFS 2009) lists one species in their Threaten-Endangered Species/Species of Concern/Species of Interest (TE/SOC/SOI) species associations with Interior Chaparral, the Ball's Monkey Grasshopper (*Eumorsea balli*).

Birds: Montezuma Quail (*Cyrtonyx montezumae*), Elf Owl (*Micrathene whitneyi*), Hooded Oriole (*Icterus cucullatus*),

Mammals: Arizona Gray Squirrel (*Sciurus arizonensis*), Mexican Free-tailed Bat *(Tadarida brasiliensis)*

Reptiles: Gila Monster (*Heloderma suspectum*)

Invertebrates: Ball's Monkey Grasshopper (*Eumorsea balli*).

D-5.1.4 Natural Dynamics

The Nature Conservancy did a review of the Historical Range of Variation for the Interior Chaparral (Schussman 2006c) and their work relates directly to the Mogollon Chaparral CE and is a primary source for this section. The Mogollon Chaparral ecosystem is complex with diverse species composition and dominance under natural conditions (Carmichael et al. 1978, DeBano 1999, Pase and Brown 1982, Schussman 2006c). Under historical natural conditions (also called natural range of variability, NRV), stands range from open to dense cover of shrubs (depending on time since last stand replacing fire and site variables that restrict shrub growth). This ecosystem appears relatively stable as most dominant shrubs have the ability to recover quickly from fire, either re-sprouting or regenerating from fire scarified seeds (DeBano 1999). Carmichael et al. (1978) suggest that chaparral species' deep, well developed root system facilitates rapid sprouting post fire. In the case of non-sprouting chaparral shrubs such as *Arctostaphylos pringlei* and *Ceanothus* species, the seeds require heat scarification to germinate and will accumulate in the seed bank until a burn treats the seeds and creates a flush of germination (Carmichael et al. 1978). However, too frequent, repeated fires can deplete the seed bank for these species. Additionally, Davis and Dieterich (1976) report that most chaparral only burns well when rate of spread is 20 feet per minute or greater so some wind or slope is necessary for it to burn.

Fire characteristics of interior chaparral are typically medium to high intensity, stand replacing crown fires that occur during summer – fall seasons. They range from medium to very high severity fires that generally top kill most re-sprouting shrubs and kill non-sprouting shrubs (Carmichael et al. 1978, Pase and Brown 1982). Cable (1975) suggests that at least 20 years recovery post-fire is necessary for most stands to burn again. Pase and Brown (1982) suggest a Fire Return Interval between 50-100 years, whereas Wright and Bailey (1982) suggest a FRI of 20-80 years. Based on these sources using a FRI range of 20-100 years seems reasonable.

Herbivory by native herbivores in the Mogollon Chaparral is relatively minor with the exception of mule deer (*Odocoileus hemionus)* and to a lesser extent white-tailed deer (*Odocoileus virginianus)* browsing. Deer eat a variety of forbs, dwarf-shrubs and shrubs (such as *Cercocarpus montanus* and *Garrya wrightii)*, as well as acorns and other fruits (Baker 1999, Cable 1975). Black bears are also key herbivores in interior chaparral and also target acorns and other fruits (Baker 1999). Significant grazing is mostly limited to the more open early seral chaparral stands, as the more common mid to late seral stands have dense canopies with little understory (Cable 1975). Information on invertebrates was not readily available for this CE.

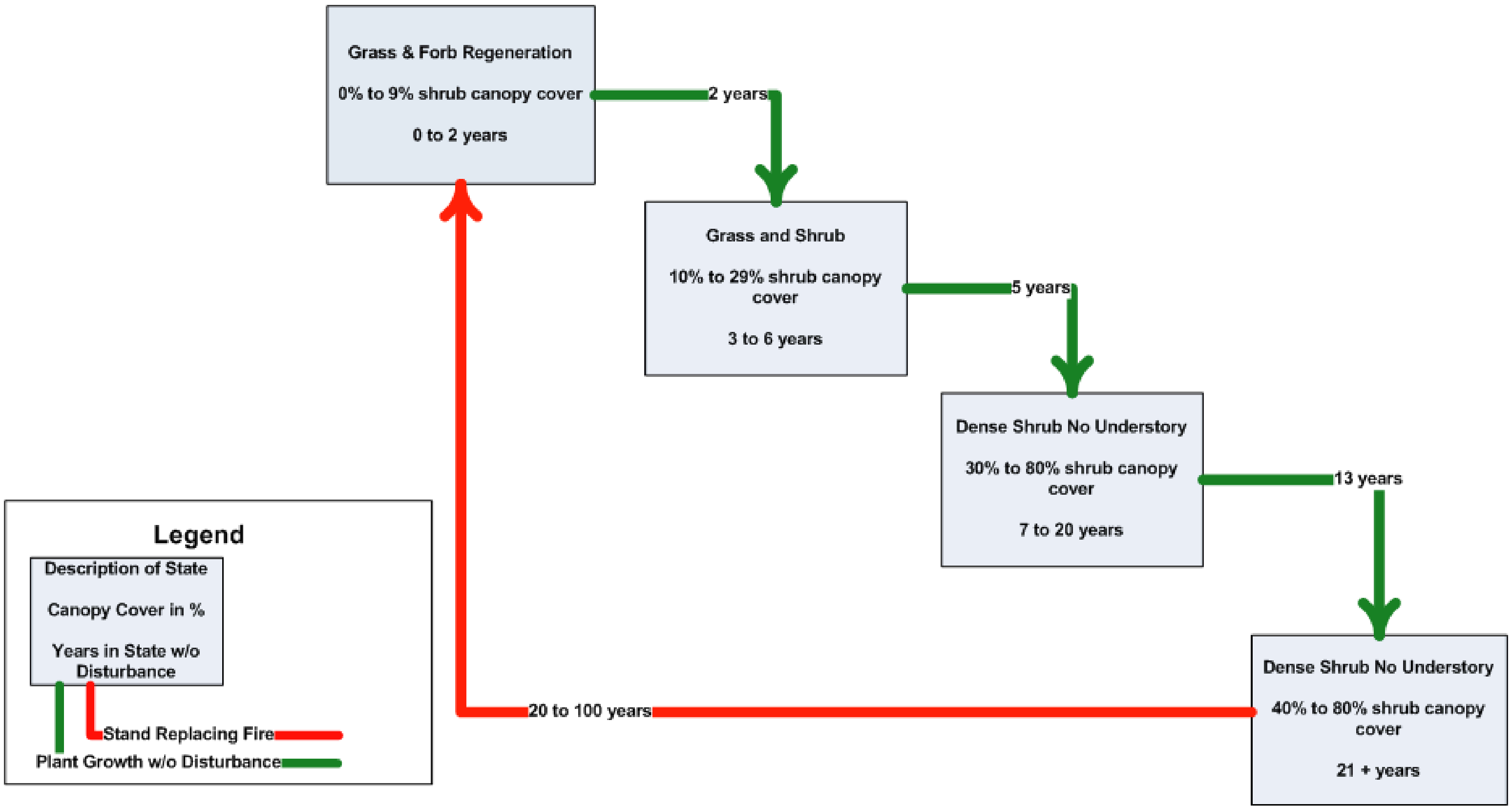
A good condition/proper functioning interior chaparral is large and uninterrupted, the surrounding landscape is also in good condition; the biotic condition is within normal range of variation, the weeds are few, the native plants are robust, have expected abundance and reproduction; birds, mammals, reptiles, insects and amphibian species present are indicative of reference, un-molested conditions; the fire regime is functioning at near historical conditions with FRI (fire return interval) of stand replacing fires every 20 to 100 years; soils have not been excessively eroded.

A poor condition/non-functioning ecosystem is highly fragmented, or much reduced in size from its historical extent; the surrounding landscape is in poor condition either with highly eroding soils, many non-native species or a large percentage of the surrounding landscape has been converted to pavement or highly maintained agriculture (row crops, irrigated crops, etc.); the biotic condition is at the limit or beyond natural range of variation, e.g. vegetation composition is altered and lacks non-sprouting chaparral shrubs such as *Arctostaphylos pringlei* and *Ceanothus* species that require occasional fire to cause heat scarification of seed. Highly palatable species such as *Cercocarpus montanus* and *Garrya wrightii*, have been eliminated by excessive browsing by native or non-native species. Characteristic birds, mammals, reptiles, and insect species are not present at expected abundances or the ratio of species shows an imbalance of predator to prey populations; abiotic condition is poor with evidence of high soil erosion, rill and gullies present or exposed soil sub horizons.

D-5.1.4.1 Natural Dynamics Model

A conceptual historical state-and-transition model was developed by a team of ecologists (Schussman 2006c) using the Vegetation Dynamics Development Tool (VDDT) to model the Interior Chaparral vegetation type (for details on tool see http://essa.com/tools/vddt/). For methods on modeling please see Schussman (2006c). We were able to use their model to represent the Mogollon Chaparral ecosystem CE because the two types represent the same vegetation (Figure D-33).

Figure D-33. Conceptual state and transition model of historical conditions for the Interior Chaparral vegetation type. This model was taken directly from Schussman (2006c). Frequency of transitions are noted when this information is supported by published sources, where no or conflicting information exists on the frequency of transitions, unknown is the notation. Note that under the Natural Dynamics model, the FRI for stand replacing fire is 30-100 years (Schussman 2006c).



D-5.1.5 Change Agent Effects on the CE

This section of the conceptual model presents a narrative description of the primary change agents and current knowledge of their effects on the Mogollon Chaparral ecosystem. The section contains two sub-sections: (1) A list of primary change agents identified for the CE; and (2) a discussion of altered dynamics caused by these agents.

D-5.1.5.1 List of Primary Change Agents

Occurrences of this shrubland ecological system are directly affected by livestock grazing, direct and indirect wildfire suppression activities, land development, and non-native plant species invasion. Table D-21 identifies the most likely impacts associated with each of these stressors.

Table D-21. Stressors and their likely impacts on the Mogollon Chaparral ecosystem CE in the Madrean Archipelago ecoregion.

Stressor	Impacts
Land Use	
Livestock browsing	Browsing of native vegetation by livestock such as goats at incompatible stocking rates, season of use, or duration can be detrimental and create sacrifice areas as well as degrade forage for native ungulates such as deer (Severson and Debano 1991).
Habitat Conversion to grassland	Habitat conversion to grassland for forage production occurs with repeated prescribed burning. For several years after burning changes in dynamics occur such as increased water yield (Davis 1989, Hibbert et al. 1974), greater nitrate concentrations in streams (Davis 1989), and increased erosion and stream sedimentation (Heede et al. 1988).
Recreation	This mostly relates to off road vehicle use, which creates additional roads and trails that fragment occurrences and contribute to increased soil erosion and compaction and non-native species dispersal (USDA-USFS 2009).
Development	
Transportation infrastructure Roadways/railways and transmission lines	Fragmentation from transportation infrastructure leads to disruptions in ecological processes such as fire, dispersal of invasive non-native species, and can alter hydrological processes when excessive runoff from roads creates gullies. Additionally, destruction of wildlife habitat and disruption of wildlife migration patterns can also occur (Bahre 1991, Bock and Bock 2002, Heinz Center 2011, Marshall et al. 2004).
Suburban/Rural (include Military), Mines/Landfill	This stress contributes to altered fire regimes, increased erosion, direct habitat loss/conversion, increased groundwater pumping, fragmentation, invasive non-native species dispersal and disruption of wildlife migration patterns (Bahre 1991, Gori and Bate 2007).
Energy (Renewable wind/solar), Oil/Gas	This stress contributes to altered fire regimes, increased erosion, direct habitat loss/conversion, fragmentation, invasive non-native species dispersal and disruption of wildlife migration patterns.

Stressor	Impacts
Uncharacteristic Fire Regime	Intensive fire management (both suppression, but more often repeated prescribed burning) causes changes in species composition (Carmichael et al. 1978, Pond and Cable 1960, Schussman 2006c). However, because the natural fire return interval is relatively long for interior chaparral (20-100 years), most stands are still within or near the natural fire return interval even with fire suppression the last one hundred years (Cable 1975, Pase and Brown 1982, USDA-USFS 2009, Wright and Bailey 1982). During the time it takes for chaparral shrub cover to recover post stand replacing fire there are temporary changes such as increased water yield (Davis 1989, Hibbert et al. 1974), greater nitrate concentrations in streams (Davis 1989) increased erosion and stream sedimentation (Heede et al. 1988). Fire suppression has led to larger patch sizes and longer fire intervals; however, that is now being coupled with potentially increased frequency of fires and less predictable behavior because of changing weather patterns (i.e. Yarnell fire).
Climate change	Alteration of precipitation and evapotranspiration rates and timing, may result in more frequent drought periods and higher intensity precipitation events, which following drought can cause significant erosion of topsoil (Garfin et al. 2012).

D-5.1.5.2 Altered Dynamics

Altered dynamics are not a large issue with interior chaparral as it is a stable vegetation type with robust ecological dynamics and appears resistant to anthropogenic disturbance. The majority of chaparral species have the ability to quickly re-sprout following disturbance events (Cable 1975, Pond and Cable 1960).

The impact of livestock grazing by cattle is relatively small because cattle use is limited to lower elevation, less steep, and more open slopes (Pase and Brown 1982), and much of this type occurs on steep slopes (Pase and Brown 1982). However, the livestock accessible sites were heavily grazed, between 1880 and 1920 (Pase and Brown 1982).

Additionally, given a natural fire return interval of 20-100 years for interior chaparral, most stands are still within or near the natural fire return interval even with fire suppression the last one hundred years. With continued fire suppression, a reduced abundance of fire dependant obligate seeders such as *Arctostaphylos pringlei* and *Ceanothus* species is predicted because they will be unable to regenerate (Carmichael et al. 1978). These robust ecological dynamics have allowed chaparral to maintain or increase its dense canopy cover regardless of human disturbance. However, fire suppression has led to larger patch sizes and longer fire intervals that are now being coupled with potentially increased frequency of fires and less predictable behavior because of changing weather patterns (i.e. Yarnell fire).

During 1950's - 1980's researchers spent 30 years attempting to convert these shrublands to grasslands for forage production for livestock and wildlife, to increase water yield, and reduce fire hazard (Cable 1975). These efforts were generally unsuccessful (Schussman 2006c). Researchers removed shrubs using prescribed fire and mechanical or chemical treatments, but the effects of the treatments did not last long (Schussman 2006c). Pond and Cable (1960) found that while using repeated burning did not kill the dominant shrub, *Quercus turbinella,* some species such as *Garrya wrightii* and *Rhamnus crocea* were killed after two years of repeated burning, reducing the diversity of the shrub layer.

Seeding of non-native grass species such as *Eragrostis lehmanniana* and *Eragrostis curvula* for forage production after shrub removal did not last as they were shaded out as shrubs re-grew to moderate to dense shrub canopy (Hibbert et al. 1974). So while non-native perennial grasses may be present, they do not dominate areas or effectively change chaparral vegetation or ecological processes as in some other ecosystems, such as the semi-desert grasslands (Hibbert et al. 1974).

Goats were also used in studies to convert shrublands to grasslands. Although goats were effective in reducing shrub cover, they over-used some area creating sacrifice areas and overused the forage most palatable to deer (*Cercocarpus montanus* and *Garrya wrightii*; Knipe 1983, Severson and DeBano 1991). Continued browsing by goats is thought to reduce and eliminate these nutritionally important species making the area unsuitable for both livestock and deer (Severson and DeBano 1991). During the seven or so years for the chaparral shrub cover to recover to pre-treatment levels, researchers also documented temporary changes such as increased water yield (Davis 1989, Hibbert et al. 1974), greater nitrate concentrations in streams (Davis 1989), and increased erosion and stream sedimentation (Heede et al. 1988).

D-5.1.5.3 Altered Dynamics Model

A conceptual state-and-transition model representing current conditions was developed by a team of ecologists (Schussman (2006c) using the Vegetation Dynamics Development Tool (VDDT) to model the Interior Chaparral native vegetation type (for details on tool see http://essa.com/tools/vddt/). The modelers identified a wide range of mechanical, chemical, and fire treatments for interior chaparral vegetation from multiple studies, conducted primarily within the Tonto National Forest. They decided not to model separate treatments in the regional current model because treatment type was variable and occurred on a relatively small portion of interior chaparral within Arizona and New Mexico. This model includes additional altered states (dominance of Lehman's lovegrass, increased cover of shrubs beyond acceptable ranges, and a degraded eroded state after loss of ground cover) as well as changes in the transitions from the above NRV. For methods on modeling please see Schussman (2006c).

We were able to use this model for Mogollon Chaparral ecosystem CE because the two types represent the same vegetation (Figure D-34 and Figure D-35).

Figure D-34. Conceptual state and transition model of current conditions for the Interior Chaparral vegetation type. This model was taken directly from Schussman 2006c. Frequency of transitions are noted when this information is supported by published sources; where no or conflicting information exists on the frequency of transitions, unknown or variable, respectively, is the notation. Note that under the Altered Dynamics model, the FRI for stand replacing fire has increased to 500-1000 years because of fire suppression. The treatments include a variety of mechanical, chemical, and fire treatments used on chaparral (Schussman 2006c).

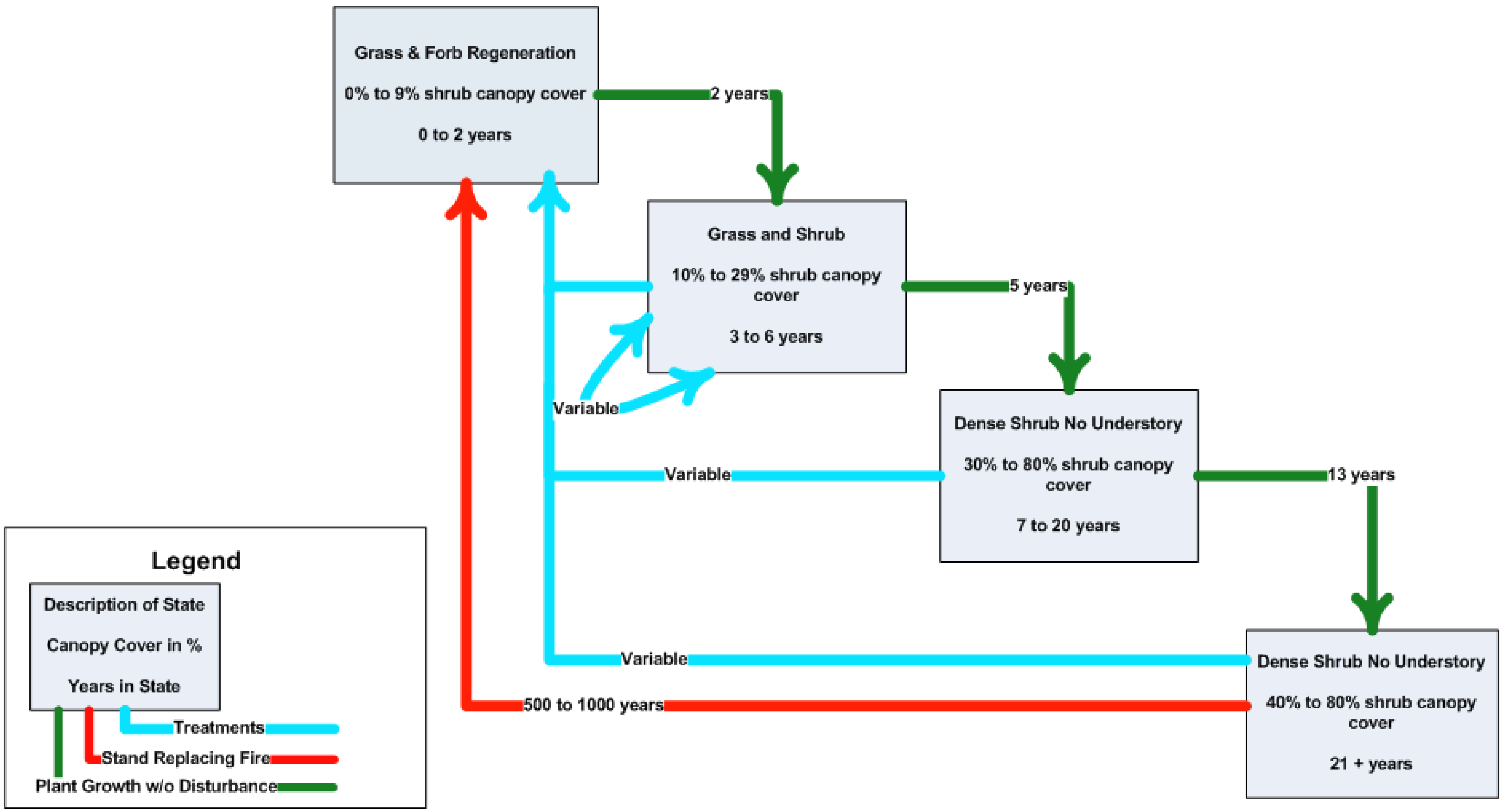
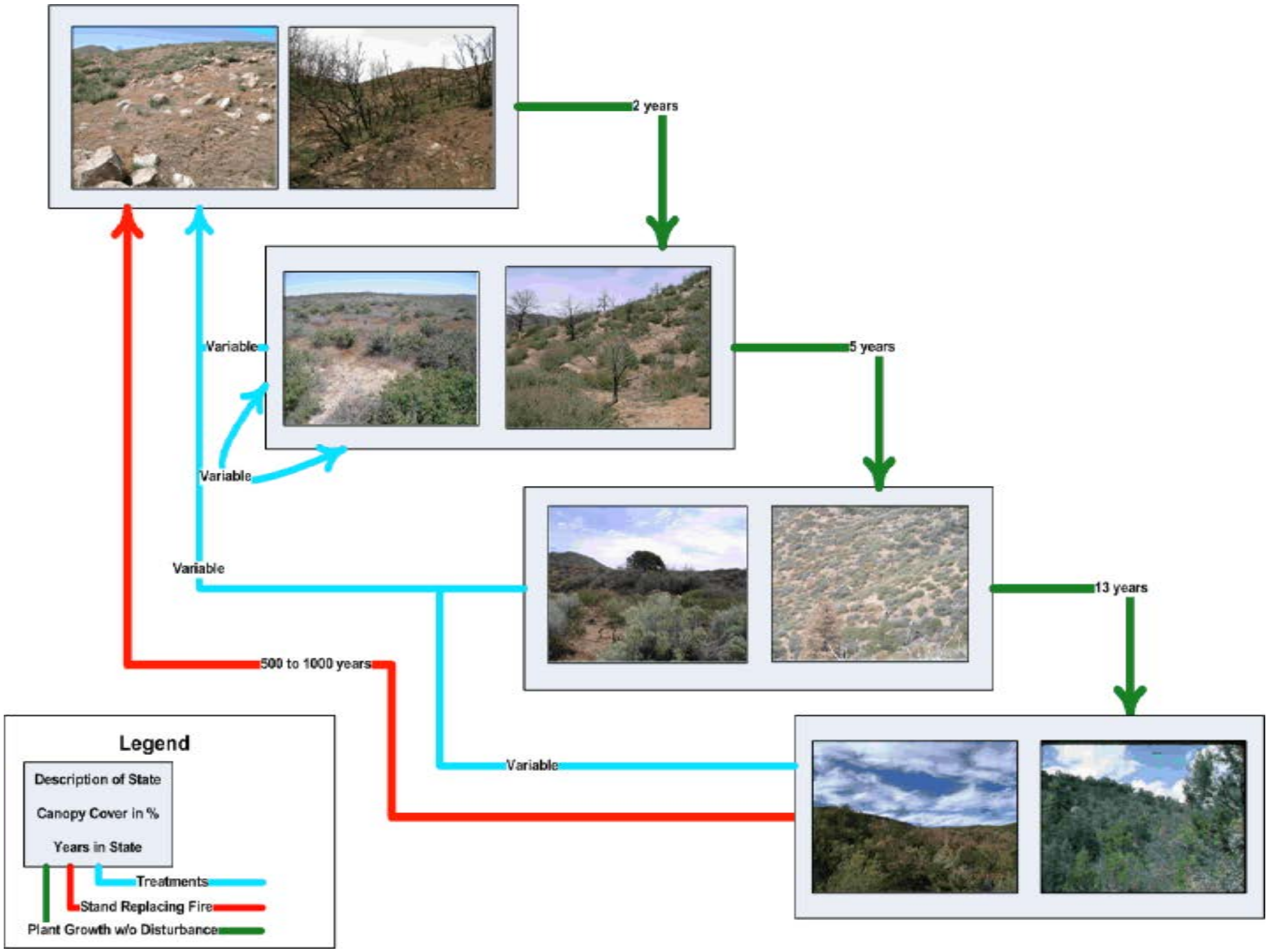


Figure D-35. Photographic depiction of conceptual state and transition model of current conditions for the Interior Chaparral vegetation type
This model was taken directly from Schussman 2006c. Frequency of transitions are noted when this information is supported by published sources; where no or conflicting information exists on the frequency of transitions, unknown or variable, respectively, is the notation. Bottom photographs courtesy of Jeff Saroka (USFS). Note that under the Altered Dynamics model, the FRI for stand replacing fire has increased to 500-1000 years because of fire suppression. The treatments include a variety of mechanical, chemical, and fire treatments used on chaparral (Schussman 2006c).



D-5.1.6 Ecological Status: Key Ecological Attributes and Indicators

This section of the conceptual model addresses Key Ecological Attributes and their potential indicators. The ecological status is a way of describing current status via criteria, functionality, or levels of attributes and asks if they are within the normal range of variation.

D-5.1.6.1 Key Ecological Attributes

Table D-22 identifies the key ecological attributes for the CE within the Madrean Archipelago ecoregion. A **key ecological attribute** of a focal ecological resource is a characteristic of the resource's biology, ecology, or physical environment that is critical to the resource's persistence in the face of both natural and human-caused disturbance. Alteration of such a characteristic beyond some critical range of variation will lead to the degradation or loss of the resource within decades or less. The KEAs table lists the identified key ecological attributes, with a brief definition, a rationale for why it is important for the CE, and a listing of stressors or change agents that might be affecting the key attribute.

Table D-22. Key Ecological Attributes (KEA) of Mogollon Chaparral ecosystem CE in the Madrean Archipelago ecoregion. Indicators for these KEAs can be used to determine the ecological status for this CE; see **Table D-2** for a list of the indicators assessed in this REA.

KEA Class: **Name**	**Definition general**	**Rationale general**	**Stressors general**
Landscape Context: **Landscape Condition**	This attribute is the amount of anthropogenic disturbance of the ecosystem that can be identified using a Land Condition Model Index (LCM). It incorporates a number of development features (including roads, urban/rural areas, agriculture, mines, transmission corridors, and energy development) that degrade the condition of the landscape.	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance (Comer and Hak 2009)	Stressors to landscape condition include multiple sources of fragmentation (reduces connectivity) that alter ecological processes (e.g., fire or surface hydrology), degrade wildlife habitat and disrupt wildlife migration patterns by creating barriers to species movement. Stressors include livestock grazing (reduces fine fuel that carry fire), urban and exurban development, and road building.
Size/Extent: **Patch Size Distribution**	The distribution of patch sizes (number and size class frequency) is a measure of fragmentation in this historically matrix or large patch ecosystem. Historical patch size/frequency is compared with current patch size/frequency.	This attribute is used to evaluate level of ecosystem fragmentation that interferes with landscape scale ecological processes. The current average patch size and total number of patches of the type are compared to earlier conditions where data are available.	Stressors include conversion to agriculture/pasture, commercial/industrial/residential use and construction of transportation infrastructure - roads, pipelines, transmission lines - that interfere with large-scale ecological processes such as fire or surface hydrology.

KEA Class: Name	Definition general	Rationale general	Stressors general
Size/Extent: **Ecosystem "Occurrence" Extent**	The area necessary to maintain ecological processes and ensure persistence is an ecosystem's minimum dynamic area (Pickett and Thompson 1978). Ecosystems with patch sizes above the minimum dynamic area (MDA) tend to exhibit vegetation structure and composition, landscape scale ecological processes, and soil and hydrology that are functioning within the natural range of variation. Fragmentation from roads and subdivisions has reduced the size of many patches so that the fire regime cannot be restored to pre-1882 frequency without management action i.e., prescribed fire. The MDA to maintain the fire regime under the historical range of natural variation for this ecological system needs to be determined.	The area necessary to maintain ecological processes and ensure persistence is an ecosystem's minimum dynamic area (Pickett and Thompson 1978). Ecosystems with patch sizes above the minimum dynamic area (MDA) tend to exhibit vegetation structure and composition, landscape scale ecological processes, and soil and hydrology that are functioning within the natural range of variation. However, the role of patch size in assessing ecological integrity is complex and related to the larger landscape context. Fragmentation from roads and subdivisions has reduced the size of many patches so that the fire regime cannot be restored to pre-1882 frequency without management action i.e., prescribed fire. The MDA to maintain the fire regime (or any natural disturbance regime) under the historical range of natural variation for this ecological system has not been determined. Little empirical study has been done in ecosystems outside of eastern forests to determine the MDA; Faber-Langendoen et al. (2012b) developed criteria for rating patch size based on the spatial patterning of the ecosystem (i.e., matrix, large patch, small patch, or linear) and provide a discussion of the protocol for assessing size/extent.	Stressors to ecosystem extent include actions such as development and fire exclusion that directly or indirectly convert the ecosystem to other land uses or cover types, or actions such as roads that fragment large patches into many small patches.

KEA Class: **Name**	**Definition general**	**Rationale general**	**Stressors general**
Biotic Condition: **Terrestrial Fauna**	The taxonomic and functional (e.g., guild) composition of the native faunal assemblage of the ecosystem including birds, mammals, reptiles and amphibians, and invertebrates; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term). Monitoring populations of key native fauna will provide information on the condition of these important components of this ecosystem.	The taxonomic and functional composition of the faunal assemblage is an important aspect of the ecological integrity of an ecosystem. Many native species of birds, mammals, reptiles and amphibians, and invertebrates use this ecosystem as habitat for feeding, resting, breeding, and movement; and their patterns of use vary over time (seasonal, annual, longer-term). These species vary in their sensitivity to different stresses such as alterations to vegetation composition, fire frequency, and water availability. Alterations in the taxonomic and functional composition of the terrestrial faunal assemblage beyond its natural ranges of variation therefore strongly indicate the types and severities of stresses imposed on the ecosystem.	Stressors to the taxonomic and functional composition of the faunal assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, floral composition, and abiotic condition of the ecosystem; and incursions of non-native species that alter the food web or directly compete with or prey on the native fauna.
Biotic Condition: **Vegetation Composition**	The overall plant species composition and diversity of an ecosystem is an important aspect of its ecological integrity and largely defines it.	The taxonomic and functional composition of the plant species assemblage is an important aspect of the ecological integrity of a terrestrial ecosystem; many ecological processes and environmental variables affect it (drought, fire regime, anthropomorphic disturbance). In addition, the impact of invasive non-native species on community function of native vegetation is well documented (Anable et al. 1992, Cable 1971, Cox et al. 1988). Pond and Cable (1960) found that using repeated burning did not kill the dominant shrub, Quercus turbinella, but did impact fire dependant obligate seeders such as Arctostaphylos pringlei and Ceanothus spp. (Carmichael et al. 1978) and more fire sensitive species such as Garrya wrightii and Rhamnus crocea reducing the diversity of the shrub layer (Pond and Cable 1960).	Stressors to the taxonomic and functional composition of the plant assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, vegetation structure, and abiotic condition of the ecosystem; especially altered fire regime, improper livestock grazing management, and incursions of non-native species that alter the food web or directly compete with the native plants.

KEA Class: Name	Definition general	Rationale general	Stressors general
Biotic Condition: **Vegetation Structure**	An assessment of the overall structural complexity of the vegetation layers, including presence or cover of multiple strata, age and structural complexity of main canopy layer, and expected frequencies of successional or age classes.	Vegetation structure is an important reflection of dynamics and creates heterogeneity within the community. The distribution of total cover, crown diversity, stem size, and age classes or cohorts reflects natural disturbance regimes across the landscape and affects the maintenance of biological diversity, particularly of species dependent upon specific stages. A dense canopy of shrubs with low cover of grass vegetation is typical of the Mogollon Chaparral CE.	Alteration of vegetation structure can come from a variety of stressors, including changes in fire regime (e.g. too frequent or too infrequent), or other removal of woody species such as using herbicide, livestock grazing or concentrated native herbivory that removes native perennial herbaceous plants, climate change, and various kinds of mechanical disturbance that damages or removes vegetation.
Abiotic Condition: **Soil Condition**	Soil is basic to the proper functioning of a terrestrial ecosystem. Good soils will enhance the resilience and function of an ecosystem. Poor condition soil will limit the function of an ecosystem and if not addressed can permanently degrade a site. Soil condition includes indicators of multiple soil properties such as soil structure (particle and pore size, vertical profile, soil aggregates) and surface condition such as presence of soil crusts.	The condition of soil/surface substrate directly affects the functioning of the ecosystem. Soil/surface substrate condition of a site can be directly evaluated using indicators of soils disturbance such as evidence of erosion and disrupted soil processes and properties. The types of disturbances (stressors) can also be recorded to indicate condition such as livestock trampling and recreational vehicles. These disturbances can directly affect soil properties by disturbing soil crusts, compacting pore space that reduces water infiltration and percolation, changing other structural characteristics, and can expose soils to increased erosional forces.	Excessive livestock trampling, vehicle use (motorbikes, off-road vehicles, construction vehicles), filling and grading, plowing, other mechanical disturbance to the soil surface, excessive soil movement (erosion or deposition) as evidenced by gully, rill, or dune formation. Climate change and drought can also lead to increased potential for erosion.
Abiotic Condition: **Fire Regime**	Fire is a natural agent of disturbance in upland vegetation communities that maintains species composition, vegetation structure, and sustains ecological processes such as nutrient cycling.	Altered (uncharacteristic) fire regime greatly influences ecosystem processes. Intensive fire management (both suppression, but more often repeated prescribed burning) causes changes in species composition (Carmichael et al. 1978, Pond and Cable 1960, Schussman 2006c). During the time it takes for chaparral shrub cover to recover post stand replacing fire there were temporary changes such as increased water yield (Davis 1989, Hibbert et al. 1974), greater nitrate concentrations in streams (Davis 1989) increased erosion and stream sedimentation (Heede et al. 1988).	Fire exclusion in fire-maintained ecosystems results in increased woody species density and cover, changes in wildlife species assemblages, and increased fuel that ultimately produce high severity fire. Specific stresses include fire suppression with building roads that act as fire breaks, and active fire suppression by land owners and agency personnel.

D-5.1.7 Relationship of KEAs to Fundamentals of Rangeland Health

The key ecological attributes and indicators listed in Table D-22 also encompass the four fundamentals of rangeland health (USDI-BLM 2006), as shown in Table D-23. The KEA of Landscape Condition specifically refers to watershed conditions; all other KEAs refer specifically to Ecological Processes and Habitat. However, many of the indirect indicators for the KEAs for Abiotic Condition focus on stressors that arise as a result of modifications to the watershed or water quality, the fourth Fundamental. These relationships are also indicated in Table D-23. Further information about interpretation and assessment of these fundamentals of rangeland health is found in Pellant et al. (2005).

Table D-23. Key Ecological Attributes (KEA) for the Mogollon Chaparral ecosystem and their relationship to fundamentals of rangeland health.

Indicator	Watershed	Ecological Processes	Water Quality	Habitat
Landscape Condition	X	X	X	X
Patch Size	X	X		X
Terrestrial Fauna				X
Vegetation Composition		X		X
Vegetation Structure				X
Soil Condition		X	X	X
Fire Regime	X	X		X

D-5.1.8 Conceptual Model Diagrams

See Figure D-33, Figure D-34, and Figure D-35 above.

D-5.2 Ecological Status Assessment Results and Interpretation

This section of the appendix presents and discusses the results of the ecological status assessment for the Mogollon Chaparral CE. The presentation addresses each indicator separately, and then addresses the overall assessment, which integrates the results of all individual indicators. The results are presented using a common framework, in which the status of an indicator – or the combination of all indicators – is scored on a scale from 0.0 to 1.0, where 0.0 indicates a condition of complete replacement of reference ecological conditions due to the impacts of stressors, and 1.0 indicates a condition of no alteration of reference ecological conditions. The same color ramp is used for all results, yellow to dark blue, where yellow equals low scores, green moderate scores and dark blues high scores.

D-5.2.1 Current Ecological Status: Development, Fire Regime, Invasives

The maps below (Figure D-36) show the ecological status results for each of the three individual indicators – development, fire regime departure, and invasives – for the Mogollon Chaparral.

The development indicator is a stressor-based indicator of the spatial extent and intensity of human modifications to the land surface that alters ecosystems or habitat in the MAR ecoregion. The indicator takes into account the density of urban development; infrastructure such as above- and below-ground distribution corridors, communication towers, and border barriers; a wide range of transportation features; mines and landfills; recreational development; agriculture; and energy development. The scoring is on a continuous scale from 0 to 1, with the highest score of 1.0 indicating no ecologically relevant modifications, and the lowest score of 0.0 indicating modifications that essentially eliminate all natural cover and ecological functions.

The development indicator results shown in the first map of Figure D-36 indicates there is very low density of development throughout the range of Mogollon Chaparral CE in the MAR ecoregion. This is likely because much of the development types such as urbanization occur below the montane zone.

It is important to note that most development impacts are scored much lower than non-development change agents; for example, site intensity values for urbanization ranged from 0.05 to 0.6 for high to low density development, respectively. This is because development typically has a much stronger on-site impact than the other indicators. However, except for urban development, most development impacts occur at smaller scales than can be displayed in these maps, but still are pervasive throughout much of the ecoregion. In particular, effects of many of the very small, local areas of development, or small linear features (e.g. dirt roads) will not be obvious at the scale of the development indicator map.

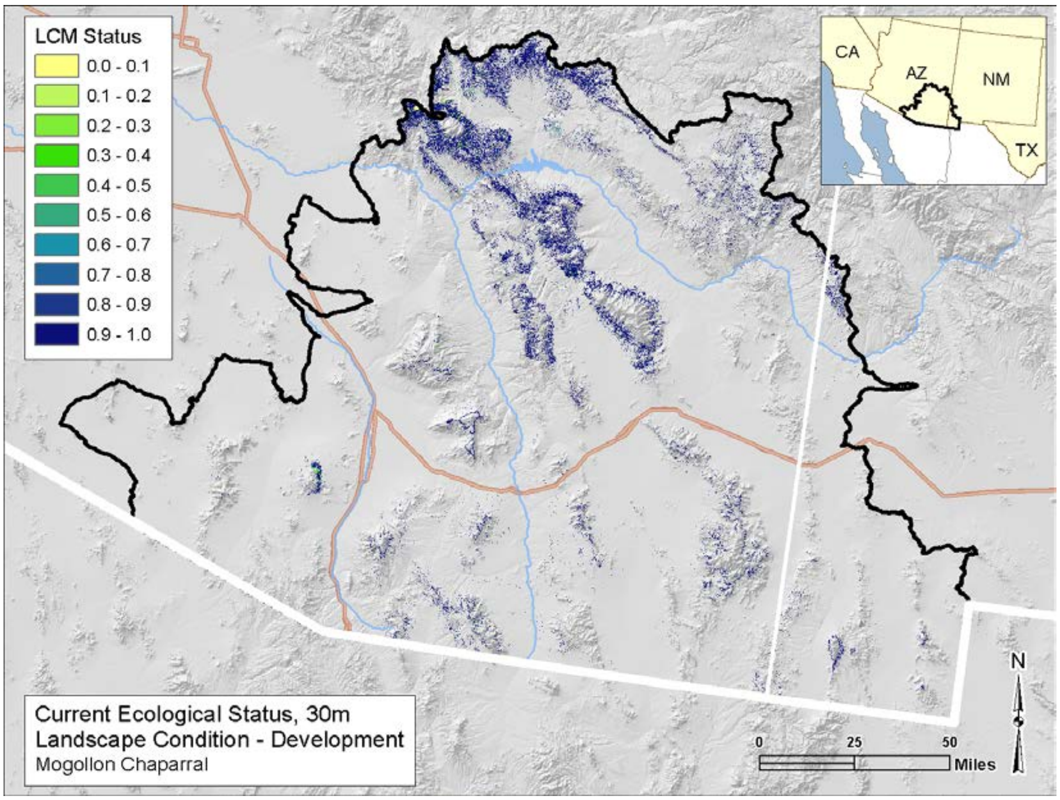
The second indicator is an indirect measure of fire regime. It is based on the Vegetation Condition Class (VCC) dataset produced by Landfire, which was developed to compare historical reference conditions with current conditions for an individual ecological system type (see **Status Assessment Methods** above). The result of VCC is a ranking of departure from expected historical range of variability, which can be interpreted as "how has the disturbance regime [for the REA purposes and relevant to this ecoregion: fire regime] changed from its historical variability for this individual CE". Only Severe Vegetation Departure (0.65) and Moderate Vegetation Departure (0.75) were used and are displayed in the map; no to minor departure was scored as 1 (dark blue in the map).

The second map in Figure D-36 shows much of the area of this CE is in moderate departure (0.7-0.8) throughout its distribution in the ecoregion. The Mogollon Chaparral has an estimated natural fire return interval between 20-100 years (Pase and Brown 1982, Wright and Bailey 1982), so many stands are still within or near the natural fire return interval even with fire suppression over the last one hundred years.

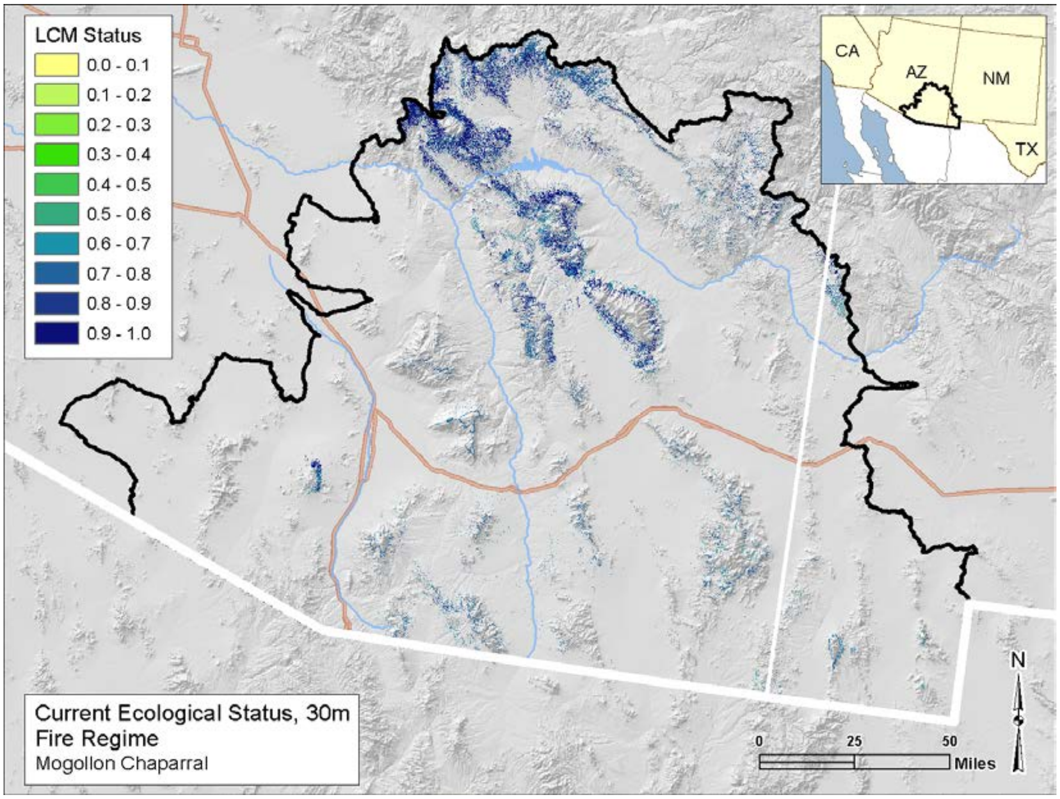
The invasive species indicator serves as an indirect measure of vegetation composition, by measuring the cover of invasive species. It includes a combination of non-native grass and forbs and native woody increasers (mesquite cover), as described previously in this appendix. The scoring is on a continuous scale from 0 to 1, with the highest score of 1.0 indicating no ecologically relevant cover of invasive species, and 0.0 indicating a conversion to non-native grasses and forbs and/or invasive mesquite. Table D-3 shows the cover classes used and the site intensity values for them, for this CE. The values range from 0.65 to 0.90. Either or both non-native invasive and native invasive woody cover may occur on in a single pixel. If both occur, then scores for that pixel are multiplied to create a new combined, lower indicator score.

Spatial results indicate relatively low invasion of exotic grasses and forbs, and/or invasive native mesquite in the Mogollon Chaparral CE. There are some areas at the lower elevation fringes of the montane areas where it occurs. Mesquite is unlikely to occur significantly in the Mogollon Chaparral CE so it is unlikely to contribute to the score.

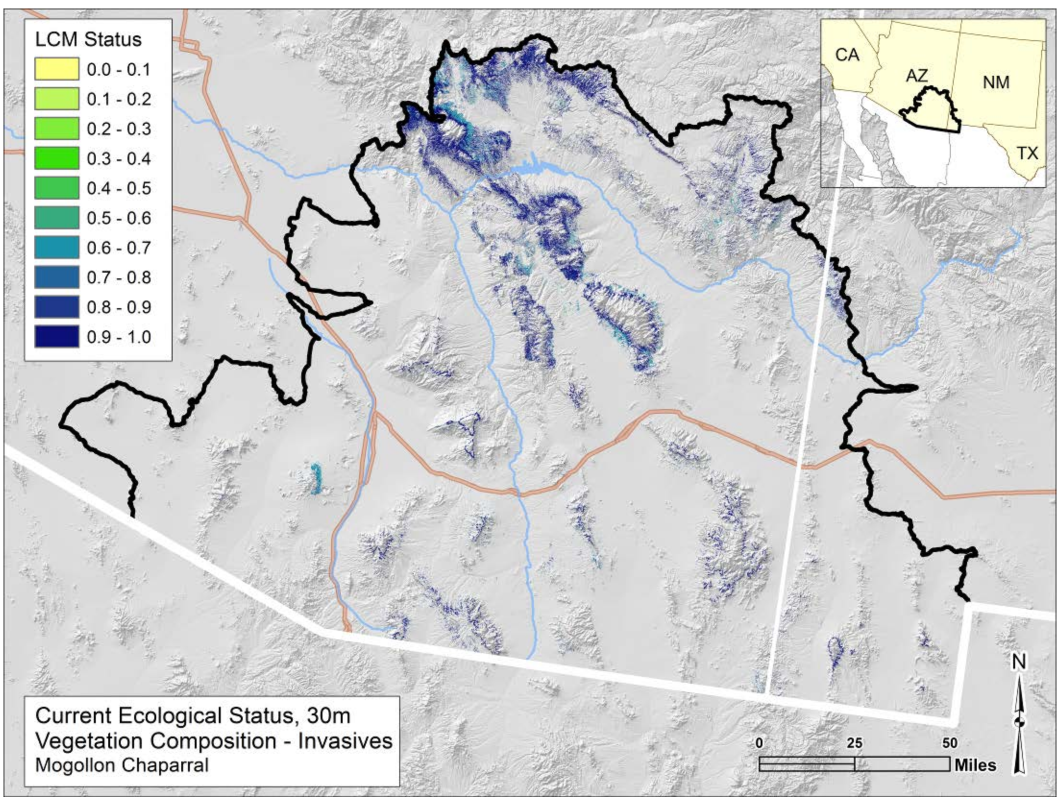
Figure D-36. Scores for three indicators for Mogollon Chaparral: development indicator (first map), fire regime departure indicator (second map), and invasive species indicator (third map) for each 30m pixel. At the ecoregion scale, many development features are not readily visible (i.e. secondary roads or highways, railroads, small agricultural fields). Yellow (equivalent to 0) indicates high impacts from the CA, dark blue (equivalent to 1) indicates little to no impact from the CA. Only 3 classes of fire regime condition are scored: no to little departure (dark blue), moderate departure and severe departure (lighter blue). For the invasives indicator results, higher cover of mesquite or invasive exotics will score between .4 and .6 (light greens), while lower cover scores between .6 and .8 (light blues).



Current Ecological Status, 30m
Landscape Condition - Development
Mogollon Chaparral



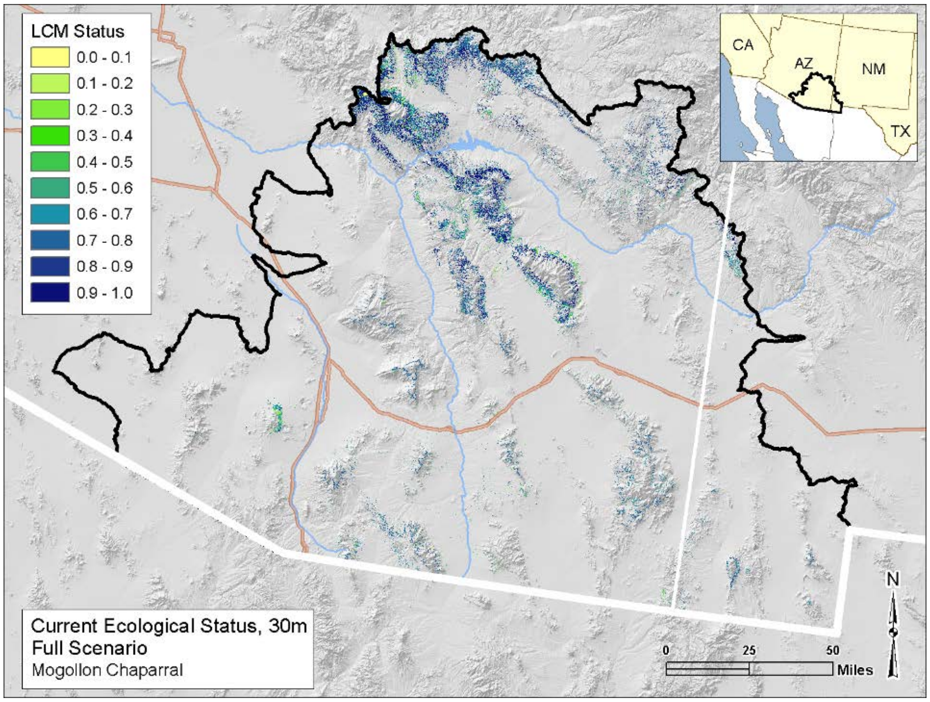
Current Ecological Status, 30m
Fire Regime
Mogollon Chaparral

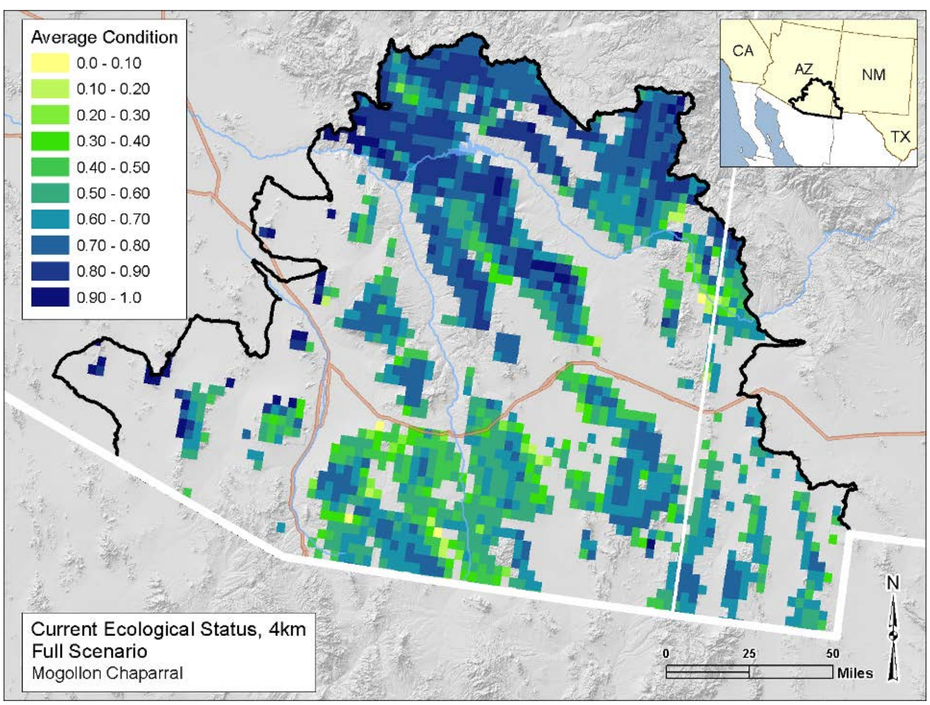


Current Ecological Status, 30m
Vegetation Composition - Invasives
Mogollon Chaparral

D-5.2.2 Current Ecological Status: Full Scenario

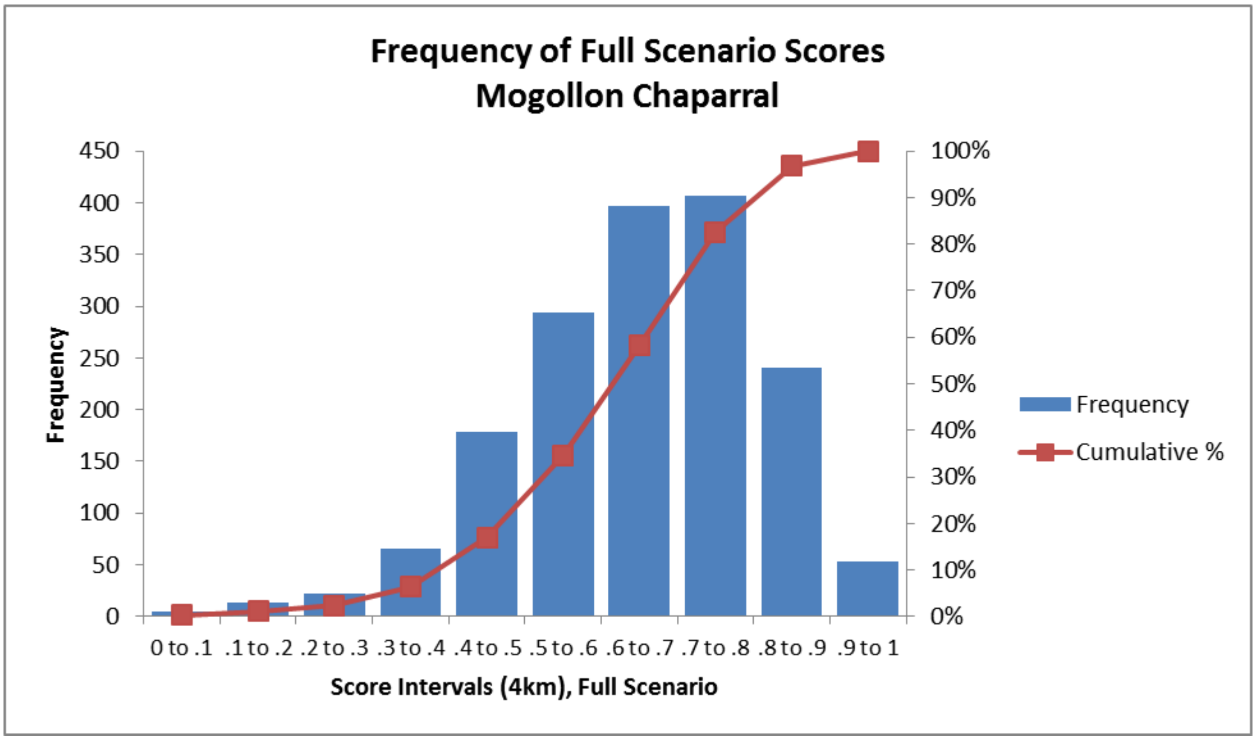
Figure D-37. Overall ecological status scores for Mogollon Chaparral for all indicators combined (development, fire regime and invasives) for each 30m pixel (top) and 4km grid cells (bottom). The score for each 4km cell is an average of all 30m pixels that are scored for the CE. Yellow scores (equivalent to 0) indicate high impacts from the CAs, dark blue (equivalent to 1) indicate little to no impact from the CAs.





The first map in Figure D-37 illustrates all three of the indicators combined into a single ecological status score per pixel of the CE's distribution. The combined, per-pixel status scores are noticeably lower than the individual scores for each indicator. The combined status scores for each pixel were summarized to the reporting unit (e.g., 4km grid) by taking the average status score from all the pixels of the CE within the reporting unit. The results, shown in the second map in Figure D-37 and in the frequency diagram (Figure D-38) indicate the widespread general degradation of the Mogollon Chaparral CE across its range in the ecoregion. However, as with the pinyon-juniper woodlands, there is a shift towards more area in better condition than for the Creosotebush, Grassland or Encinal CEs. About 60% of the 4km grid cells fall at or below the 0.7 score. There are a few local areas of better ecological condition, a result of low level of development, low or no cover of invasive species, and moderate fire regime departure. Mogollon Chaparral occurrences are relatively small patch and have limited distribution in the southern portion of the MAR ecoregion so that fact needs to be considered when evaluating the results.

Figure D-38. Frequency distribution of the 4km ecological status scores for the Mogollon Chaparral, with cumulative percent. The x-axis represents the 0.1 increment scoring intervals, while the y-axis shows the number of grid cells in each interval (left) and the cumulative percentage of the grid cells for each interval (right). For this CE, most of the status scores fall in the range from 0.5 to 0.9.



D-5.3 References for the CE

Anable, M. E., M. P. McClaran, and G. B. Ruyle, 1992. Spread of introduced Lehmann lovegrass *Eragrostis lehmanniana* Nees. in southern Arizona, USA. Biological Conservation, 61, 181-188.

Arizona Game and Fish Department (AGFD). 2012. Arizona's State Wildlife Action Plan: 2012-2022. Arizona Game and Fish Department, Phoenix, Arizona.

Bahre, C.J. 1991. *A* legacy of change: historic human impact on vegetation of the Arizona borderlands. The University of Arizona Press, Tucson, AZ.

Bock, C. E. and J. H. Bock 2002.Numerical response of grassland birds to cattle ranching versus exurban development in southeastern Arizona. 87th Annual Meeting of the Ecological Society of America and the 14th Annual International Conference of the Society for Ecological Restoration.

Bock, C.E. and J.H. Bock. 1982. Numerical response of grassland birds to cattle ranching versus exurban development in southeastern Arizona. 87th Annual Meeting of the Ecological Society of America and the 14th Annual International Conference of the Society for Ecological Restoration. 2002.

Baker, M. B. 1999. History of Watershed Research in the Central Arizona Highlands. Fort Collins, Colorado, Rocky Mountain Research Station

Cable, D. R. 1971. Lehmann lovegrass on the Santa Rita Experimental Range, 1937-1968. Journal of Range Management. 24: 17-21.

Cable, D. R. 1975a. Range management in the chaparral type and its ecological basis: The status of our knowledge. Research Paper RM-155. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 30 pp.

Carmichael, R. S., O. D. Knipe, C. P. Pase, and W. W. Brady. 1978. Arizona chaparral: Plant associations and ecology. Research Paper RM-202. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 16 pp.

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. Ecological systems of the United States: A working classification of U.S. terrestrial systems. NatureServe, Arlington, VA.

Cox, J. R., G. B. Ruyle, J. H. Fourle, and C. Donaldson. 1988. Lehmann lovegrass--central South Africa and Arizona, USA. Rangelands. 10(2): 53-55.

Davis, E.A. 1989. Prescribed fire in Arizona chaparral: effects on stream water quality. Forest Ecology and Management, 26, 189-206.

Davis, J. R., and J.H. Dieterich. 1976. Predicting rate of tire spread (ROS) in Arizona oak chaparral: Field workbook. USDA For. Servo Gen. Tech. Rep. RM-24, 8 p. Rocky Mt. For. and Range Exp. Stn. Fort Collins, Colo. 80521

DeBano, L. F. 1999. Chaparral shrublands in the southwestern United States. Chapter 7. Pages 83-94 in: P. F. Ffolliott and A. Ortega-Rubio, editors. Ecology and Management of Forests, Woodlands, and Shrublands in Dryland Regions of the United States and Mexico: Perspectives for the 21st Century. Co-edition number 1. University of Arizona-Centro de Investigacione.

Dick-Peddie, W. A. 1993. New Mexico vegetation: Past, present, and future. University of New Mexico Press, Albuquerque. 244 pp.

Dieterich, J.H. and T.W. Swetnam. 1987. Dendrochronology of a fire scarred ponderosa pine (*Pinus-ponderosa*). Forest Science, **30**, 237-247.

Faber-Langendoen, D., J. Rocchio, S. Thomas, M. Kost, C. Hedge, B. Nichols, K. Walz, G. Kittel, S. Menard, J. Drake, and E. Muldavin. 2012b. Assessment of wetland ecosystem condition across landscape regions: A multi-metric approach. Part B. Ecological Integrity Assessment protocols for rapid field methods (L2). EPA/600/R-12/021b. U.S. Environmental Protection Agency Office of Research and Development, Washington, DC.

Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy. editors. 2013. Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment, A report by the Southwest Climate Alliance. Washington, DC: Island Press.

Gori, D. and J. Bate. 2007. Historical Range of Variation and State and Transition Modeling of Historical and Current Landscape Conditions for Pinyon-Juniper of the Southwestern U.S. Prepared for the U.S.D.A. Forest Service, Southwestern Region by The Nature Conservancy, Tucson, AZ. 141 pp.

Heede, B.H., M.D. Harvey, and J.R. Laird. 1988. Sediment delivery linkages in a chaparral watershed following a wildfire. Environmental Management, 12, 349-358.

Hibbert, A.R., E.A., Davis, and D.G. Scholl. 1974. Chaparral conversion potential in Arizona Part I: Water yield response and effects on other resources. July 1974. Rocky Mountain Forest and Experiment Station, Fort Collins, Colorado, United States Department of Agriculture.

Heinz Center. 2011. Managing and Monitoring Arizona's Wildlife in an Era of Climate Change: Strategies and Tools for Success Report and Workshop Summary. Prepared for: U.S. Department of Interior. Bureau of Land Management and The Arizona Game and Fish Department by the H. John Heinz III Center for Science Economics and the Environment. January 13, 2011. Washington, D. C. 67 pp. plus appendices.

Knipe, O.D. (1983) Effects of Angora Goat Browsing on Burned-Over Arizona Chaparral. Rangelands, **5**, 252-255.

Marshall, R.M., A.Turner, A. Gondor, D. Gori. C. Enquist, G. Luna, R. Paredes Aguilar, S. Anderson, S. Schwartz, C. Watts, E. Lopez, P. Comer. 2004. An ecological analysis of conservation priorities in the Apache Highlands Ecoregion. Prepared by The Nature Conservancy of Arizona, Instituto del Medio Ambiente y el Desarrolla Sustentable del Estado de Sonora, agency and institutional partners. 152 pp.

Muldavin, E., P. Mehlhop, and E. DeBruin. 1994a. A survey of sensitive species and vegetation communities in the Organ Mountains of Fort Bliss. Volume III: Vegetation communities. Report prepared for Fort Bliss, Texas, by New Mexico Natural Heritage Program, Albuquerque.

Muldavin, E., Y. Chauvin, and G. Harper. 2000b. The vegetation of White Sands Missile Range, New Mexico: Volume I. Handbook of vegetation communities. Final report to Environmental Directorate, White Sands Missile Range. New Mexico Natural Heritage Program, University of New Mexico, Albuquerque. 195 pp. plus appendices

NatureServe. 2013. International Ecological Classification Standard: International Vegetation Classification. Central Databases. NatureServe, Arlington, VA.

Pase , C. P. and D. E. Brown. 1982. Interior Chaparral. Pages 95-99 in: Brown, D. E., editor. 1982. Biotic communities of the American Southwest-United States and Mexico. Desert Plants Special Issue 4(1-4):1-342.

Pellant, M., P. Shaver, D.A. Pyke, and J.E. Herrick. 2005. Interpreting indicators of rangeland health, version 4. Technical Reference 1734-6. BLM/WO/ST-00/001+1734/REV05. U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center, Denver, CO. 122 pp.

Pickett, S.T.A., and J.N. Thompson. 1978. Patch dynamics and the size of nature reserves. Biological Conservation 13: 27-37.

Pond, F.W. and D.R. Cable. 1960. Effect of heat treatment on sprout production of some shrubs of the chaparral in central Arizona. Journal of Range Management, 13, 313-317.

Reynolds H. G. and R.R. Johnson. 1964. Habitat relations of vertebrates of the Sierra Ancha Experimental Forest. USDA Forest Service, Research Paper RM-4.

Schussman, H. 2006c. Historical Range of Variation and State and Transition Modeling of Historical and Current Landscape Conditions for Interior Chaparral of the Southwestern U.S. Prepared for the U.S.D.A. Forest Service, Southwestern Region by The Nature Conservancy, Tucson, AZ. 24 pp.

Severson, K.E. and L.F. Debano. 1991. Influence of Spanish goats on vegetation and soils in Arizona chaparral. Journal of Range Management, 44, 111-117.

Tirmenstein, D. 1999d. *Quercus turbinella*. In: Fire Effects Information System [Online]. USDA Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). [Available: http://www.fs.fed.us/database/feis/] (accessed 11 March 2010).

USDA-NRCS. 2014. Selected Approved Ecological Site Descriptions for Major Land Resource Area 041-Southeastern Arizona Basin and Range. US Department of Agriculture. Natural Resource Conservation Service. Website accessed September 2014. https://esis.sc.egov.usda.gov/Welcome/pgApprovedSelect.aspx?type=ESD

USDA-USFS. 2009. Ecological sustainability report. Coronado National Forest. United States Department of Agriculture. Forest Service. Southwest Region. February 2009. Pp. 118.

Wright, H. A., and A. W. Bailey. 1982. Pinyon-juniper. Pages 195-208 in: Fire ecology: United States and southern Canada. Wiley-Interscience Publication, John Wiley and Sons, New York. 501 pp.

Subalpine/Montane Forests & Woodlands

D-6 Madrean Montane Conifer-Oak Forest and Woodland Ecological System

D-6.1 Conceptual Model

D-6.1.1 Classification

The ecosystem conservation elements for the MAR REA were selected from NatureServe's classification of terrestrial ecological systems (Comer et al. 2003). Over three dozen ecological systems occur in the MAR, but only a select subset was chosen for the REA. The CE concept provided in this conceptual model includes these NatureServe ecological system types:

Primarily:

- Madrean Lower Montane Pine-Oak Forest and Woodland (CES305.796)
- Madrean Upper Montane Conifer-Oak Forest and Woodland (CES305.798)

In part:

- Southern Rocky Mountain Ponderosa Pine Woodland (CES306.648) or Southern Rocky Mountain Ponderosa Pine Savanna (CES306.649)
- Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland (CES306.828) in the Pinaleño Mountains.

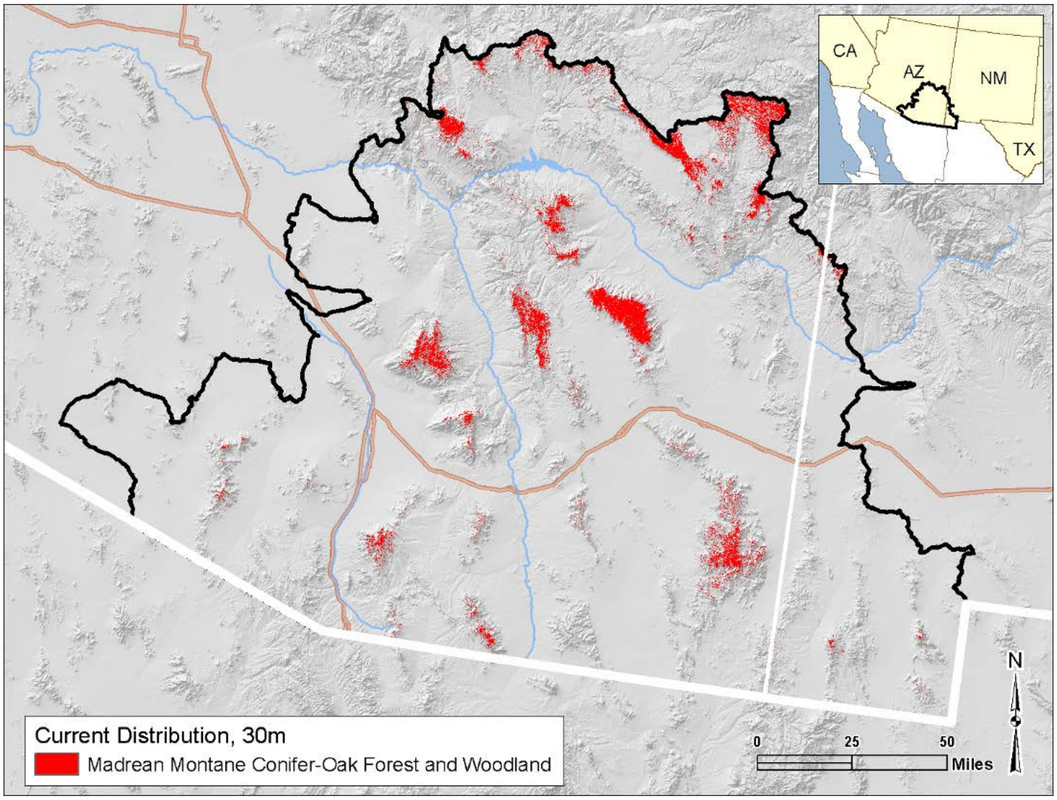
There are other terrestrial ecological systems in the NatureServe classification that also occur in the MAR, or in adjacent ecoregions, which are similar to this CE concept but are not included in this conservation element. These are listed here to help the reader understand what is not included in this conceptual model; each of these other ecological systems has information that can be searched for and reviewed on NatureServe's on-line Explorer website (http://explorer.natureserve.org/servlet/NatureServe). The System Code beginning with CES (Community Ecological System) is an information rich database code that refers to the North American Ecological Division (302) where the system primarily occurs and the number used to identify the system (Comer et al. 2003).

- Madrean Pinyon-Juniper Woodland (CES305.797)
- Madrean Encinal (CES305.795)

D-6.1.2 Summary

Madrean Montane Conifer-Oak Forest and Woodland CE is composed of the Madrean Lower Montane Pine-Oak Forest and Woodland (CES305.796) and the Madrean Upper Montane Conifer-Oak Forest and Woodland (CES305.798) ecological systems. It also includes any wide ranging *Pinus ponderosa* stands occurring in the MAR (usually classified as part of Southern Rocky Mountain Ponderosa Pine Woodland (CES306.648) or Southern Rocky Mountain Ponderosa Pine Savanna (CES306.649). Stands occur on mountains and plateaus in the Sierra Madre Occidentale and Sierra Madre Orientale in Mexico, Trans-Pecos Texas, southern New Mexico and Arizona, generally south of the Mogollon Rim (Figure D-39).

Figure D-39. Distribution of Madrean Montane Conifer-Oak Forest and Woodland at 30m resolution. The distribution was derived from the NatureServe (2013) terrestrial ecological systems map. Appendix G (ecological integrity) has a table listing the areal extent of this ecological system and its % of the assessment area.



The lower montane forests and woodlands (Figure D-40) are composed of Madrean pines (*Pinus arizonica, Pinus engelmannii, Pinus leiophylla*, or *Pinus strobiformis*) and evergreen oaks (*Quercus arizonica, Quercus emoryi*, or *Quercus grisea*) intermingled with patchy shrublands on most mid-elevation slopes (1500-2300 m elevation). Other tree species include *Cupressus arizonica, Juniperus deppeana, Pinus cembroides, Pinus discolor, Pinus ponderosa* (with Madrean pines or oaks), and *Pseudotsuga menziesii*. Subcanopy and shrub layers may include typical encinal and chaparral species such as *Agave* spp., *Arbutus arizonica, Arctostaphylos pringlei, Arctostaphylos pungens, Garrya wrightii, Nolina* spp., *Quercus hypoleucoides, Quercus rugosa*, and *Quercus turbinella*. Some stands have moderate cover of perennial graminoids such as *Muhlenbergia emersleyi, Muhlenbergia longiligula, Muhlenbergia virescens*, and *Schizachyrium cirratum*. Fires are frequent with perhaps more crown fires than in typical ponderosa pine woodlands, which tend to have more frequent surface fires on gentle slopes. Adjacent stands include higher elevation conifer-oak forests (Madrean Upper Montane Conifer-Oak Forest and Woodland (CES305.798)) and Madrean Pinyon-Juniper Woodland (CES305.797) and Madrean Encinal (CES305.797) at lower elevations.

Figure D-40. Madrean Lower Montane Pine-Oak Forest and Woodland in Arizona (source http://azfirescape.org)

The upper montane to subalpine forests (Madrean Upper Montane Conifer-Oak Forest and Woodland (CES305.798) are confined to the upper elevations in the Sierra Madre Occidentale and Sierra Madre Orientale of Mexico. In the U.S., it is restricted to north and east aspects at high elevations (1980-2440 m) in the Sky Islands (Chiricahua, Huachuca, Pinaleño, Santa Catalina, and Santa Rita mountains, among others) and along the Nantanes Rim. It is more common in Mexico and does not occur north of the Mogollon Rim. These higher elevation stands are characterized by large- and small-patch forests dominated by *Pseudotsuga menziesii, Abies coahuilensis,* or *Abies concolor* with *Pinus strobiformis* often present and Madrean oaks especially *Quercus hypoleucoides* and *Quercus rugosa* at higher elevations as well as *Quercus arizonica, Quercus emoryi, Quercus grisea,* and *Quercus toumeyi*. If *Quercus gambelii* is prominent in the shrub layer, then other Madrean elements are present. This system may include stands of *Quercus gravesii* woodlands. It is similar to Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland (CES306.823) which typically lacks Madrean elements.

This CE as defined for the MAR REA also may include small patches of montane mixed conifer and subalpine Engelmann spruce forest at the highest elevations of the larger mountain ranges that are characterized by *Picea engelmanii, Abies lasiocarpa, Abies concolor, Acer grandidentatum, Pinus strobiformis, Pinus flexilis or Pinus ponderosa.* The subalpine forest is essentially limited to the Pinaleño Mountains and is included in the Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland

(CES306.828). Adjacent stands include Madrean Pinyon-Juniper Woodland (CES305.797) and encinal Madrean Encinal (CES305.795) at lower elevations and sparse rock outcrop as it is typically the uppermost ecosystem.

This description is based on several references, including Dick-Peddie (1993), Ffolliott and Baker (1999), Moir and Ludwig (1979), Muldavin et al. (1996), NatureServe Explorer (2013), Pase and Brown (1982), Schussman and Gori (2006), Smith (2006a), Smith (2006b), Smith (2006c) and Stuever and Hayden (1997b).

A crosswalk of this system to USDA Natural Resource Conservation Service (NRCS) approved Ecological Site Descriptions (ESD) by Major Land Resource Areas (MLRA) is provided in Table D-24 (USDA-NRCS 2014). For complete list of ESDs for MLRA 41 see https://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD.)

Table D-24. Madrean Montane Conifer-Oak Forest and Woodland ecological system CE crosswalk with approved Ecological Site Descriptions (provisional cross-walk).

MLRA	Ecological Site Description Name	Site ID
041-Southeastern Arizona Basin and Range	No Approved ESDs identified	

D-6.1.3 Species of Conservation or Management Concern

Below are listed some species of concern associated with this ecological system CE.

Listed below are typical Threaten-Endangered Species/Species of Concern/Species of Interest (TE/SOC/SOI) species associations from Coronado National Forest Ecological Sustainability Report (USDA-USFS 2009) for Madrean Pine-Oak Woodland, plus TE/SOC/SOI species associations from Spruce-fir Forest, Mixed Conifer Forest, and Ponderosa Pine Forest, which are included in the concept of this Madrean Montane Conifer-Oak Woodland CE. Also species are listed for montane conifer from both the New Mexico Comprehensive Wildlife Conservation Strategy NMDGF (2006), and the Arizona State Wildlife Action Plan (AZGFD 2012).

Amphibians: Barking Frog (*Craugastor augusti*).

Birds: Band-tailed Pigeon (*Patagioenas fasciata*), Mexican Spotted Owl (*Strix occidentalis lucida*), Northern (Apache) Goshawk (*Accipiter gentilis apache*), Lucifer hummingbird (*Calothorax lucifer*); whiskered screech owl (*Otus trichopsis*), Gould's turkey, Montezuma quail (*Cyrtonyx montezumae*), Mexican jay *(Aphelocoma wollweberi),* bridled titmouse (*Baeolophus wollweberi)*.

Mammals: Abert's Squirrel (*Sciurus aberti*); Arizona Gray Squirrel (*Sciurus arizonensis*); Black Bear (*Ursus americanus*); Chiricahua Fox Squirrel (*Sciurus nayaritensis chiricahuae*); Coues' White-tailed Deer (*Odocoileus virginianus couesi*); Elk (*Cervus elaphus*); southern pocket gopher *(Thomomys umbrinus*); and Mt. Graham Red Squirrel (*Tamiasciurus hudsonicus grahamensis*).

Reptiles: Slevin's Bunchgrass Lizard (*Sceloporus slevini*) (in open, grassy stands);Twin-spotted Rattlesnake (*Crotalus pricei*); New Mexico Ridge-nosed Rattlesnake (*Crotalus willardi obscurus*); brown vinesnake (*Oxybelis aeneus*); Arizona Ridge-nosed Rattlesnake (*Crotalus willardi*).

Invertebrates: Arizona Mantleslug (Pallifera pilsbryi); Lichen Grasshopper (Trimerotropis saxatilis) (in rocky areas); Patagonia Eyed Silkmoth (*Automeris patagoniensis*); Pinaleño Monkey Grasshopper (*Eumorsea pinaleno*); Pinaleño Mountainsnail (*Oreohelix grahamensis*); Pungent Talussnail

(*Sonorella odorata*); Cross Snaggletooth (*Gastrocopta quadridens*); Huachuca talussnail, Rosemont talussnail, and many other land mollusks.

Vascular Plants: Catalina Beardtongue (*Penstemon discolor*)(in rocky areas); Chiricahua Gentian (*Gentianella wislizeni*); Chiricahua Mountains Larkspur (*Delphinium andesicola*); Giant-trumpets (*Macromeria viridiflora*); Heliograph Peak Fleabane (*Erigeron heliographis*); Heller's Whitlow-grass (*Draba helleriana var. bifurcata*); Huachuca Mountain Lupine (*Lupinus huachucanus*); Lemmon's Beggar-ticks (*Bidens leptocephala*); Mexican Hemlock-Parsley (*Conioselinum mexicanum*); Mt. Graham Beardtongue (*Penstemon deaveri*); New Mexico Lupine (*Lupinus neomexicanus*); Pinaleño Mountains Rubberweed (*Hymenoxys ambigens*); Purple-spike Coralroot (*Hexalectris warnockii*); Timberland Blue-eyed Grass (*Sisyrinchium longipes*); White-flowered Cinquefoil (*Potentilla albiflora*), and many other plants.

D-6.1.4 Natural Dynamics

Under historical natural conditions (also called natural range of variability, NRV), the Madrean Montane Conifer-Oak Forest and Woodland ecosystem varied from open woodlands (10-20% cover) with pines dominating the overstory and perennial bunch grass dominating the understory to moderately dense woodlands (20-40% tree cover) with less dense herbaceous layer and more tree and shrub cover. Lower elevation tree line of pines is primarily controlled by dry season water stress (Barton 1993). Fire and drought are the primary disturbances of this ecosystem (USDA-USFS 2009).

Information on fire return intervals is varied depending on elevation zone with fires frequently starting at lower elevations and burning upslope into the montane zone. Lower montane elevation pine-oak stands had frequent, low intensity surface fires (mean fire return every 6-14 years) as a result of lightning ignitions primarily between early spring and summer (Bahre 1985, Kaib et al. 1996, Schussman and Gori 2006, Swetnam and Baisan 1996, Swetnam et al. 1992, Swetnam et al. 2001). However, minimum fire-free periods of 20-30 years are necessary for pines to establish and become resistant (thick bark) to surface fires (Barton et al. 2001). More frequent fire favors oaks and other sprouting species over pines and other conifers, which can alter stand composition. Less frequent fire (FRI >50 years) results in more conifer recruitment and denser vegetation that can lead to higher intensity, mixed severity and patches of stand replacing fires that also favors oaks and other sprouting species (Barton 1999, Barton et al. 2001, Danzer et al. 1996, Schussman and Gori 2006).

For the inclusions of Ponderosa Pine Woodland in the Madrean Conifer-Oak Forest and Woodland the historical mean fire return interval is similar (Smith 2006a). In Arizona and New Mexico, Swetnam and Baisan (1996) found the historical mean fire return interval ranges from 2 to 17 years for fires scarring one or more trees, and 4 to 36 years for fires scarring between 10% and 25% of trees between the years of 1700 and 1900. However in the more mesic subalpine fir communities a fire return interval of up to 400 years is not uncommon.

Herbivory by native herbivores in the Madrean montane conifer-oak forests and woodlands is variable in this type. For more open stands with grass-dominated understory herbivores are similar to semi-desert grasslands. Large herbivores include browsers like Coues' white-tailed deer (*Odocoileus virginianus couesi*), mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*), and rodents such as yellow nosed cotton rat (*Sigmodon ochrognathus*), whitethroated wood rat (*Neotoma albigula*), southern pocket gopher (*Thomomys umbrinus*), Apache squirrel (*Sciurus nayaritensis*), Arizona gray squirrel (*Sciurus arizonensis*), porcupine (*Erethizon dorsatum*), Bailey's pocket mouse (*Chaetodipus baileyi*), and eastern cotton tail (*Sylvilagus floridanus*) are common in the Madrean pine-oak woodlands (Majka al. 2007, Schussman and Gori 2006). Southwestern forest trees have been host to several species of insects, pathogenic fungi, and parasitic plants, however there are no accounts of historical insect outbreak, fungi or parasitic plant periodicity (Dahms and Geils 1997).

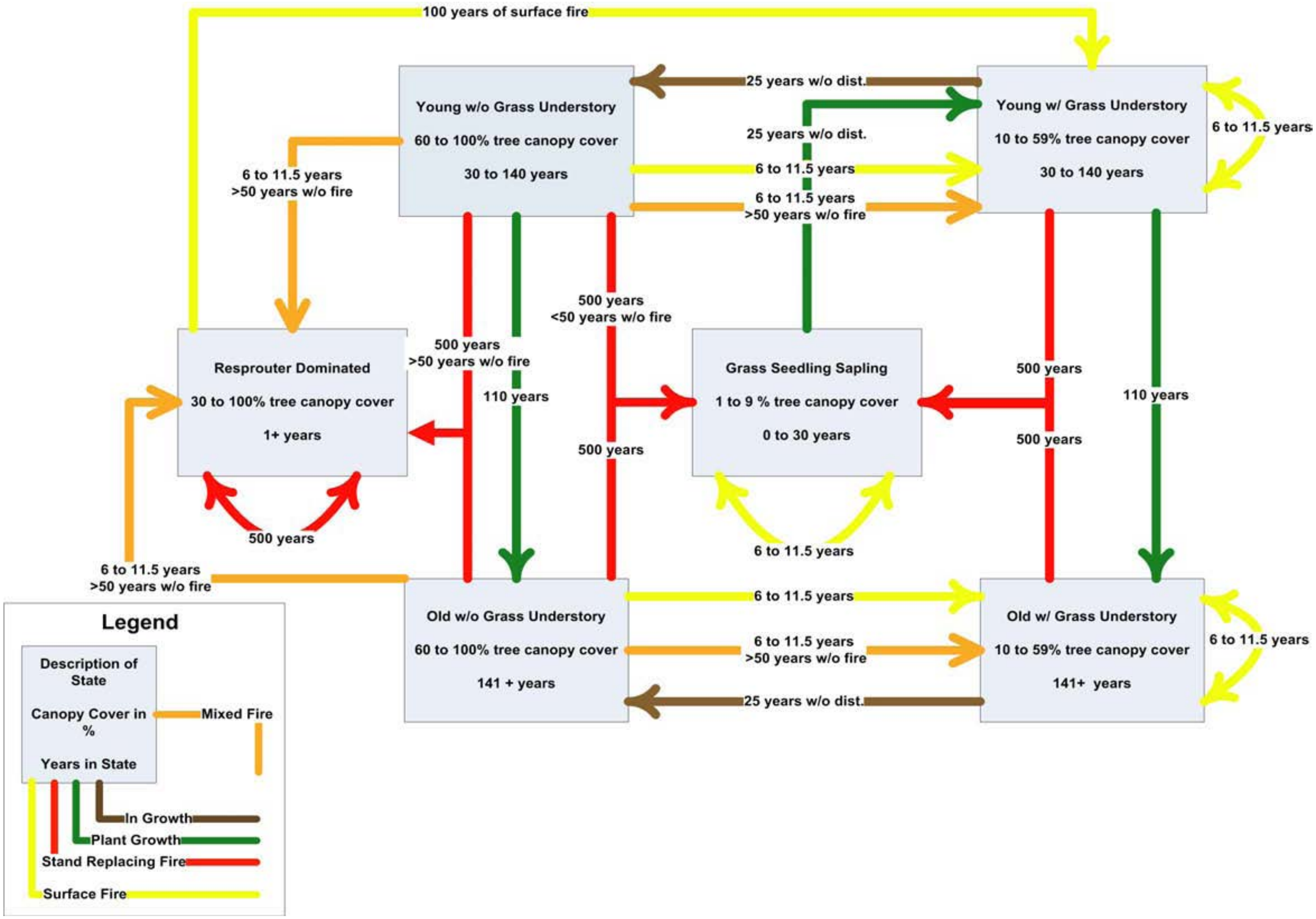
A good condition/proper functioning occurrence of Madrean Montane Conifer-Oak Forest and Woodland ecosystem is large and uninterrupted; the surrounding landscape is also in good condition with soils that have not been excessively eroded. The biotic condition is within normal range of variation, the weeds are few, the native plants are robust, have expected abundance and reproduction; birds, mammals, reptiles, insects and amphibian species present are indicative of reference, un-molested conditions; the fire regime is functioning at near historical conditions. There is a diversity of stand age and size classes in response to a functioning natural fire regime. For the majority of the type (lower montane pine-oak woodlands) that is frequent (mean fire return every 6-14 years), low intensity surface fires with occasional fire free periods of 20-30 years minimum to allow for conifers to establish and become resistant (thick bark) to surface fires. For upper montane conifer oak and mixed conifer forests, the historical fire regime would have less frequent fires, mixed severity and occasional stand replacing fires. The subalpine spruce forest only rarely burns but has high severity, stand replacing fires under extreme fire conditions.

A poor condition/non-functioning occurrence is highly fragmented, or much reduced in size from its historical extent; the surrounding landscape is in poor condition either with highly eroding soils, many non-native species or a large percentage of the surrounding landscape has been converted to exurban development; the biotic condition is at the limit or beyond natural range of variation. The montane conifer-oak woodland and forest stands would have high density of trees and excessive fuel loading from passive (livestock grazing) and active fire suppression. Characteristic birds, mammals, reptiles, and insects and amphibian species are not present at expected abundances or the ratio of species shows an imbalance of predator to prey populations.

D-6.1.4.1 Natural Dynamics Model

A conceptual historical state-and-transition model was developed by a team of ecologists (Schussman and Gori 2006) using the Vegetation Dynamics Development Tool (VDDT) to model the Madrean Pine-Oak Woodland (for details on tool see http://essa.com/tools/vddt/). For methods on modeling please see Schussman and Gori (2006) (Figure D-41). This is the primary forest type of the CE. For models of other montane forest and woodland types treated as inclusions in this CE, please refer to Smith (2006a, 2006b, 2006c).

Figure D-41. Conceptual state and transition model of historical conditions for the Madrean Pine Oak Woodland vegetation type. This model was taken directly from Schussman and Gori (2006). Frequency of transitions is noted (Schussman and Gori 2006).



D-6.1.5 Change Agent Effects on the CE

This section of the conceptual model presents a narrative description of the primary change agents and current knowledge of their effects on Madrean Montane Conifer-Oak Forest and Woodland ecosystem. The section contains two sub-sections: (1) A list of primary change agents identified for the CE; and (2) a discussion of altered dynamics caused by these agents.

D-6.1.5.1 List of Primary Change Agents

Occurrences of this woodland and forest ecological system are directly affected by livestock grazing, direct and indirect wildfire suppression, land development, recreation, and non-native plant species invasion. Table D-25 identifies the most likely impacts associated with each of these stressors.

Table D-25. Stressors and their likely impacts on the Madrean Montane Conifer-Oak Forest and Woodland ecosystem in the Madrean Archipelago ecoregion.

Stressor	Impacts
Land Use	
Livestock grazing	Grazing of native vegetation by livestock at incompatible stocking rates, season of use, or duration can be detrimental to grass vigor resulting in decline of grass cover and shifts species composition to more grazing tolerant or less palatable species (Milchunas 2006). Over time this often results in increased woody cover or bare ground and erosion. Heavy grazing can indirectly decrease fire return intervals by removing fine fuels that carry fire (Kaib et al. 1996; Swetnam and Baisan 1996).
Harvesting of fuelwood; silviculture	Fuel wood cutting has impacted stands in southeastern Arizona historically and is still common for domestic use (Bahre 1991, Bennet 1992). Logging has also occurred. Changes stand structure such as increased number of stems per acre, decreased crown volume and depth, decreased tree height and foliage volume (USDA-USFS 2009.)
Recreation	This mostly relates to off road vehicle use, which creates additional roads and trails that fragment woodlands and increase soil erosion and compaction and non-native species dispersal (USDA-USFS 2009).
Development	
Transportation infrastructure Roadways/railways and transmission lines	Fragmentation from transportation infrastructure leads to disruptions in ecological processes such as fire, dispersal of invasive non-native species, and can alter hydrological processes when excessive runoff from roads creates gullies that can lower water tables. Additionally, destruction of wildlife habitat and disruption of wildlife migration patterns can also occur (Bahre 1991, Bock and Bock 2002, Finch 2004, Heinz Center 2011, Marshall et al. 2004, McPherson 1997, Ockenfels et al. 1994, Schussman 2006b).
Suburban/Rural (include Military), Mines/Landfill	This stress contributes to altered fire regimes, increased erosion, direct habitat loss/conversion, increased groundwater pumping, fragmentation, invasive non-native species dispersal and disruption of wildlife migration patterns. (Bahre 1991, Finch 2004, McPherson 1997).

Stressor	Impacts
Energy (Renewable wind/solar), Oil/Gas	While unlikely to be common in these montane areas, this stress contributes to altered fire regimes (e.g. protection of facilities), increased erosion, direct habitat loss/conversion, increased groundwater pumping, fragmentation, invasive non-native species dispersal and disruption of wildlife migration patterns.
Uncharacteristic Fire Regime	Fire suppression has increased woody species, lead to changes in woody species composition and lead to an uncharacteristic fire regime in many stands (Barton 1999, Gori and Enquist 2003, Muldavin et al. 2002, Turner et al. 2003). Insect outbreaks in forests also affect fire regime.
Climate change	Alteration of precipitation and evapotranspiration rates and timing, may result in more frequent drought periods and higher intensity precipitation events, which following drought can cause significant erosion of topsoil.Climate change has also affected insect and disease outbreak in forests (Garfin et al. 2012).

D-6.1.5.2 Altered Dynamics

Madrean Montane Conifer-Oak Forest and Woodland stands have been impacted by fragmentation, silviculture, fire management, and livestock grazing over the last century. The lower montane woodlands are characterized by a strong perennial grass layer and are driven by many of the same ecological processes as encinal, primarily fire and grazing. The upper montane forests have less forage available and are less impacted by livestock but more impacted by logging and active fire suppression. Fragmentation of landscape can impact the movement of fires that start in lower elevation savannas and woodlands and burn upslope into the montane zones.

It is generally agreed that the fire regime has been altered for Montane Conifer-Oak Forest and Woodland *by passive fire suppression* via removal of fine fuels through livestock grazing, as well as active suppression over the last 100 years. This has reduced the number of fires and increased fire severity in conifer-oak forests and woodlands and adjacent vegetation types like encinal across much of the southwestern US and adjacent Mexico (Kaib et al. 1996, Swetnam and Baisan 1996).

Structurally as tree canopy becomes denser the cover of shade-intolerant grass understory is eliminated and replaced with shade tolerant shrubs or no understory when tree canopy closes. The Coronado National Forest Assessment (USDA-USFS 2009) shows a large forest structural class shift from historical natural or reference conditions to current conditions for two montane forest types. The Madrean Pine Oak Woodland shows the largest declines in young pine without oak in understory (grassy) and old pine-oak woodlands with understory to old pine-oak woodlands without understory (Table D-26).

Table D-26. Reference and Current Conditions: Madrean Pine Oak Woodland on the Coronado National Forest (from USDA-USFS 2009).

Structural Class	Reference	Current
Grass, seedling, saplings	4%	9%
Young pine oak w/o understory	3%	12%

Structural Class	Reference	Current
Young pine oak w/understory	24%	5%
Old pine oak w/understory	60%	10%
Old pine oak w/o understory	4%	64%
Resprouter dominated	5%	0%

Ponderosa pine structural classes for historical (reference) and current conditions have also shifted in the Coronado National Forest and are displayed below (Table D-27). There has been a major shift from open tree canopy (<30% cover) old forest with regeneration to mid-aged, mature and old forest with closed tree canopy (>30% cover). These changes in tree canopy density have increased risk from uncharacteristically large insect outbreaks and destruction by unnaturally large and intense wildfires (USDA-USFS. 2009).

Table D-27. Reference and Current Conditions: Ponderosa Pine Woodland on the Coronado National Forest (from USDA-USFS 2009). The distribution of Ponderosa pine structural classes for historical (reference) and current conditions is displayed below.

Structural Class	Reference	Current
Open forest states (Canopy closure <30%)		
Grass, seedling, saplings	0%	1%
Young forest	0%	4%
Mid-aged forest	<1%	6%
Mature forest	<1%	<1%
Old forest with regeneration	99%	<1%
Closed forest states (Canopy closure >30%)		
Grass, seedling, saplings	0%	1%
Young forest	0%	7%
Mid-aged forest	0%	47%
Mature and old forest	0%	32%

This altered fire regime or uncharacteristic fire has large effects on the tree canopy and understory vegetation structure of these woodlands. The increased density of woody species in the Madrean Montane Conifer-Oak Forest and Woodland has changed the fire regime to more mixed severity and stand replacing fires when fires occur (Barton 1999, Barton et al. 2001, Danzer et al. 1996, Schussman and Gori 2006, Smith 2006a, USDA-USFS 2009).

In addition, species composition is also affected by fire regime as more frequent fire favors oaks and other sprouting species over pines and other conifers, and less frequent fire (FRI >50 years) results in more conifer recruitment (Barton 1999, Barton et al. 2001, Danzer et al. 1996, Schussman and Gori 2006).

Fuel wood cutting for mining and domestic use was common in Madrean conifer-oak forest and woodland in southeastern Arizona until the late 1800's, and is still common in Arizona and northern Mexico today (Bahre 1991, Bennet 1992). Although fuel wood harvesting had a dramatic effect historically its consequences were generally local and short-lived (Turner et al. 2003). Logging has also impacted stands in this ecosystem.

Madrean conifer-oak forest and woodlands have been altered through road construction, exotic species introductions, logging, and fire suppression, contributing to what has been called the "no analogue" condition: the current evolutionary environment may be different from the historical evolutionary environment, and some historical conditions may be neither attainable nor desirable as management goals (Swetnam et al. 1999).

Fragmentation has a large impact especially around urban areas and has increased greatly in the last 70 years (Bahre 1991). It has been well documented as an ecological stressor and threat in many assessments and reports (Bahre 1991, Bock and Bock 2002, Finch 2004, Heinz Center 2011, Marshall et al. 2004, McPherson 1997, Ockenfels et al. 1994, Schussman 2006b). Urban development has lead to the loss and fragmentation many vegetation types and the alteration of ecological processes, such as fire, that use to maintain the vegetation with home, road and fence building (Bahre 1991, Finch 2004, McPherson 1997). In addition, roads are vectors for the spread of invasive non-native plant seeds, and for wildlife species, road kill increases, migration routes and home ranges are altered, and dispersal ability is compromised (USDA 2009).

D-6.1.5.3 Altered Dynamics Model

A conceptual state-and-transition model representing current conditions was developed by a team of ecologists (Schussman and Gori 2006) using the Vegetation Dynamics Development Tool (VDDT) to model the Madrean Pine-Oak Woodland (for details on tool see http://essa.com/tools/vddt/). Results are displayed below in two figures, one with the name of the different states in the boxes and one with representative pictures (Figure D-42 and Figure D-43). For methods on modeling please see Schussman and Gori (2006). This is the primary forest type of the CE. For models of other montane forest and woodland types treated as inclusions in this CE, please refer to Smith (2006a, 2006b, 2006c).

Figure D-42. Conceptual state and transition model of current conditions for the Madrean Pine Oak Woodland vegetation type. This model was taken directly from Schussman and Gori 2006. Frequency of transitions is noted (Schussman and Gori 2006).

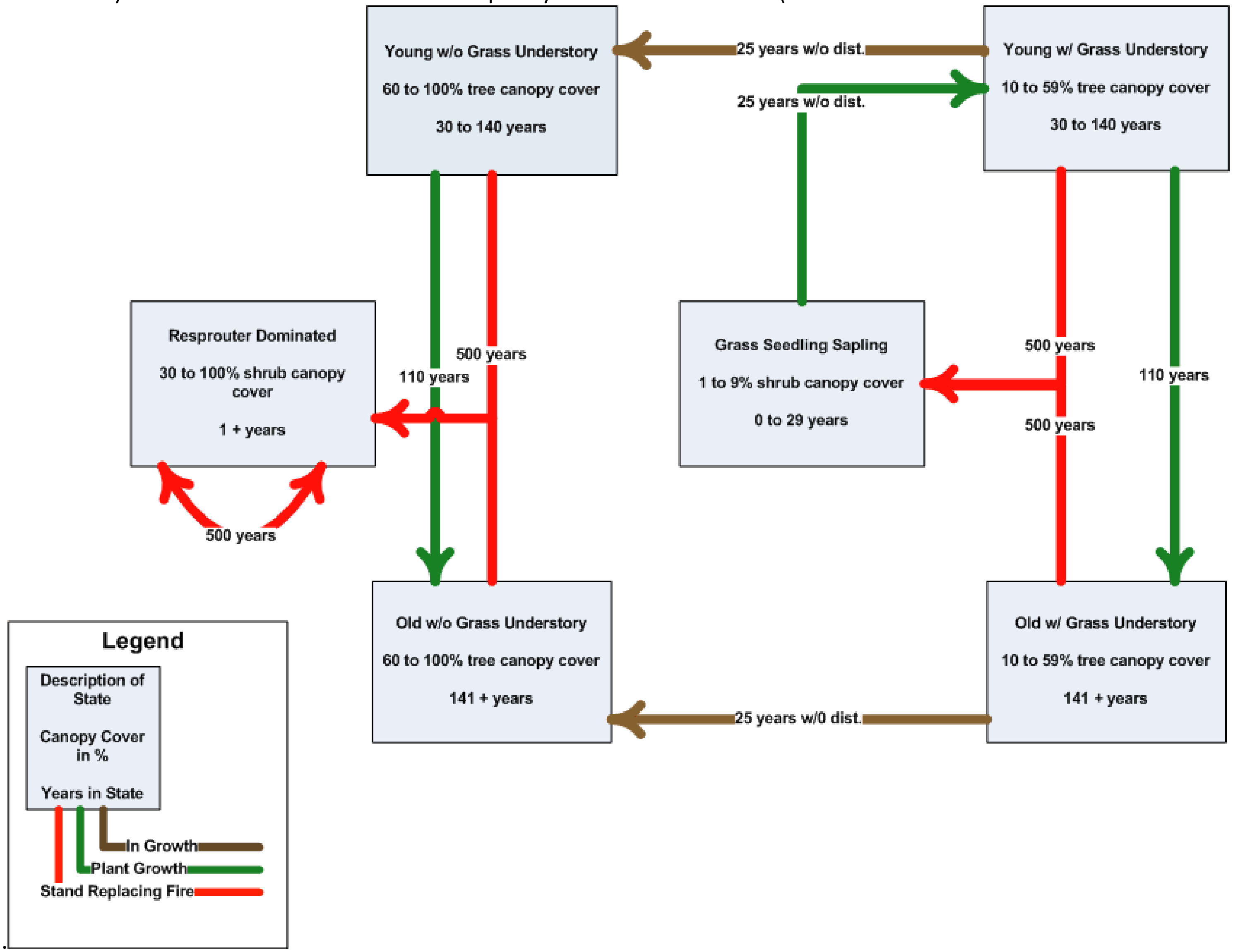
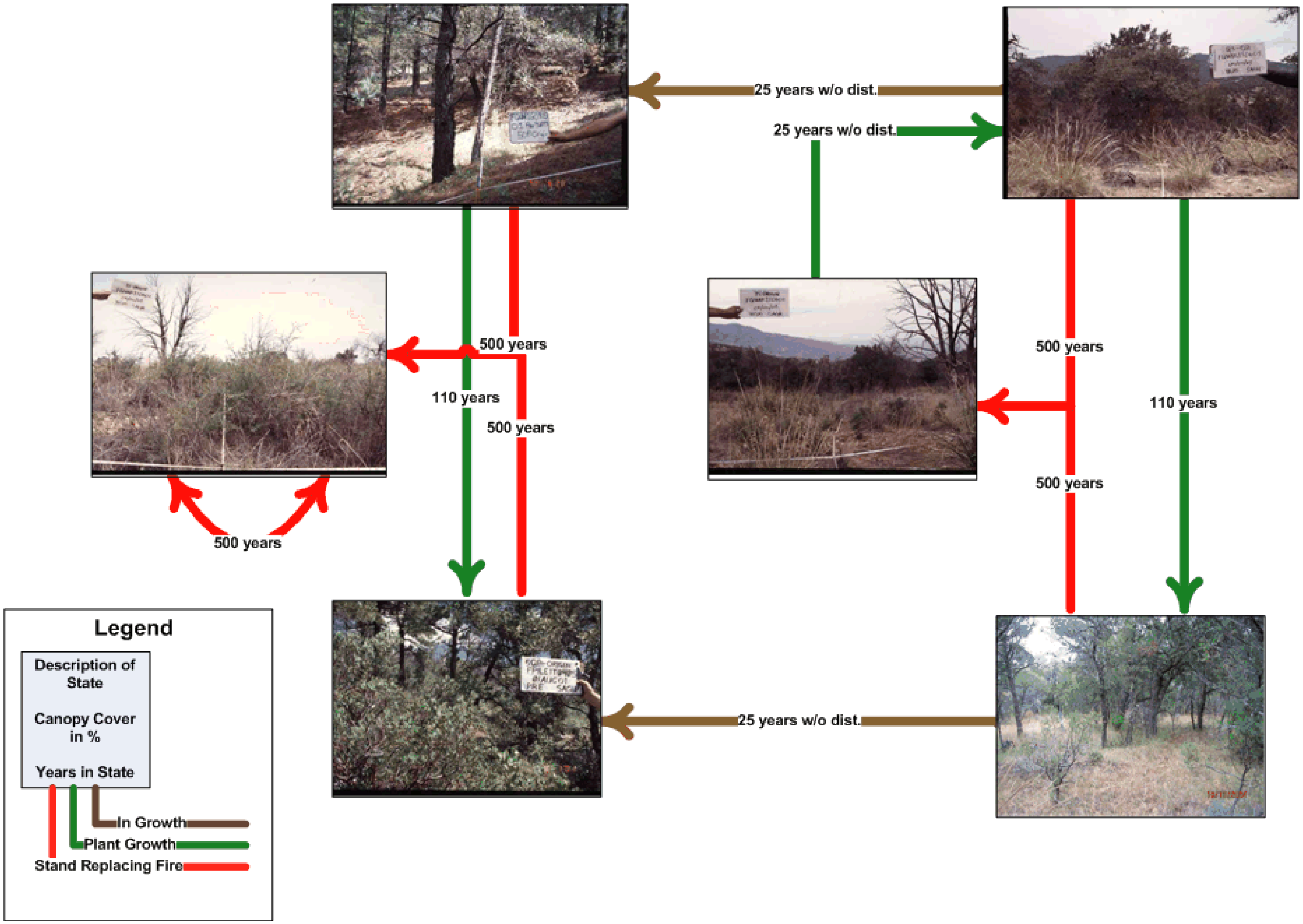


Figure D-43. Photographic depiction of conceptual state and transition model of current conditions for the Madrean Pine-Oak Woodland vegetation type. This model was taken directly from Schussman and Gori 2006. Frequency of transitions is noted. Photographs courtesy of James Leckie (Saguaro National Park) and Coronado National Forest (Schussman and Gori 2006).



D-6.1.6 Ecological Status: Key Ecological Attributes and Indicators

This section of the conceptual model addresses Key Ecological Attributes and their potential indicators. The ecological status is a way of describing current status via criteria, functionality, or levels of attributes and asks if they are within the normal range of variation.

D-6.1.6.1 Key Ecological Attributes

Table D-28 identifies the key ecological attributes for the CE within the Madrean Archipelago ecoregion. A **key ecological attribute** of a focal ecological resource is a characteristic of the resource's biology, ecology, or physical environment that is critical to the resource's persistence in the face of both natural and human-caused disturbance. Alteration of such a characteristic beyond some critical range of variation will lead to the degradation or loss of the resource within decades or less. The KEAs table lists the identified key ecological attributes, with a brief definition, a rationale for why it is important for the CE, and a listing of stressors or change agents that might be affecting the key attribute.

Table D-28. Key Ecological Attributes (KEA) of Madrean Montane Conifer-Oak Forest and Woodland ecosystem CE in the Madrean Archipelago ecoregion. Indicators for these KEAs can be used to determine the ecological status for this CE; see **Table D-2** for a list of the indicators assessed in this REA.

KEA Class: **Name**	**Definition general**	**Rationale general**	**Stressors general**
Landscape Context: **Landscape Condition**	This attribute is the amount of anthropogenic disturbance of the ecosystem that can be identified using a Land Condition Model Index (LCM). It incorporates a number of development features (including roads, urban/rural areas, agriculture, mines, transmission corridors, and energy development) that degrade the condition of the landscape.	Ecological conditions and landscape dynamics that support ecological systems or species habitat are affected by land use. Land use impacts vary in their intensity where they occur, as well as their ecological effects with distance (Comer and Hak 2009)	Stressors to landscape condition include multiple sources of fragmentation (reduces connectivity) that alter ecological processes (e.g., fire or surface hydrology), degrade wildlife habitat and disrupt wildlife migration patterns by creating barriers to species movement. Stressors include livestock grazing (reduces fine fuel that carry fire), urban and exurban development, and road building.
Size/Extent: **Patch Size Distribution**	The distribution of patch sizes (number and size class frequency) is a measure of fragmentation in this historically matrix or large patch ecosystem. Historical patch size/frequency is compared with current patch size/frequency.	This attribute is used to evaluate level of ecosystem fragmentation that interferes with landscape scale ecological processes. The current average patch size and total number of patches of the type are compared to earlier conditions where data are available.	Stressors include conversion to agriculture/pasture, commercial/industrial/residential use and construction of transportation infrastructure - roads, pipelines, transmission lines - that interfere with large-scale ecological processes such as fire or surface hydrology.

KEA Class: **Name**	**Definition general**	**Rationale general**	**Stressors general**
Size/Extent: **Ecosystem "Occurrence" Extent**	This attribute assesses the current size (ha) of the occurrence or stand as affects its biodiversity richness, structural complexity, and "internal" ecological processes, especially landscape scale processes like fire. Patch Size is measured as percentage of the Minimum Dynamic Area (MDA) for the ecosystem. This CE is a Large Patch type that functions best when patches are large ranging from 20 to 2000 hectares (approximately 50 to 5000 acres).	The area necessary to maintain ecological processes and ensure persistence is an ecosystem's minimum dynamic area (Pickett and Thompson 1978). Ecosystems with patch sizes above the minimum dynamic area (MDA) tend to exhibit vegetation structure and composition, landscape scale ecological processes, and soil and hydrology that are functioning within the natural range of variation. However, the role of patch size in assessing ecological integrity is complex and related to the larger landscape context. Fragmentation from roads and subdivisions has reduced the size of many patches so that the fire regime cannot be restored to pre-1882 frequency without management action i.e., prescribed fire. The MDA to maintain the fire regime (or any natural disturbance regime) under the historical range of natural variation for this ecological system has not been determined. Little empirical study has been done in ecosystems outside of eastern forests to determine the MDA; Faber-Langendoen et al. (2012b) developed criteria for rating patch size based on the spatial patterning of the ecosystem (i.e., matrix, large patch, small patch, or linear) and provide a discussion of the protocol for assessing size/extent.	Stressors to ecosystem extent include actions such as development and fire exclusion that directly or indirectly convert the ecosystem to other land uses or cover types, or actions such as roads that fragment large patches into many small patches.

KEA Class: Name	Definition general	Rationale general	Stressors general
Biotic Condition: **Terrestrial Fauna**	The taxonomic and functional (e.g., guild) composition of the native faunal assemblage of the ecosystem including birds, mammals, reptiles and amphibians, and invertebrates; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term). Monitoring populations of key native fauna will provide information on the condition of these important components of this ecosystem.	The taxonomic and functional composition of the faunal assemblage is an important aspect of the ecological integrity of an ecosystem. Many native species of birds, mammals, reptiles and amphibians, and invertebrates use this ecosystem as habitat for feeding, resting, breeding, and movement; and their patterns of use vary over time (seasonal, annual, longer-term) (Finch 2004, McClaran and McPherson 1999, McPherson 1997). These species vary in their sensitivity to different stresses such as alterations to vegetation composition, fire frequency, and water availability. Alterations in the taxonomic and functional composition of the terrestrial faunal assemblage beyond its natural ranges of variation therefore strongly indicate the types and severities of stresses imposed on the ecosystem.	Stressors to the taxonomic and functional composition of the faunal assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, floral composition, and abiotic condition of the ecosystem; and incursions of non-native species that alter the food web or directly compete with or prey on the native fauna.
Biotic Condition: **Vegetation Composition**	The overall plant species composition and diversity of an ecosystem is an important aspect of its ecological integrity and largely defines it.	The taxonomic and functional composition of the plant species assemblage is an important aspect of the ecological integrity of a terrestrial ecosystem; many ecological processes and environmental variables affect it (drought, fire regime, anthropomorphic disturbance). In addition, the impact of invasive non-native species on community function of native vegetation is well documented (Anable et al. 1992, Cable 1971, Cox et al. 1988). Livestock grazing can affect the structure and composition of shrub and herbaceous layers, soil structure and water infiltration, as well as species diversity (USDA-USFS 2009). Plant species vary in their sensitivity to different stresses such as grazing or lack of fire. This can alter the taxonomic composition of the terrestrial floral assemblage beyond its natural range of variation and strongly indicate the types and severities of stresses imposed on the ecosystem (Kaib et al. 1996, Swetnam and Baisan 1996).	Stressors to the taxonomic and functional composition of the plant assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, vegetation structure, and abiotic condition of the ecosystem; especially altered fire regime, improper livestock grazing management, and incursions of non-native species that alter the food web or directly compete with the native plants.

KEA Class: Name	Definition general	Rationale general	Stressors general
Biotic Condition: **Vegetation Structure**	An assessment of the overall structural complexity of the vegetation layers, including presence or cover of multiple strata, age and structural complexity of main canopy layer, and expected frequencies of successional or age classes.	Vegetation structure is an important reflection of dynamics and creates heterogeneity within the community. The distribution of total cover, crown diversity, stem size, and age classes or cohorts reflects natural disturbance regimes across the landscape and affects the maintenance of biological diversity, particularly of species dependent upon specific stages. An open to closed conifer & oak tree canopy with low to moderate cover of native perennial grass defines Madrean Conifer-Oak Forest and Woodland CE.	Alteration of vegetation structure can come from a variety of stressors, including changes in fire regime (e.g. too frequent or too infrequent), logging or other removal of woody species, livestock grazing or concentrated native herbivory that removes native perennial herbaceous plants, climate change, and various kinds of mechanical disturbance that damages or removes vegetation.
Abiotic Condition: **Soil Condition**	Soil is basic to the proper functioning of a terrestrial ecosystem. Good soils will enhance the resilience and function of an ecosystem. Poor condition soil will limit the function of an ecosystem and if not addressed can permanently degrade a site. Soil condition includes indicators of multiple soil properties such as soil structure (particle and pore size, vertical profile, soil aggregates) and surface condition such as presence of soil crusts.	The condition of soil/surface substrate directly affects the functioning of the ecosystem. Soil/surface substrate condition of a site can be directly evaluated using indicators of soils disturbance such as evidence of erosion and disrupted soil processes and properties. The types of disturbances (stressors) can also be recorded to indicate condition such as livestock trampling and recreational vehicles. These disturbances can directly affect soil properties by disturbing soil crusts, compacting pore space that reduces water infiltration and percolation, changing other structural characteristics, and can expose soils to increased erosional forces.	Excessive livestock trampling, vehicle use (motorbikes, off-road vehicles, construction vehicles), filling and grading, plowing, other mechanical disturbance to the soil surface, excessive soil movement (erosion or deposition) as evidenced by gully, rill, or dune formation. Climate change and drought can also lead to increased potential for erosion.
Abiotic Condition: **Fire Regime**	Fire is a natural agent of disturbance in upland vegetation communities that maintains species composition, vegetation structure, and sustains ecological processes such as nutrient cycling.	Altered (uncharacteristic) fire regime greatly influences ecosystem processes (Barton 1999, Muldavin et al. 2002, Turner et al. 2003). For Madrean Conifer-Oak Forest and Woodland, low intensity surface fire (mean FRI of 6-14 years) with occasional fire free periods of 20-30 years are necessary for pines to establish and become resistant (thick bark) to surface fires and is key to maintaining these forests and woodlands (Bahre 1985, Barton et al. 2001, Kaib et al. 1996, McPherson 1995, Swetnam and Baisan 1996, Swetnam et al. 1992, Wright 1980).	Fire exclusion in fire-maintained ecosystems results in increased woody species density and cover, changes in wildlife species assemblages, and increased fuel that ultimately produce high severity fire. Specific stresses include fire suppression with building roads that act as fire breaks, and active fire suppression by land owners and agency personnel.

D-6.1.7 Relationship of KEAs to Fundamentals of Rangeland Health

The key ecological attributes and indicators listed in Table D-28 also encompass the four fundamentals of rangeland health (USDI-BLM 2006), as shown in Table D-29. The KEA of Landscape Condition specifically refers to watershed conditions; all other KEAs refer specifically to Ecological Processes and Habitat. However, many of the indirect indicators for the KEAs for Abiotic Condition focus on stressors that arise as a result of modifications to the watershed or water quality, the fourth Fundamental. These relationships are also indicated in Table D-29. Further information about interpretation and assessment of these fundamentals of rangeland health is found in Pellant et al. (2005).

Table D-29. Key Ecological Attributes (KEA) for the Madrean Montane Conifer-Oak Forest and Woodland, and their relationship to fundamentals of rangeland health.

Indicator	Watershed	Ecological Processes	Water Quality	Habitat
Landscape Condition	X	X	X	X
Patch Size	X	X		X
Terrestrial Fauna				X
Vegetation Composition		X		X
Vegetation Structure				X
Soil Condition		X	X	X
Fire Regime	X	X		X

D-6.1.8 Conceptual Model Diagrams

See Figure D-41, Figure D-42, and Figure D-43.

D-6.2 Ecological Status Assessment Results and Interpretation

This section of the appendix presents and discusses the results of the ecological status assessment for the Madrean Montane Conifer-Oak Forest and Woodland CE. The presentation addresses each indicator separately, and then addresses the overall assessment, which integrates the results of all individual indicators. The results are presented using a common framework, in which the status of an indicator – or the combination of all indicators – is scored on a scale from 0.0 to 1.0, where 0.0 indicates a condition of complete replacement of reference ecological conditions due to the impacts of stressors, and 1.0 indicates a condition of no alteration of reference ecological conditions. The same color ramp is used for all results, yellow to dark blue, where yellow equals low scores, green moderate scores and dark blues high scores.

D-6.2.1 Current Ecological Status: Development, Fire Regime, Invasives

The maps below (Figure D-44) show the ecological status results for each of the three individual indicators – development, fire regime departure, and invasives – for the Madrean Montane Conifer-Oak Forest and Woodland.

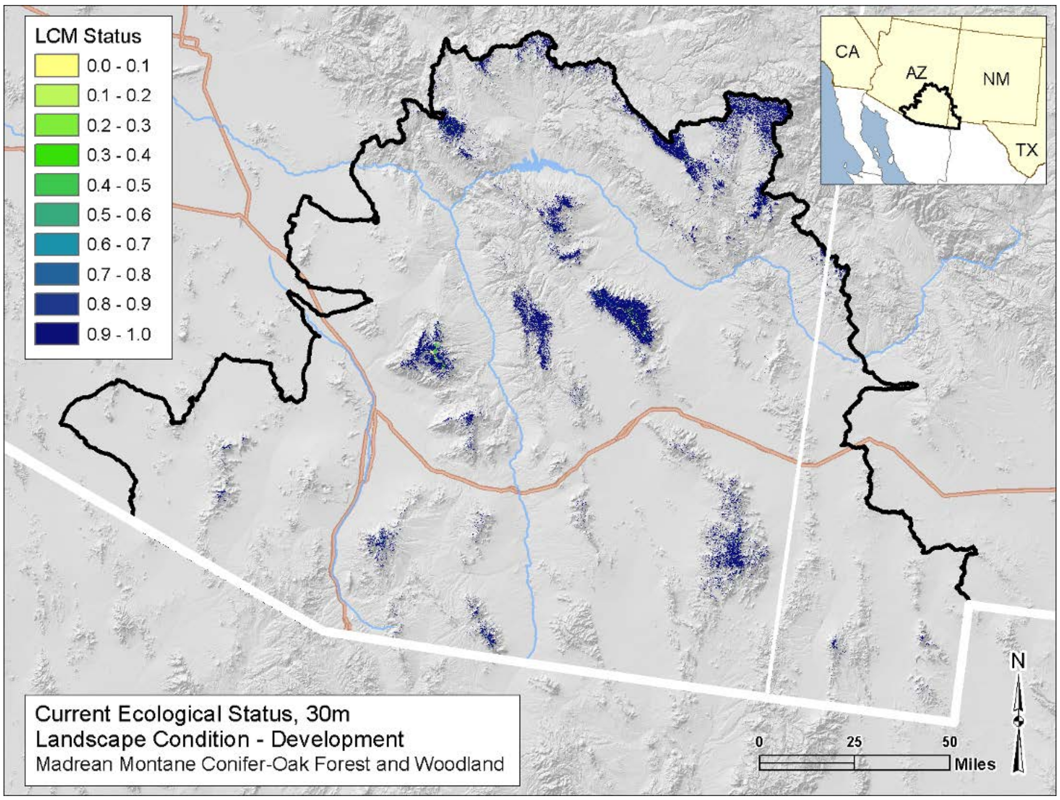
The development indicator is a stressor-based indicator of the spatial extent and intensity of human modifications to the land surface that alters ecosystems or habitat in the MAR ecoregion. The indicator takes into account the density of urban development; infrastructure such as above- and below-ground distribution corridors, communication towers, and border barriers; a wide range of transportation features; mines and landfills; recreational development; agriculture; and energy development. The scoring is on a continuous scale from 0 to 1, with the highest score of 1.0 indicating no ecologically relevant modifications, and the lowest score of 0.0 indicating modifications that essentially eliminate all natural cover and ecological functions.

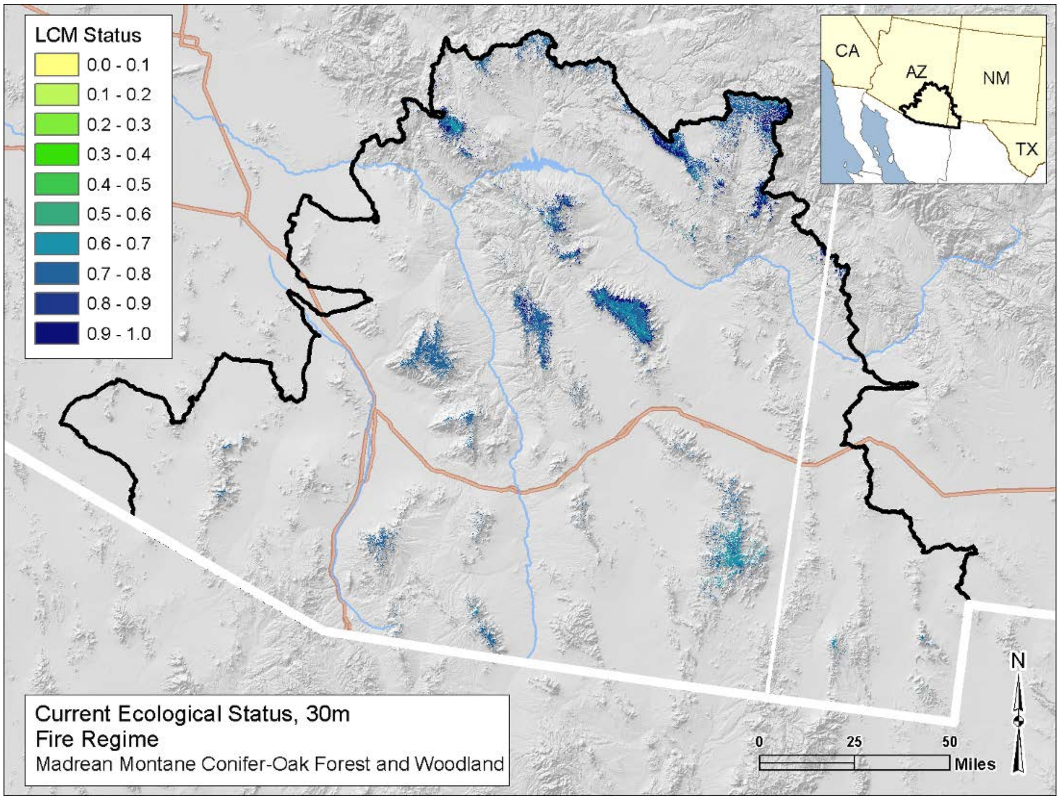
The development indicator results shown in the first map of Figure D-44 indicates that there is very little development within or adjacent to the Madrean Montane Conifer-Oak Forest and Woodland CE. A small patch of development can be seen in the Catalina Mountains, where the Mt Lemmon observatory and visitor center are located, with associated roads and infrastructure.

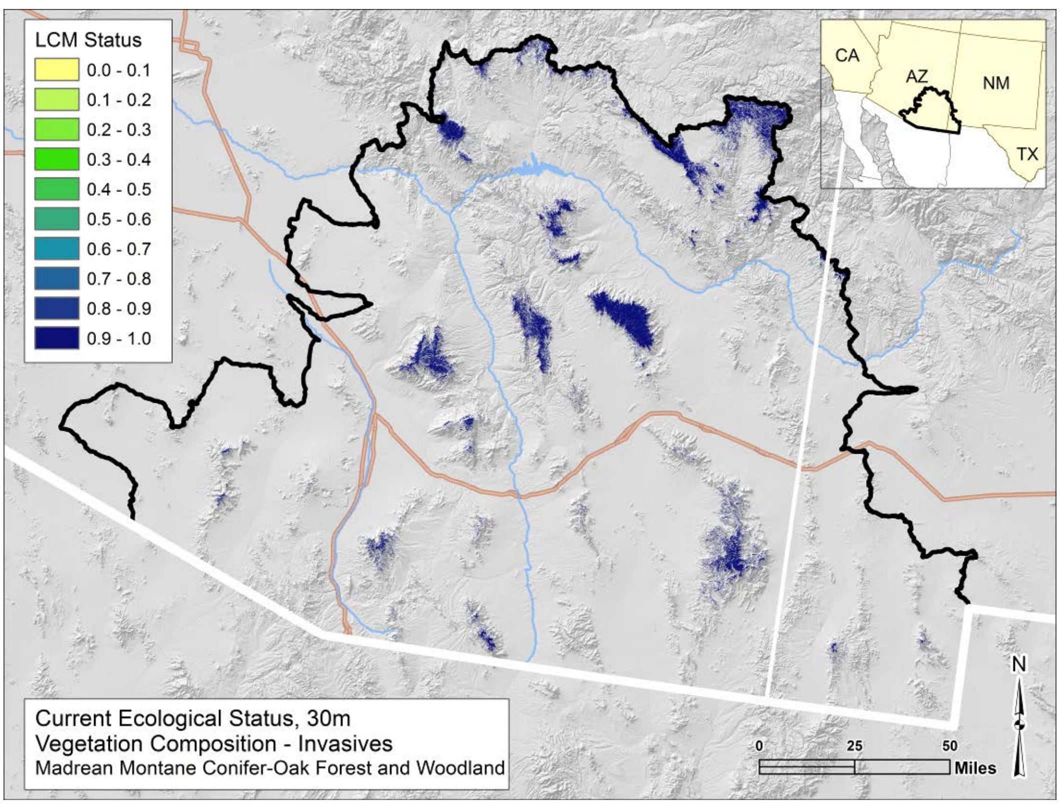
It is important to note that most development impacts are scored much lower than non-development change agents; for example, site intensity values for urbanization ranged from 0.05 to 0.6 for high to low density development, respectively. This is because development typically has a much stronger on-site impact than the other indicators. However, except for urban development, most development impacts occur at smaller scales than can be displayed in these maps, but still are pervasive throughout much of the ecoregion. In particular, effects of many of the very small, local areas of development, or small linear features (e.g. dirt roads) will not be obvious at the scale of the development indicator map.

The second indicator is an indirect measure of fire regime. It is based on the Vegetation Condition Class (VCC) dataset produced by Landfire, which was developed to compare historical reference conditions with current conditions for an individual ecological system type (see **Status Assessment Methods** above). The result of VCC is a ranking of departure from expected historical range of variability, which can be interpreted as “how has the disturbance regime [for the REA purposes and relevant to this ecoregion: fire regime] changed from its historical variability for this individual CE”. Only Severe Vegetation Departure (0.65) and Moderate Vegetation Departure (0.75) were used and are displayed in the map; no to minor departure was scored as 1 (dark blue in the map).

Figure D-44. Scores for three indicators for Madrean Montane Conifer-Oak Forest and Woodland: development indicator (first map), fire regime departure indicator (second map), and invasive species indicator (third map) for each 30m pixel. At the ecoregion scale, many development features are not readily visible (i.e. secondary roads or highways, railroads, small agricultural fields). Yellow (equivalent to 0) indicates high impacts from the CA, dark blue (equivalent to 1) indicates little to no impact from the CA. Only 3 classes of fire regime condition are scored: no to little departure (dark blue), moderate departure and severe departure (lighter blues). For the invasives indicator results, higher cover of mesquite or invasive exotics will score between .4 and .6 (light greens), while lower cover scores between .6 and .8 (light blues).




LCM Status
0.0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1.0
CA
AZ
NM
TX
Current Ecological Status, 30m
Fire Regime
Madrean Montane Conifer-Oak Forest and Woodland
0
25
50
Miles
N


LCM Status
0.0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 0.7
0.7 - 0.8
0.8 - 0.9
0.9 - 1.0
CA
AZ
NM
TX
Current Ecological Status, 30m
Vegetation Composition - Invasives
Madrean Montane Conifer-Oak Forest and Woodland
0
25
50
Miles
N

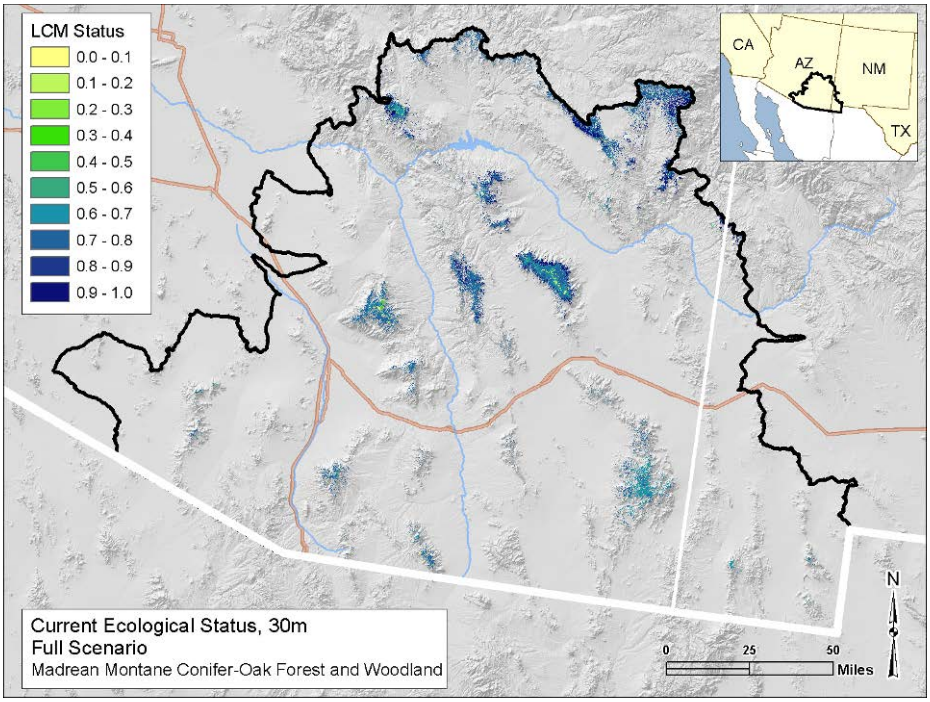
The second map in Figure D-44 shows a mixture of severe (0.6-0.7) and moderate (0.7-0.8) departure for the Madrean Montane Conifer-Oak Forest and Woodland CE across the MAR ecoregion. The higher elevation stands are more departed because of fewer fires. Fragmentation of landscape can impact the movement of fires that start in lower elevation savannas and woodlands and burn upslope into the montane zones. This spatial result is supported by research documenting the results of fire exclusion in the REA. Active and passive fire suppression over the last century has excluded fire from much of these woodlands (Schussman and Gori. 2006). Historical fire regimes for the Madrean Conifer-Oak Forest and Woodland included low intensity surface fire (mean FRI of 6-14 years) with occasional fire free periods of 20-30 years are necessary for pines to establish and become resistant (thick bark) to surface fires and is key to maintaining these forests and woodlands (Bahre 1985, Barton et al. 2001, Kaib et al. 1996, McPherson 1995, Swetnam and Baisan 1996, Swetnam et al. 1992, Wright 1980). Fire exclusion has reduced the number of fires and increased fire severity in conifer-oak forests and woodlands and adjacent vegetation types like encinal across much of the southwestern US and adjacent Mexico (Kaib et al. 1996, Swetnam and Baisan 1996).

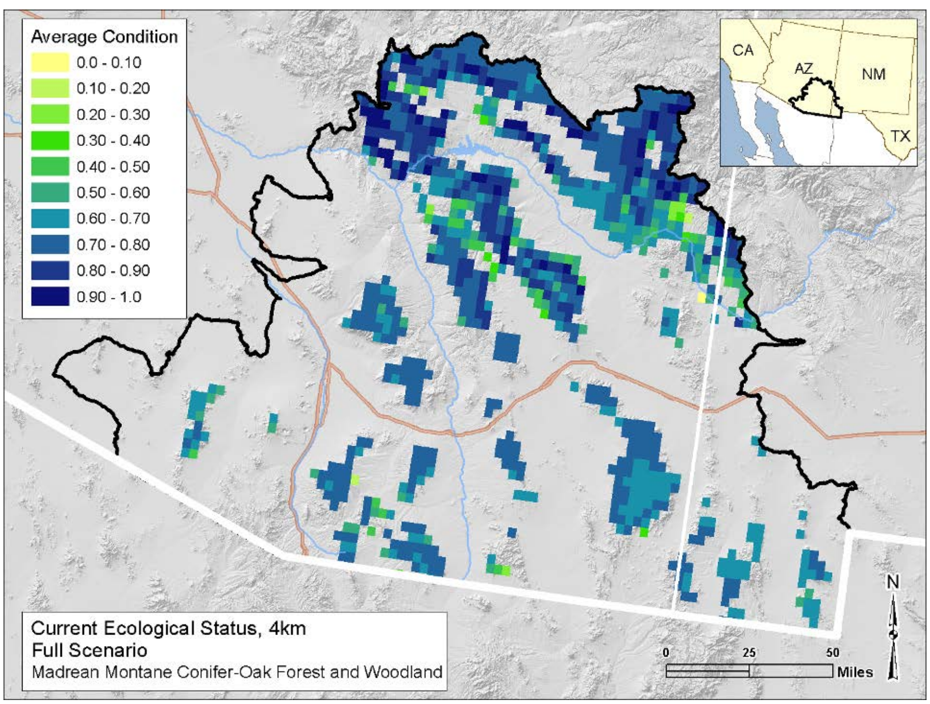
The invasive species indicator serves as an indirect measure of vegetation composition, by measuring the cover of invasive species. It includes a combination of non-native grass and forbs and native woody increasers (mesquite cover), as described previously in this appendix. The scoring is on a continuous scale from 0 to 1, with the highest score of 1.0 indicating no ecologically relevant cover of invasive species, and 0.0 indicating a conversion to non-native grasses and forbs and/or invasive mesquite. Table D-3 shows the cover classes used and the site intensity values for them, for this CE. The values range from 0.65 to 0.90. Either or both non-native invasive and native invasive woody cover may occur on in a single pixel. If both occur, then scores for that pixel are multiplied to create a new combined, lower indicator score.

The third map in Figure D-44 indicates relatively low invasion of exotic grasses and forbs, and/or invasive native shrub in the Madrean Montane Conifer-Oak Forest and Woodland CE. This result is what would be expected, as both the invasive exotics and native mesquite represented by the ILAP invasives datasets are very uncommon at the higher elevations. Mesquite does not occur in the Madrean Montane Conifer-Oak Forest and Woodland CE.

D-6.2.2 Current Ecological Status: Full Scenario

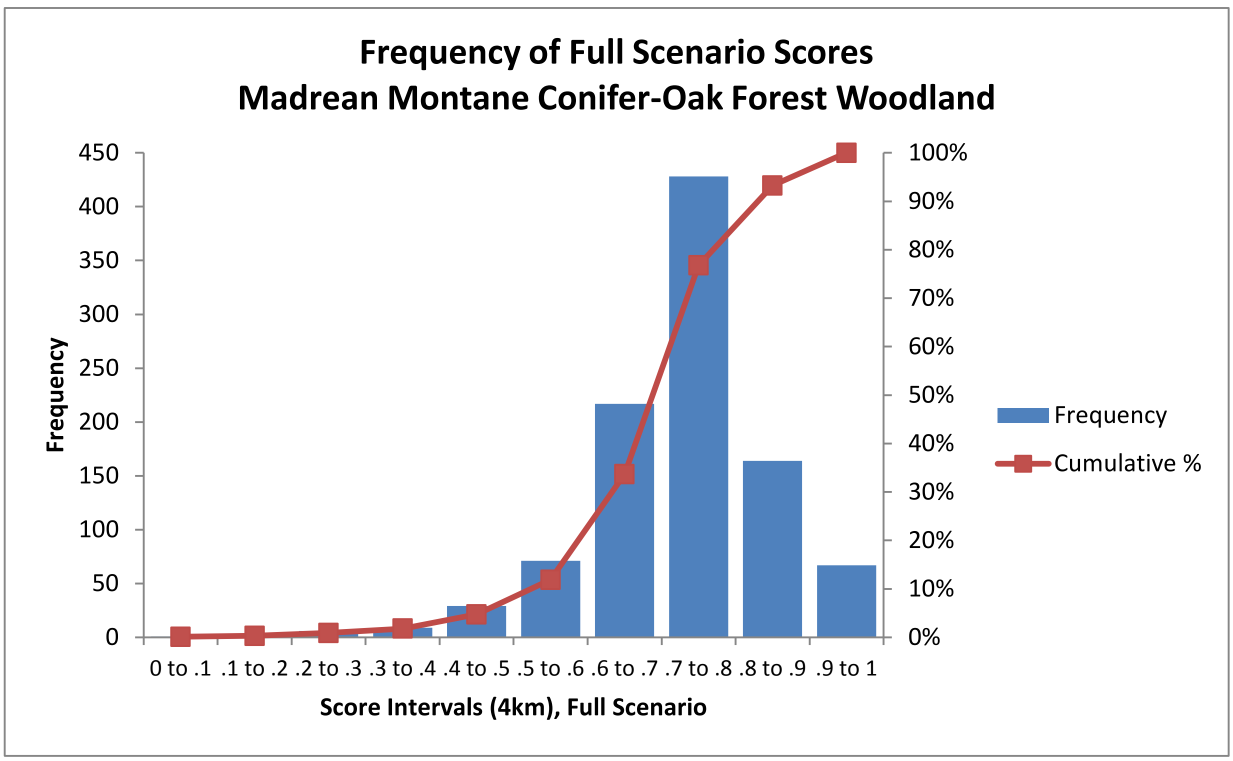
Figure D-45. Overall ecological status scores for Madrean Montane Conifer-Oak Forest and Woodland for all indicators combined (development, fire regime and invasives) for each 30m pixel (top) and 4km grid cells (bottom). The score for each 4km cell is an average of all 30m pixels that are scored for the CE. Yellow scores (equivalent to 0) indicate high impacts from the CAs, dark blue (equivalent to 1) indicate little to no impact from the CAs.





The first map in Figure D-45 illustrates all three of the indicators combined into a single ecological status score per pixel of the CE's distribution. The combined, per-pixel status scores are noticeably lower than the individual scores for each indicator. The combined status scores for each pixel are then summarized to the reporting unit (e.g., 4km grid) by taking the average status score from all the pixels of the CE within the reporting unit. The results, shown in the second map in Figure D-45 and the frequency diagram (Figure D-46) indicate that the Madrean Montane Conifer-Oak Forest and Woodland is generally less degraded in condition than the other terrestrial CEs. Compared to the other CEs, only some 35% of the grid cells fall at or below the 0.7 score. This is a result of the higher elevations where this CE occurs, away from most development impacts and certainly where the invasives are a minor problem. The results are driven by moderate and severe departure in fire regime for the Madrean Montane Conifer-Oak Forest and Woodland CE across the MAR ecoregion. There are a few local areas of better ecological conditions, a result low level of development, low or no cover of invasive species, and moderate fire regime departure. The map clearly shows better condition areas in the northern portion of the MAR ecoregion.

Figure D-46. Frequency distribution of the 4km ecological status scores for the Madrean Montane Conifer-Oak Forest and Woodland, with cumulative percent. The x-axis represents the 0.1 increment scoring intervals, while the y-axis shows the number of grid cells in each interval (left) and the cumulative percentage of the grid cells for each interval (right). For this CE, most of the status scores fall in the range from 0.6 to 0.9.



D-6.3 References for the CE

Anable, M. E., M. P. McClaran, and G. B. Ruyle, 1992. Spread of introduced Lehmann lovegrass *Eragrostis lehmanniana* Nees. in southern Arizona, USA. Biological Conservation, 61, 181-188.

AZGFD [Arizona Game and Fish Department]. 2012. Arizona's State Wildlife Action Plan: 2012-2022. Arizona Game and Fish Department, Phoenix, Arizona.

Bahre, C. J. 1985. Wildfire in southeastern Arizona between 1859 and 1890. Desert Plants, 7, 190-194.

Bahre, C.J. 1991. *A legacy of change: historic human impact on vegetation of the Arizona borderlands*. The University of Arizona Press, Tucson, AZ.

Barton, A.M. 1993. Factors controlling plant distributions: drought, competition, and fire in montane pines in Arizona. Ecological Monographs, 63, 367-397.

Barton, A.M. 1999. Pines versus oaks: effects of fire on the composition of Madrean forests in Arizona. Forest Ecology and Management, 120, 143-156.

Barton, A.M., T.W. Swetnam, and C.H. Baisan. 2001. Arizona pine (*Pinus arizonica*) stand dynamics: local and regional factors in a fire-prone Madrean gallery forest of southeast Arizona, USA. Landscape Ecology, 16, 351-369.

Bennet, D.A. 1992. Fuelwood extraction in southeastern Arizona. Pages 96-97 *in* P.F. Ffolliott, G.J. Gottfried, D.A. Bennett, V.M. Hernandez C., A. Ortega-Rubio, and R.H. Hamre (tech. coords.). Ecology and management of oak and associated woodlands: perspectives in the Southwest in: Ffolliott, P.F. G.J. Gottfried, and D.A. Bennett and others, tech. coords.rn United States and northern Mexico. Proceedings; 1992 April 27-30; Sierra Vista, AZ. General Technical Report RM-218. Fort Collins, CO: USDA Forest Service, Rocky Mountain and Range Experiment Station.

Bock, C. E. and J. H. Bock 2002.Numerical response of grassland birds to cattle ranching versus exurban development in southeastern Arizona. 87th Annual Meeting of the Ecological Society of America and the 14th Annual International Conference of the Society for Ecological Restoration.

Brown, D.E. 1982. Madrean Evergreen Woodland. Pages 59-65 in: Brown, D. E., editor. 1982. Biotic communities of the American Southwest-United States and Mexico. Desert Plants Special Issue 4(1-4):1-342.

Cable, D. R. 1971. Lehmann lovegrass on the Santa Rita Experimental Range, 1937-1968. Journal of Range Management. 24: 17-21.

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. Ecological systems of the United States: A working classification of U.S. terrestrial systems. NatureServe, Arlington, VA.

Comer, P. J., and J. Hak. 2009. NatureServe Landscape Condition Model. Technical documentation for NatureServe Vista decision support software engineering. NatureServe, Boulder, CO.

Comer, P., and J. Hak. 2012. Landscape condition model of the western United States. NatureServe, Boulder, CO. In preparation.

Cox, J. R., G. B. Ruyle, J. H. Fourle, and C. Donaldson. 1988. Lehmann lovegrass--central South Africa and Arizona, USA. Rangelands. 10(2): 53-55.

Dahms, C.W. and B.W. Geils tech. eds. 1997. An assessment of forest ecosystem health in the Southwest. General Technical Report RM-GTR-295. Fort Collins, CO. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 97 p.

Danzer, S. R., C. H. Baisan, and T. W. Swetnam. 1996. The influence of fire and land-use history on stand dynamics in the Huachuca mountains of southeastern Arizona. Effects of fire on Madrean province ecosystems. RM-GTR 289. United States Department of Agriculture.

Dick-Peddie, W. A. 1993. New Mexico vegetation: Past, present, and future. University of New Mexico Press, Albuquerque. 244 pp.

Faber-Langendoen, D., J. Rocchio, S. Thomas, M. Kost, C. Hedge, B. Nichols, K. Walz, G. Kittel, S. Menard, J. Drake, and E. Muldavin. 2012b. Assessment of wetland ecosystem condition across landscape regions: A multi-metric approach. Part B. Ecological Integrity Assessment protocols for rapid field methods (L2). EPA/600/R-12/021b. U.S. Environmental Protection Agency Office of Research and Development, Washington, DC.

Ffolliott, P. F and M.B. Baker. 1999. Montane Forests in the southwestern United States. Chapter 4. Pages 39-52 in: P. F. Ffolliott and A. Ortega-Rubio, editors. Ecology and Management of Forests, Woodlands, and Shrublands in Dryland Regions of the United States and Mexico: Perspectives for the 21st Century. Co-edition number 1. University of Arizona-Centro de Investigacione.

Finch, D.M. 2004. Assessment of Grassland Ecosystem Conditions in the Southwestern United States. Fort Collins, Colorado, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Garfin, A. Jardine, R. Merideth, M. Black, and S. LeRoy. editors. 2013. Assessment of Climate Change in the Southwest United States: A Report Prepared for the National Climate Assessment, A report by the Southwest Climate Alliance. Washington, DC: Island Press.

Gori, D. F. and C. A. F. Enquist. 2003. An assessment of the spatial extent and condition of grasslands in central and southern Arizona, southwestern New Mexico and northern Mexico. The Nature Conservancy, Arizona Chapter. Pp29.

Heinz Center. 2011. Managing and Monitoring Arizona's Wildlife in an Era of Climate Change: Strategies and Tools for Success Report and Workshop Summary. Prepared for: U.S. Department of Interior. Bureau of Land Management and The Arizona Game and Fish Department by the H. John Heinz III Center for Science Economics and the Environment. January 13, 2011. Washington, D. C. 67 pp. plus appendices.

Kaib, M., C.Baisan, H. D. Grissino-Mayer, and T. W. Swetnam. 1996. Fire history of the Gallery pine-oak forests and adjacent grasslands of the Chiracahua Mountains of Arizona. Pages 253-264 in: Folliott, P. F., D. F. DeBano, D. M. Baker, G. J. Gottfried, G. Solis-Garza, C. B. Edminster, D. G. Neary, L. S. Allen, and R. H. Hamre, eds. 1996. Effects of fire on Madrean province ecosystems-a symposium proceedings. Gen. Tech. Rep. RM-289; 1996 March 11-15; Tucson, AZ. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Experiment Station. 277 pp.

Majka, D., J. Jenness, and P. Beier. 2007 Arizona CorridorDesigner.Toolbox Documentation. http://corridordesign.org/.

Marshall, R.M., A.Turner, A. Gondor, D. Gori. C. Enquist, G. Luna, R. Paredes Aguilar, S. Anderson, S. Schwartz, C. Watts, E. Lopez, P. Comer. 2004. An ecological Analysis of Conservation Priorities in the Apache Highlands Ecoregion. Prepared by The Nature Conservancy of Arizona, Instituto del Medio Ambiente y el Desarrolla Sustentable del Estado de Sonora, agency and institutional partners. 152 pp.

McClaran, M.P. and McPherson, G.R. 1999. Chapter 17, Oak Savanna in the American Southwest. Pages 275-287 in R.C. Anderson, J.S., Fralish and J.M. Baskin, editors. *Savannas, Barrens, and Rock Outcrop Plant Communities of North America*. Cambridge University Press, Cambridge, England.

McPherson, G.R. 1997. Ecology and management of North American savannas. The University of Arizona Press, Tucson, Arizona.

McPherson, G. R. 1995. The role of fire in the desert grasslands. Pages 130-151 in: M. P. McClaran and T. R. Van Devender, editors. The Desert Grassland. University of Arizona Press, Tucson.

Milchunas, D.G. 2006. Responses of plant communities to grazing in the southwestern United States. Gen. Tech. Rep. RMRS-GTR-169. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 126 p.

Moir, W.H., and Ludwig, J.A. 1979. A classification system of spruce-fir and mixed conifer habitat types of Arizona and New Mexico. Res. Pap. RM-207. Ft. Collins, CO: USDA, FS, 47 pp.

Muldavin, E. H., R. L. DeVelice, and F. Ronco, Jr. 1996. A classification of forest habitat types southern Arizona and portions of the Colorado Plateau. General Technical Report RM-GTR-287. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 130 pp.

Muldavin, E, T. Neville, C. McGuire, P. Pearthree, and T. Biggs. 2002. Soils, geology and vegetation change in the Malpais Borderlands. Publication No. 05-GTR-228. Natural Heritage New Mexico, Museum of Southwestern Biology, University of New Mexico. 26 p. NatureServe. 2013. International Ecological Classification Standard: International Vegetation Classification. Central Databases. NatureServe, Arlington, VA.

NatureServe. 2013. International Ecological Classification Standard: International Vegetation Classification. Central Databases. NatureServe, Arlington, VA.

NMDGF [New Mexico Department of Game and Fish]. 2006. Comprehensive Wildlife Conservation Strategy for New Mexico. New Mexico Department of Game and Fish. Santa Fe, NM. 526 pp + appendices.

Ockenfels, R.A., C.L. Ticer, A., Alexander, and, J.A. Wennerlund. 1994. Home ranges, movement patterns, and habitat selection of pronghorn in central Arizona a final report. March 1994. Phoenix, Arizona, Arizona Game and Fish Department Research Branch.

Pase, C.P. and D.E. Brown. 1982. 122.3 Rocky Mountain (Petran) and Madrean Montane Conifer Forests. Pages 43-48 in: Brown, D. E., editor. 1982. Biotic communities of the American Southwest-United States and Mexico. Desert Plants Special Issue 4(1-4):1-342

Pellant, M., P. Shaver, D.A. Pyke, and J.E. Herrick. 2005. Interpreting indicators of rangeland health, version 4. Technical Reference 1734-6. BLM/WO/ST-00/001+1734/REV05. U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center, Denver, CO. 122 pp.

Pickett, S.T.A., and J.N. Thompson. 1978. Patch dynamics and the size of nature reserves. Biological Conservation 13: 27-37.

Schussman, H. 2006b. Historical Range of Variation for Madrean Encinal of the Southwestern U.S. Prepared for the U.S.D.A. Forest Service, Southwestern Region by The Nature Conservancy, Tucson, AZ. 16 pp.

Schussman, H. and D. Gori. 2006. Historical Range of Variation and State and Transition Modeling of Historical and Current Landscape Conditions for Madrean Pine-Oak of the Southwestern U.S. Prepared for the U.S.D.A. Forest Service, Southwestern Region by The Nature Conservancy, Tucson, AZ. 35 pp.

Smith, E. 2006a. Historical Range of Variation and State and Transition Modeling of Historical and Current Landscape Conditions for Ponderosa Pine of the Southwestern U.S. Prepared for the U.S.D.A. Forest Service, Southwestern Region by The Nature Conservancy, Tucson, AZ. 43 pp.

Smith, E. 2006b. Historical Range of Variation and State and Transition Modeling of Historical and Current Landscape Conditions for Mixed Conifer of the Southwestern U.S. Prepared for the U.S.D.A. Forest Service, Southwestern Region by The Nature Conservancy, Tucson, AZ. 31 pp.

Smith, E. 2006c. Historical Range of Variation and State and Transition Modeling of Historical and Current Landscape Conditions for Spruce-Fir of the Southwestern U.S. Prepared for the U.S.D.A. Forest Service, Southwestern Region by The Nature Conservancy, Tucson, AZ. 37 pp.

Stuever, M. C. and J. S. Hayden. 1997b. Plant associations of Arizona and New Mexico. Edition 3. Volume 1: Forests. USDA Forest Service, Southwestern Region, Habitat Typing Guides. 291 pp

Swetnam, T.W., C.D. Allen, J.L. Betancourt. 1999. Applied historical ecology: using the past to manage for the future. Ecological Applications 9(4):1189-1206.

Swetnam, T.W. and C.H. Baisan,. 1996. Fire histories of montane forests in the Madrean borderlands. Effects of fire on Madrean Province ecosystems: A symposium proceedings. RM-GTR-289. December 1996. USDA Forest Service.

Swetnam, T. W., C.H. Baisain, A.C. Caprio, and P.M. Brown. 1992. Fire history in a Mexican oak-pine woodland and adjacent montane conifer gallery forest in southeastern Arizona. Pages 165-173 in P.F. Ffolliott, G.J. Gottfried, D.A. Bennett, V.M. Hernandez C., A. Ortega-Rubio, and R.H. Hamre (tech. coords.). Ecology and management of oak and associated woodlands: perspectives in the southwestern United States and northern Mexico. Proceedings; 1992 April 27-30; Sierra Vista, AZ. General Technical Report RM-218. Fort Collins, CO: USDA Forest Service, Rocky Mountain and Range Experiment Station.

Swetnam, T.W., C.H. Baisan, and, M.J. Kaib. 2001. Forest fire histories of La Frontera: Fire-scar reconstructions of fire regimes in the United States/Mexico borderlands. In G.L. Webster and C.J. Bahre (eds.), Vegetation and Flora of La Frontera: Historic vegetation change along the United States/Mexico boundary. University of New Mexico Press.

Swetnam, T.W. and J.L. Betancourt. 1990. Fire - Southern oscillation relations in the southwestern United States. Science, 1017-1020.

Turner, R.M., R.H. Webb, J.E. Bowers, and J.R Hastings. 2003. The changing mile revisited An ecological study of vegetation change with time in the lower mile of an arid and semiarid region. University of Arizona Press, Tucson, Arizona.

Unnasch, R.S., D. P. Braun, P. J. Comer, G. E. Eckert. 2009. The Ecological Integrity Assessment Framework: A Framework for Assessing the Ecological Integrity of Biological and Ecological Resources of the National Park System. Report to the National Park Service. 46 pp.

USDA-NRCS. 2014. Selected Approved Ecological Site Descriptions for Major Land Resource Area 041-Southeastern Arizona Basin and Range. US Department of Agriculture. Natural Resource Conservation Service. Website accessed September 2014. https://esis.sc.egov.usda.gov/Welcome/pgApprovedSelect.aspx?type=ESD

USDA-USFS [U.S. Forest Service]. 2009. Ecological sustainability report. Coronado National Forest. United States Department of Agriculture. Forest Service. Southwest Region. February 2009. Pp. 118.

USDI-BLM [U.S. Bureau of Land Management]. 2006. 43CFR4180.1 Fundamentals of Rangeland Health. Code of Federal Regulations and Federal Register, Accessed February 2013 http://federal.eregulations.us/cfr/section/2006/04/18/43-cfr-4180.1

Wright, H. A. The role and use of fire in the semidesert grass-shrub type. 1980. Ogden, UT, U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station.

Appendix E Aquatic Ecological Systems: Conceptual Models and Ecological Status

Version December 8, 2014

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Tables

Figures

Overview of Appendix E

This appendix contains the conceptual models and ecological status assessment results for the aquatic conservation elements (CEs) assessed for the Madrean Archipelago REA. Appendix A describes the methods for selection of the CEs and the change agents (CAs), as well as the collection and organization of management questions (MQs) of interest to many partners active in this ecoregion. Appendices B and C present the assessment methods: B describes the methodological approaches to the geospatial assessments, while C contains the technical GIS documentation. Other appendices contain the conceptual models and ecological status assessment results for the terrestrial CEs (Appendix D) and species CEs (Appendix F). Three additional appendix volumes contain the ecoregional conceptual model and methods / results for the ecological integrity assessment (Appendix G); the conceptual models, methods and results for assessment of Mesquite Expansion: Restoration Opportunities (Appendix H); and the climate changes methods and results (Appendix I).

The content of this appendix is organized into the following major sections:

1. The Overview of Appendix E explains the content of the appendix to help the reader navigate the content, including a summary of how the CE conceptual models are organized, what material is provided in each one, and how the results of the assessment are organized for each CE.
2. The second section, Status Assessment Methods, provides a brief summary of the status assessment methods that are specific to the CEs in this appendix; readers should reference Appendix B for complete details on the scientific rationale and technical approach to the status assessments.
3. The third section, Aquatic/Wetland/Riparian Ecological Systems: Conceptual Models and Ecological Status, contains the conceptual models and assessment results for each CE and is the primary focus of this appendix.

To help visually organize the content for readers, headings are **not** numbered for the sections containing the background or supporting or overview information. In addition, headings for the broader categorizations of the ecological systems (e.g., Basin River and Riparian), are similarly **not** numbered. Sections containing the individual CE assessment content – conceptual models, status assessment results, and other CE-specific information – have outline-numbered headings (e.g., C-1, C-1.1, C-1.2, etc.).

The individual CE content follows the below structure**:**

1. Ecological System X
    - 1.1. Conceptual Model
        - 1.1.1. Classification
        - 1.1.2. Summary
        - 1.1.3. Species of Conservation or Management Concern
        - 1.1.4. Natural Dynamics
            - 1.1.4.1. Natural Dynamics Model
        - 1.1.5. Change Agent Effects on the CE
            - 1.1.5.1. List of Primary Change Agents
            - 1.1.5.2. Altered Dynamics
            - 1.1.5.3. Altered Dynamics Model
        - 1.1.6. Ecological Status: Key Ecological Attributes and Indicators
            - 1.1.6.1. Key Ecological Attributes

Overview of the Conceptual Models

The conceptual models combine text, concept diagrams, and tabular summaries in order to state assumptions about the ecological composition, structure, dynamic processes, and interactions with major CAs within the ecoregion. These conceptual models lead then to spatial models to enable gauging the relative ecological status of each Conservation Element (CE). Below is summary of content included for each CE.

The ecosystem conservation elements for the MAR REA were selected from NatureServe's classification of terrestrial ecological systems (Comer et al. 2003). Over three dozen ecological systems occur in the MAR, but only a select subset were chosen for the REA; methods for selection are described in Harkness et al. (2013). **Table E-1** lists the aquatic ecological system CEs in the ecoregion, along with the percentages of the surface area of the ecoregion that each aquatic ecological system covers (Harkness et al. 2013).

Table E-1. Aquatic ecological system conservation elements (ecosystem CEs) selected for the Madrean Archipelago REA; classification follows Comer et al. 2003.

Level 2 in ecoregional conceptual model	Ecosystem Name	Percent of Ecoregion
Connected Stream and Wetland Ecosystems		**4.5%**
Basin River & Riparian	North American Warm Desert Riparian Woodland and Shrubland, Mesquite Bosque and Stream	3.3%
Marshes/Cienegas	North American Warm Desert Ciénega, Marsh and Pond	1.0%
Montane Streams & Riparian	North American Warm Desert Lower Montane and Foothill Riparian Woodland and Shrubland and Stream	<1%
Isolated Wetland Ecosystem		**<1%**
Playa Lakes	North American Warm Desert Playa & Ephemeral Lake	<1%

The descriptive material builds upon the descriptions for terrestrial ecological systems that NatureServe has been compiling since 2003 when the ecological systems classification was first developed (see http://www.natureserve.org/explorer/index.htm to search and download existing descriptions). For this REA, additional material was added for each ecological system CE, especially focused on content describing natural and altered vegetation dynamics, as well as threats and stressors to the system. For the wetland/aquatic CEs, content was developed pertaining to the aquatic portion of the habitat: information pertaining to aquatic species, reproductive needs, as well as hydrologic needs (water temperature and chemistry) and in channel and within pond dynamics (water depths, rate of flow, interaction with groundwater and more). The information developed is generally intended to cover the full range of distribution of the CE, which can extend beyond the ecoregion, and but does focus on the characteristics or dynamics as they occur within this ecoregion.

The descriptions include many names of plant species that are characteristic of the ecological system type. In the text sections these names are provided as scientific names. Vascular plant species nomenclature follows the nationally standardized list of Kartesz (1999), with very few exceptions. Nomenclature for nonvascular plants follows Anderson (1990) and Anderson et al. (1990) for mosses, Egan (1987, 1989, 1990, 1991) and Esslinger and Egan (1995) for lichens, and Stotler and Crandall-Stotler (1977) for liverworts/hornworts. Where information is available, animal or plant species of conservation or management concern have been identified that are known to be strongly associated with the ecological system.

Conservation Element Characterization

The conservation element characterization of the conceptual model includes a narrative of the CE distribution, biophysical and hydrological setting, hydrologic regime, hydrologic dynamics and floristic composition.

The first section of the conceptual model deals with the classification used, the NatureServe terrestrial ecological systems, as described above. For each CE the NatureServe name and tracking code are provided; in some cases 2 or more ecological systems are conceptually combined into one CE for the MAR REA in which case all are listed. The classification section also lists the ecological systems that are similar to those in the CE. Similarity might be due to floristic, structural or geographic overlap with the CE; similar ecological systems are listed to help clarify what is and what is not included in the CE concept, as reviewers of draft conceptual models expressed some confusion about the MAR CE in their comments.

The natural vegetation and ecosystem dynamics are described in narrative text, with supporting literature cited. For the wetlands and aquatic CEs the diagrams were developed specifically for the MAR REA, and portray the structural components and functional relationships that characterize the ecosystem.

Species of Conservation or Management Concern Associated with Ecosystem

Some species of conservation or management concern are closely associated with these ecological system CEs. These species are of conservation or management concern due primarily to their relative vulnerability to extinction through alteration of this ecosystem. These vulnerabilities stem from their sensitivity to past or current land/water uses, natural rarity, or forecasted vulnerabilities to climate change effects. Because of this strong association, the ecosystem type provides a practical way to “capture” or adequately represent these individual species and provide a reliable indication of the ecological status for each of these species. This is an approach, called “coarse filter / fine filter”, originally proposed by scientists from The Nature Conservancy (Jenkins 1976, Noss 1987) and has been used extensively in a variety of forms for regional and local landscape assessments (Nachlinger et al. 2001, Noss et al. 2002). For most of these species, the ecological system type serves as the focal resource for purposes of resource assessment. Although some of the species listed in this sub-section may be assessed individually (see separate conceptual models for them), most are listed to make users aware of associated species that are of concern.

The lists provided in the conceptual model were derived through consultation of State Wildlife Action Plans, or other sources, but are not definitively complete. Many reports list species of concern without providing information on related habitats or requirements. Time was not available to do detailed research on individual species in order to relate them to a MAR ecosystem CE. The sources for the list in each CM are provided. These species are listed by informal taxonomic groups, generally with common names followed by scientific names.

Change Agent Effects on the CE

In this section the primary change agents and current knowledge of their effects on the CE are characterized. Some CAs have specific effects on each CE such as the alteration of expected fire regimes and the interacting effects of introduced weed infestations. Known change agents are listed and altered ecosystem dynamics of the CE are described, with a narrative on the effects of CAs on the individual CE. Wildfire and invasive plant CAs are described and modeled within the context of their effects on upland and aquatic ecosystem CEs. The altered dynamics section also contains a diagrammatic representation of the currently in-place 'altered' dynamics, again making use of either ESDs developed by NRCS, or TNC's altered dynamics diagrams.

Conceptual Model Diagrams

For the wetlands and aquatic CEs the diagrams portray the structural components and functional relationships that characterize the ecosystem. Two diagrams are provided: the first represents the key ecological attributes (ovals), ecosystem drivers (labeled arrows), and the functional relationships between them, and a second diagram portrays the stressors and change agents (boxes) that are currently acting upon the key attributes (ovals) of the ecosystem. These are not state and transition models as used for upland systems. While state and transition models do exist for the lowland riparian CE, they do not exist for the other three CE's. Information from Ecological Site Descriptions (e.g. Robinett 2005a) are used in conceptual model text where possible and appropriate, but for consistency, state and transition models are not provided for aquatic CEs.

Ecological Status: Key Ecological Attributes and Indicators

NatureServe's ecological integrity assessment framework identifies and outlines practical criteria for assessing the ecological status of each CE within an ecoregion (Faber-Langendoen et al. 2006, Unnasch et al. 2009). This section of the conceptual model addresses key ecological attributes and their potential indicators. The ecological status is a way of describing current status via criteria, functionality, or levels of attributes and asks if they are within the normal range of variation. Is it within its "proper functioning condition"? Attributes are direct and indirect measures of ecosystem status or function. Key ecological attributes (or their indicators) should be measured to take the "pulse" of an ecosystem. High scores indicate high ecological integrity and high ecological functionality.

Key Ecological Attributes

The key ecological attributes for the CE within the Madrean Archipelago ecoregion are identified in this section. A **key ecological attribute** of a focal ecological resource is a characteristic of the resource's biology, ecology, or physical environment that is critical to the resource's persistence in the face of both natural and human-caused disturbance, e.g., resistance or resilience (De Leo and Levin 1997, Holling 1973, Parrish et al. 2003, Unnasch et al. 2009). Alteration of such a characteristic beyond some critical range of variation will lead to the degradation or loss of the resource within decades or less.

For each CE, a table provides identified key ecological attributes, with a brief definition, a rationale for why it is important for the CE, and a listing of stressors or change agents that might be affecting the key attribute.

Key ecological attributes of a resource include critical or dominant characteristics of the resource, such as specific characteristics of:

a) demographic or taxonomic composition;
b) functional composition;
c) spatial structure;
d) range or extent.

They also include critical biological and ecological processes and characteristics of the environment that:

a) limit the regional or local spatial distribution of the resource;
b) exert pivotal causal influence on other characteristics;
c) drive temporal variation in the resource's structure, composition, and distribution;
d) contribute significantly to the ability of the resource to resist change in the face of environmental disturbances or to recover following a disturbance; or
e) determine the sensitivity of the resource to human impacts.

Conservation of key ecological attributes contributes to current ecological integrity and to the resilience of ecological systems in the face of large-scale or long-term stressors (Parrish et al. 2003). The ecological integrity assessment framework (Unnasch et al. 2009) identifies four classes of key ecological attributes, concerning: landscape context; resource size or extent; biotic condition; and abiotic condition. These four may overlap, and provide a guide for considering and identifying key ecological attributes. They also provide a basis for integrating information on key ecological attributes.

- "Landscape context" refers both to the spatial structure (spatial patterning and connectivity) of the landscape within which the focal resource occurs; and to critical processes and environmental features that affect the focal ecological resource from beyond its immediate geographic scope.
- "Size" refers to the numerical size and/or geographic extent of a focal resource.
- "Biotic condition" refers to biological composition, reproduction and health, and succession; and critical ecological processes affecting biological structure, functional organization (e.g., food-web guild structure), and interactions.
- "Abiotic condition" refers to physical environmental features and dynamics within the geographic scope of the focal resource that significantly shape biotic conditions, such as fire, weather, and hydrologic regimes; and soil and geological conditions and dynamics.

Taken together these attributes tell the story of the current status of an ecosystem. For example, a good condition/proper functioning ecosystem is large and uninterrupted, the surrounding landscape is also in good condition; the biotic condition is within normal range of variation: the weeds are few, the native plants are robust, have expected abundance and reproduction; birds, mammals, reptiles, amphibians, fish, or invertebrate species present are indicative of reference, un-molested conditions; the hydrologic or fire regime is within normal reference ranges, the highs and lows are within normal parameters, there are no excessive sediment loads or surface erosional processes, ecosystem geomorphology and soil are in proper form.

A poor condition/non-functioning ecosystem is highly fragmented, or much reduced in size from its historic extent; the surrounding landscape is in poor condition either with highly eroding soils, many non-native species or a large percentage of the surrounding landscape has been converted to pavement or highly maintained agriculture (row crops, irrigated crops, etc.); the biotic condition is at the limit or beyond natural range of variation, i.e. very few native species expected for this ecosystem are present, or are in poor physical condition and are barely able to reproduce; birds, mammals, reptiles and amphibian species expected are not present or the ratio of species shows an imbalance of predator to prey populations, or have more opportunistic species and a lack of interior, poor competitor species (i.e. species guilds are not within the normal range of variation); abiotic condition is poor with high soil erosion, high sediment loads into water bodies, hill and gullies present, fire occurs too infrequently and much higher severity than acceptable, or the hydrologic regime has been altered by reduced flows or lowered groundwater table, resulting in changes to vegetation structure and composition.

Indicators of Key Attributes

Assessing the status of key ecological attributes requires explicit identification of indicators (also called metrics) – specific means for measuring their status. These are the detailed metrics that measure the amount or status of each key attribute. There are many potential indicators, and the choice is largely dependent on the purpose of the assessment and available data. An indicator may be a specific, measurable characteristic of the key ecological attribute; or a collection of such characteristics combined into a "multi-metric" index. Such indicators directly evaluate the condition of the KEAs and their responses to stressors (change agents).

Alternatively, indicators may evaluate the severity and extent of the stressors themselves. Such "stressor" indicators may consist of a single measurement type, or a collection of such measurements combined into a multi-metric stressor index. Indicators of stressors are often used as indirect indicators of a key ecological attribute, because data on stressor condition are often far more readily available than data on direct indicators. Examples of stressor-based indicators include measures of overall landscape development such as the Landscape Condition Model methodology (Comer and Faber-Langendoen 2013, Comer and Hak 2009); measurements of invasive non-native annual grass distributions that affect fire regimes; or measurements of fragmentation due to development.

Table E-2 lists the indicators chosen for each KEA for the aquatic CEs in the MAR REA. This table also lists which part or scenario of the analysis the indicator used. How the indicators are brought into the analysis is explained in Appendix B. "Assessment Methods: Approaches and Rationales".

References for the CE

Literature is listed that is relevant to the classification, distribution, floristic composition, ecological processes, threats, stressors, or management of each CE, in some cases from portions of its range outside of the ecoregion. These are not exhaustive literature surveys, but rather an accumulation of known references. Some documents may be listed that are not cited in the narrative text. A separate section at the end of the entire Appendix lists the references cited in this methodological overview.

Overview of the Status Assessment Results

Each CE summary has a section titled **Ecological Status Assessment Results and Interpretation**. This section of the individual CE material presents the results of the CE status assessments, and includes both maps and accompanying interpretive text. Readers are referenced to Appendix B for the overall methodological approach for assessing status, and descriptions of scenarios that were used, including data inputs, process model diagrams, data outputs, and limitations. Readers can also reference Appendix C for detailed technical documentation of GIS steps for creating the inputs, conducting the status assessment, and the resultant output files.

Maps are provided for each CE showing the status or condition scores for each individual indicator at the resolution of the analysis unit (30m pixels) as well as the CE's overall ecological status scores, which is a combination of all indicators, at both a 30m resolution and rolled up to either the 5th or 6th level HUC (HUC10 or HUC12) reporting unit depending on the CE. The following series of status results maps and charts are provided for each CE:

Maps of individual indicator scores

- Development, 30 meter resolution
- Invasives, 30 meter resolution
- Native Biotic Integrity, 30 meter resolution
- Water Use, 30 meter resolution
- Habitat Quality, 30 meter resolution

Maps and charts of comprehensive ecological status assessment results

- Ecological status, 30 meter resolution
- Ecological status averaged across 5th level HUC reporting units for the North American Warm Desert (NAWD) Riparian Woodland, Shrubland Mesquite Bosque & Stream CE and the NAWD Lower Montane and Foothill Riparian Woodland and Shrubland and Stream CE; or 6th level HUC reporting units for the NAWD Ciénega, Marsh and Pond CE, and the NAWD Playa CE.
- Chart showing frequency distribution of ecological status scores within HUC reporting units

The individual indicator results maps are grouped together for each CE, followed by text explanation and interpretation. The overall ecological status maps and accompanying charts are presented in a second grouping, followed by interpretive text. The interpretive text for the results does include material that is repeated for each CE, so that the reader will not need to return to the methods sections repeatedly.

Status Assessment Methods

Appendix B describes the conceptual scientific approach and rationale for the ecological status assessment (**Appendix B: Rationale for Ecological Status Assessment Approach**) and the detailed technical approach for conducting the assessment (**Appendix B: Ecological Status Assessment Technical Approach**). As described there, a raster-based spatial modeling tool, the Landscape Condition Model (LCM), was used to assess ecological status of CEs. Two categories of inputs are needed to assess ecological status using the LCM: 1) the CE response models, and 2) the spatial KEA indicator scenarios. The CE response model is a series of numeric values that characterize how each CA is expected to reduce status or condition of the CE onsite (site intensity values) and, in some cases, offsite (distance values); the response model values were assigned by ecologists on the contractor team using the information on the CE's ecology and dynamics as summarized in the CE's conceptual model. The site intensity values indicate the degree to which the impact of the specified CA features degrades the ecological status of the CE where the CA feature is present. The KEA indicator scenarios are aggregations of spatial raster datasets representing the CA features that were identified to assess each of the indicators for the CE. The starting point of the model is a theoretically perfect status or condition score of 1.0 for each pixel of a CE's distribution; zero is the lowest status score. The LCM tool applies the CE response model values for each of the CA features to the KEA indicator scenarios to calculate overall ecological status scores for the CE across its distribution. Where multiple CA features overlap, the associated response model values were multiplied to approximate a cumulative CA effect. The overall ecological status scores indicate the degree to which the combined CAs present in the CE's distribution degrade the ecological status of the CE, accounting for distance effects as appropriate. Readers should refer to Appendix B for more detail and background on how the status assessment was conducted.

Linking CE Conceptual Models to Status Assessment Approach

It is important that the ecological status assessment of CEs be grounded in what is known about each of the CEs – their ecology, dynamic processes, and stressors. The conceptual models developed for the species and species assemblage CEs of the MAR provided the scientific context and current knowledge base from which to identify the key ecological attributes (KEAs) and their indicators to be assessed to characterize ecological status, and to characterize CE responses to CAs via the CE response models (see **Appendix B: Rationale for Ecological Status Assessment Approach)**.

KEAs, Indicators, and Scenarios

The status assessment of the aquatic CEs in the MAR focused on five primary KEA/indicator pairs for which spatial data were available: 1) Landscape Condition/Development, 2) Biotic Condition/Native Biotic Integrity, 3) Biotic Condition/Invasives, 4) Abiotic Condition/Hydrologic Regime, and 5) Abiotic Condition/Habitat Quality (geomorphic condition). Data for direct measures of status were not available for three of the five KEAs, and the assessment applied indirect, stressor-based measures instead. For each KEA, a scenario (**Appendix B: Scenario Generation: Current and Future**) was developed to spatially represent the change agents comprising those stressors: development for landscape condition, invasive species for biotic condition, and water use for hydrologic regime. Two KEA/indicator pairs are direct measures of status: Biotic Condition/Native Biotic Integrity is a measure of native fish, endangered species and macro-invertebrates; and Abiotic Condition/Habitat Quality is a measure of channel stability and physical structural components for the floodplain and channel. Direct measures of status complement the indirect measures. However, the direct measures depend on relatively small numbers of sample points spread across the ecoregion, i.e., on much smaller data sets compared to the indirect measures. As a result, the assessment is dominated by the indirect, stressor-based indicators for an overall, ecoregion-wide assessment. The direct measures convey the condition of their KEAs for limited number of locations.

Table E-2 lists the KEAs identified in the conceptual models for each CE and the associated indicators and KEA indicator scenarios that were assessed for the aquatic CEs; see **Appendix B—Assessment Methods: Approaches and Rationale** for additional details on assessment methods. Key ecological attributes are discussed within each CE's conceptual model in this appendix.

Note that three indicators were not assessed for every aquatic CE. The Habitat Quality indicator was not assessed for the ciénega, marsh and pond CE, nor the playa CE. The data on Proper Functioning Condition (PFC) and stream channel stability (Aquatic Habitat Assessment), provided by the Arizona Department of Environmental Quality, include sampling locations on streams and rivers, none of which coincided with the ciénega, marsh and pond CE or playa CE locations used for this assessment. The Native Biotic Integrity Indicator was not assessed for the playa CE, as these data were only available for streams and rivers. Lastly, the Water Use indicator was not assessed for the NAWD Lower Montane and Foothill Riparian Woodland and Shrubland and Stream CE, as the majority of the impacts occur at lower elevations. There are small isolated intensive water use areas associated with mines that correspond with the higher elvation riparian CE; however, there were very few such areas, and the direct impact of the mine locations is included in the development indicator.

Table E-2. List of key ecological attributes identified for aquatic ecosystem CEs in the conceptual models and their corresponding indicators and KEA indicator scenarios that were assessed for the aquatic CEs.

KEA Class: **KEA Name**	**Indicator Name**	**KEA Indicator Scenario** (as named in Appendix B)	**Type and Description of Indicator Used**	**NAWD* Riparian Woodland, Shrubland Mesquite Bosque & Stream CE**	**NAWD* Lower Montane & Foothill Riparian Woodland & Shrubland & Stream CE**	**NAWD* Ciénega, Marsh & Pond CE**	**NAWD* Playa CE**
Landscape Context: **Landscape Cover**	**Development**	**Current Scenario Landscape Condition**	Stressor-based: Development impact	x	x	x	x
Biotic Condition: **Non-native Riparian & Aquatic Flora & Fauna Compostition**	**Invasive Species**	**Current Scenario Invasives**	Stressor-based: Presence of non-native invasive terrestrial & aquatic species	x	x	x	x
Biotic Condition: **Native Riparian & Aquatic Flora & Fauna Compostition**	**Native Biotic Integrity**	**Current Scenario Native Biotic Integrity**	Direct: Native fish index, Endangered Species and macro-invertebrate index	x	x	x	n/a
Abiotic Condition: **Hydrologic Regime**	**Water Use**	**Current Scenario Water Use**	Stressor-based: Total Water Use (ground & surface water)	x	n/a	x	x
Abiotic Condition: **Geomorphology**	**Habitat Quality**	**Current Scenario Habitat Quality**	Direct: Condition of floodplain, stream banks & channel bed	x	x	n/a	n/a

KEA Class: **KEA Name**	**Indicator Name**	**KEA Indicator Scenario** (as named in Appendix B)	**Type and Description of Indicator Used**	**NAWD* Riparian Woodland, Shrubland Mesquite Bosque & Stream CE**	**NAWD* Lower Montane & Foothill Riparian Woodland & Shrubland & Stream CE**	**NAWD* Ciénega, Marsh & Pond CE**	**NAWD* Playa CE**
***NAWD = North American Warm Desert**							

CE Response Model for Aquatic/Wetland/Riparian Ecological Systems

As described in Appendix B (**Ecological Status Assessment Technical Approach)** and above, the KEA scenarios were input into the LCM in conjunction with a response model for each CE. As noted above, a response model was needed to tell the LCM how the CA affects the status or condition of the CE indicator. The response model was constructed using information from the CE conceptual models for how a CE is expected to respond in the presence of the CAs (and in some cases, a distance out from the CA) for a particular indicator; the response model used for all aquatic ecological system CEs (except where noted) is summarized in Table E-**3**.

Table E-3**. CE response model values used for all aquatic ecological system CEs.** This table lists site intensity and distance decay values used for all aquatic ecological systems for the indicators of Development, Water Use, Invasives, Native Biotic Integrity, and Habitat Quality. Site intensity values range from 0.0 - 1.0 and are relative to each other. Site intensity values reflect how much an activity (as reflected in the indicator) removes ecological status of the CE. A value of 0.05 removes 95% of the status, 0.5 removes 50%, 0.7 30% and so on. Where two or more activities occur within the same pixel, the intensity values were multiplied together. See Appendix B for conceptual information and Appendix C for GIS documentation and application methods.

Indicator Component	**Site Intensity**	**Distance (meters)**
Development		
Infrastructure		
----Border Barrier - Pedestrian	0.5	100
----Border Barrier – Vehicle	0.6	100
----Communication Towers	0.3	200
----Below Ground Corridors	0.7	200
----Above Ground Corridors	0.5	100
Transportation		
----Dirt & 4-wheel Drive Roads	0.3	200
----Local/Rural/Private Roads	0.2	500
----Primary Highways w/ Limited Access	0.05	2000
----Primary Highways w/o Limited Access	0.05	1000
----Airstrips	0.5	500
----Railroads	0.5	200
Mining & Landfills		
----High Impact Mines/Landfills	0.05	200
----Medium Impact Mines/Landfills	0.6	50

Indicator Component	**Site Intensity**	**Distance (meters)**
----Low Impact Mines/Landfills	0.9	none
Energy		
----Geothermal Energy	0.5	200
----Wind Energy	0.8	500
----Solar Energy	0.5	500
----Oil & Gas Wells	0.4	500
Recreation		
----Trails - Hiking/Biking/Horse	0.7	100
Agriculture		
----Agriculture	0.3	200
Urbanization		
----Low Density Development	0.6	200
----Medium Density Development	0.5	200
----High Density Development	0.05	2000
Dams		
----Very Large Inundation Area	0.4	1000
----Large Inundation Area	0.4	500
----Dam Present	0.4	200
Invasives		
----Aquatic Invasives - High Impact Species	0.5	1200
----Aquatic Invasives - Low Impact Species	0.7	1200
----Aquatic - Presence of Tamarisk	0.7	none
----Terrestrial Invasives - Low Cover	0.9	none
----Terrestrial Invasives - Medium Cover	0.8	none
----Terrestrial Invasives - High Cover	0.7	none
Aquatic Habitat Quality		
----Aquatic Habitat - Good Condition	0.9	100
----Aquatic Habitat – Impaired	0.8	100
----Aquatic Habitat - Very Impaired	0.7	100
----PFC – High	0.9	100
----PFC – Medium	0.7	100
Aquatic Native Biotic Indicators		
----Macroinvertebrate Index - High	0.9	100
----Macroinvertebrate Index - Medium	0.7	100
----Macroinvertebrate Index - Low	0.5	100
----Endangered Species Index - High	0.9	500
----Endangered Species Index - Medium	0.7	500
----Native Fish Richness Index - High	0.9	200
----Native Fish Richness Index - Medium	0.7	200
----Native Fish Richness Index - Low	0.5	200
Water Use*		

Indicator Component	**Site Intensity**	**Distance (meters)**
----Total Water Use – Low	0.9	none
----Total Water Use – Medium	0.8	none
----Total Water Use - Medium-High	0.6	none
----Total Water Use – High	0.5	none
* **Water Use site intensity values were set for no impact (1) for NAWD Lower Montane and Foothill Riparian Woodland and Shrubland and Stream CE—see that CE section for details**		

KEA Indicator Scenarios

Aquatic CEs occupy such a small proportion of the MAR landscape (**Table E-1**), that it can be difficult to visualize their individual pixels and associated indicator scores on an ecoregion-wide map. Therefore, the following paragraphs and maps provide information on three of the five scenarios (Landscape Condition - Development, Water Use, and Invasives) that are better illustrated ecoregion-wide. The discussion of status results for individual indicators for the CE status assessments will refer back to this section and its maps. Native Biotic Integrity and Habitat Quality results have very little variation in scores so ecoregional maps are not illustrative, and are not presented on an ecoregion-wide scale.

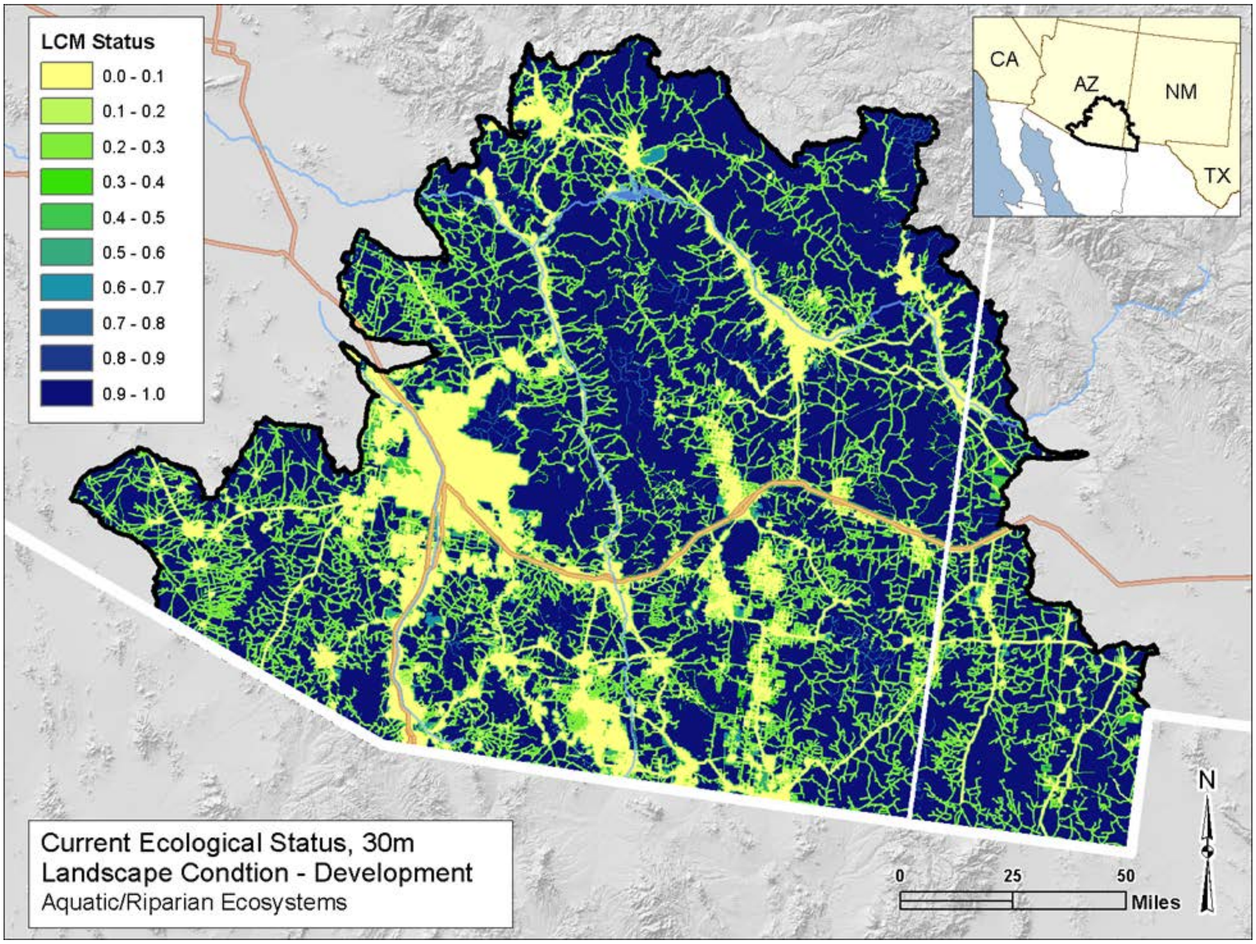
For all CEs, the LCM first intersected the CE distribution map with the KEA indicator scenario, and then the response model was applied to those intersecting pixels to derive a raster map of the calculated status or condition score for each pixel in the CE's distribution. The output of each scenario model is a stack of raster layers (when there are overlapping CAs) that are attributed with the specific CAs present in each pixel to account for cumulative effects of multiple CAs in the same location.

Region-Wide Landscape Condition - Development Scenario

The development indicator specific to the aquatic CEs is a stressor-based indicator of the spatial extent and intensity of human modifications to the land surface that alter land cover and watershed functions crucial to the ecological integrity of aquatic and wetland conservation elements in the MAR ecoregion. This indicator takes into account the density of urban development; infrastructure such as above- and below-ground distribution corridors, communication towers, and border barriers; a wide range of transportation features; mines and landfills; dams; recreational development; agriculture; and energy development. The indicator scoring is on a continuous scale, from 1.0 indicating no ecologically relevant modifications to 0.0 indicating modifications that essentially eliminate all natural cover and natural watershed functions.

The development scenario was first assessed across the entire ecoregion, using the site intensity and distance decay values assigned for aquatic CEs, to derive an ecoregion-wide set of status scores for the development indicator. The development indicator results, as mapped across the whole ecoregion (**Figure E-1**), show several large areas and corridors of intense development, representing areas of municipal and agricultural development. Development impacts are especially noticeable in the Tucson metropolitan area; in and around every residential community in the ecoregion; and along corridors associated with interstate highways 10 and 19, US highways 70 and 191, and many other larger roads.

Figure E-1. Landscape Condition scenario representing the Development indicator for aquatic ecological system CEs, displayed for the entire MAR ecoregion. This map is for illustrative purposes only and the data will not be delivered. Individual CE data have been delivered. Scoring is a continuous scale, from 1.0 indicating no removal of ecological integrity to 0.0 indicating essentially an eliminatation of all ecological integrity for each 30 m pixel.



Region-Wide Water Use Scenario

The water use indicator tracks the magnitude of water consumption by people, agriculture, and industry per unit area; and tracks the consumption of surface and ground water together. Human activities in the MAR ecoregion consume the two types of water resources as substitutes for each other, relying on surface water wherever available and on groundwater wherever surface water is scarce. However, both diversions of surface water and pumping of ground water from an aquatic or wetland CE is ecologically detrimental to the CE. Further, the effects of water use on an aquatic CE occurrence do not depend on the type of use to which the water was diverted – e.g., as drinking water for people or livestock, to run a mine or irrigate crops. The effects depend only on how overall water use alters the availability of water for the CE.

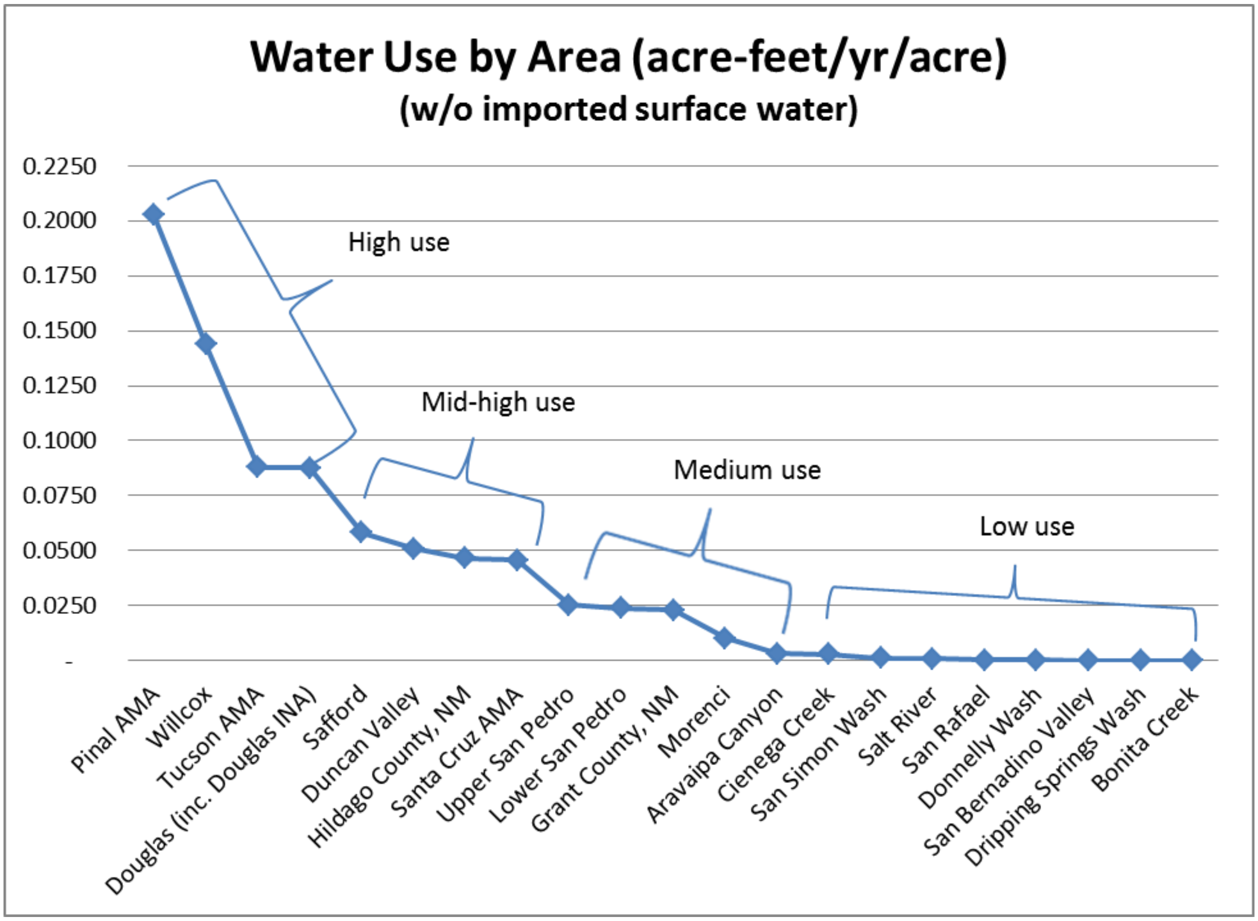
The water use indicator does not provide a relative measure of how intensively people are using water per se. In keeping with the goals of an REA, this indicator instead estimates the relative magnitude of the likely impacts of water use on aquatic ecological resources, in a manner compatible with the spatial coarseness of the available data on water use across the ecoregion. The raw data on water use for the ecoregion consist of estimates of the amount of surface and groundwater used per year in each groundwater basin (in AZ) or county (in NM) included in the ecoregion. These basins and counties vary widely in area, human population density, and types of land and water uses. The impacts of water use on aquatic ecological systems in an ecoregion, in turn, depend on how much water is removed from (or intercepted before reaching) these systems, at what times of the year, over what areas, relative to conditions prior to the development of water resources in the ecoregion. The raw data do not include information on the quantities or timing of water losses to specific aquatic ecological system occurrences. In the absence of such finer-grained information, the water use indicator converts the raw data on water use per basin or county to data on water use per unit of area. This conversion provides a simple way to scale the magnitude of water use, for comparing basins and counties to each other in terms of the relative magnitude of the potential impacts of water use on aquatic ecological resources.

It is similar to the logic of the development effects —the site intensity and distance values are meant to capture the likely pattern of impacts to ecological resources, not merely the location and intensity of development.

The raw data on water use available for this assessment are reported as total water volume used per year by Groundwater Basin in AZ and by County in NM. These spatial reporting units vary greatly in area, making it misleading to compare their raw water use rates. A thousand acre-feet of water consumed in one year across an area of 100,000 acres has a much smaller impact on water availability within that area than does the same rate of consumption across an area of only 1,000 acres. Of course, the ecological impacts of water use also depend on where the water is taken out of the natural flow system. Pumping from a well on the margins of a watershed has less impact on an aquatic CE site located near the center of the watershed than does pumping from a well close to the CE site; and water use downstream (or down-gradient, for groundwater) from an aquatic CE site has less impact than does water use upstream/up-gradient. Unfortunately, water use data and flow/routing models are not available within the MAR ecoregion to assess the effects of water diversions and consumption at such finer spatial scales. Consequently, the present assessment standardized the water use data by converting the annual rate of consumption in each spatial unit (Groundwater Basin or County) to volume per year per unit of surface area. **Figure E-2** shows the standardized rate of water use by the spatial reporting units present in the raw water data. Standardizing to per capita consumption is not appropriate.

The assessment of water use does not track return flows from irrigation or wastewater systems, which are not “consumed” in the parlance of water resources management, just relocated. The assessment of water use also does not track consumption of water imported from other ecoregions, such as from the Colorado River, which does not take water away from aquatic CE occurrences within the MAR ecoregion. Only two groundwater basins in the ecoregion import water, the Tucson Active Management Area (AMA) and the Pinal AMA.

Figure E-2. Water use standardized by area, with the rank interpretation from highest to low use areas.

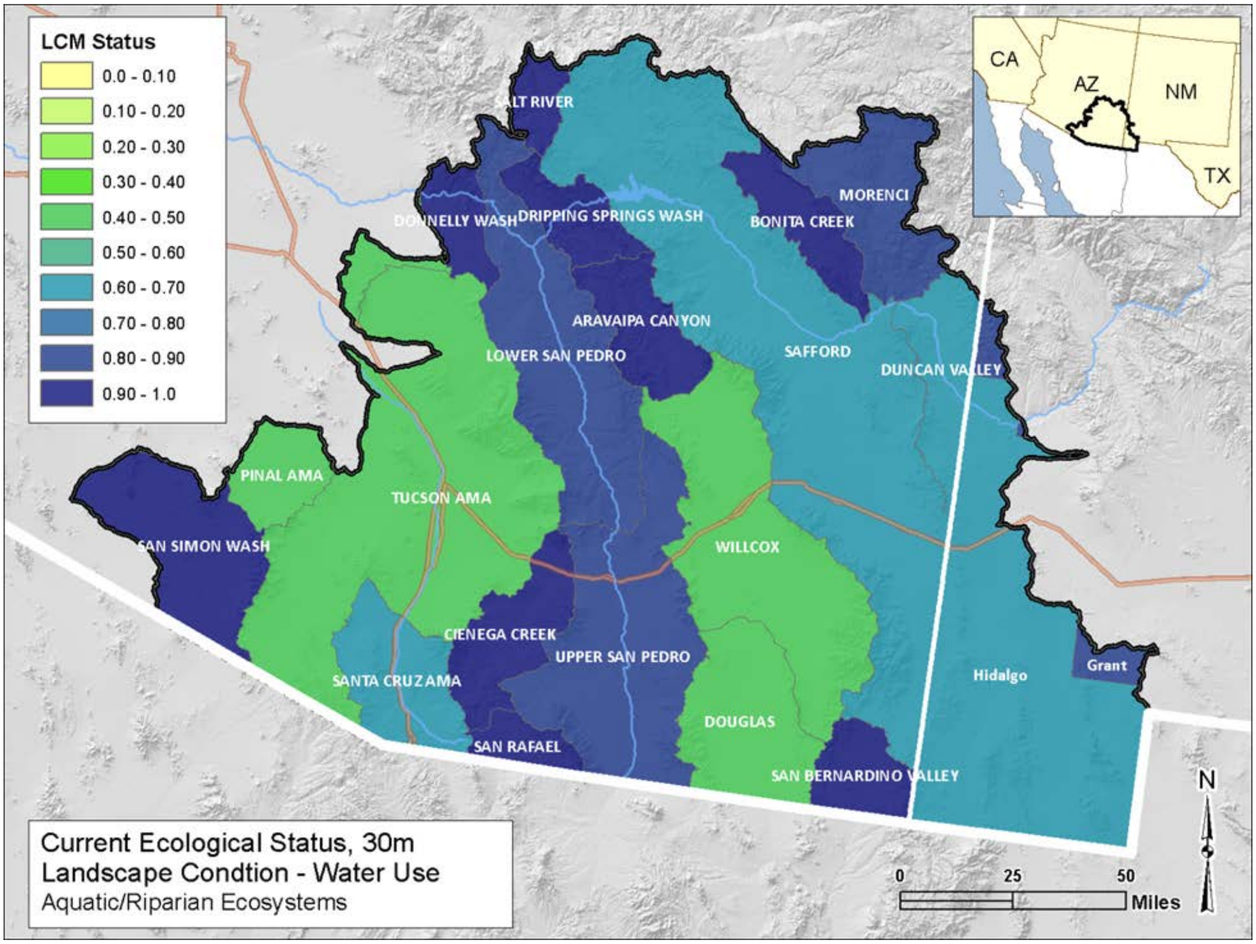


The assessment categorized the standardized rates of water use into four categories based on natural groupings in the data: High, Medium-High, Medium, and Low. The four categories were quantified and assigned intensity values as follows:

- Low: Intensity value = 1.0; water use values < 0.0035
- Medium: Intensity value = 0.8; water use values 0.01 – 0.0252
- Medium-High: Intensity value = 0.6; water use values 0.0458 – 0.0583
- High: Intensity value = 0.5; water use values > 0.0878.

Figure E-3 shows the water use intensity values for the groundwater basins in Arizona and counties in New Mexico that occur in or overlap with the MAR ecoregion. The assessment applied these intensity values to three of the four aquatic ecological systems CE types for the ecoregion. The assessment took a different approach with the fourth aquatic ecological system CE type, the North American Warm Desert Lower Montane Riparian Woodland, Shrubland and Stream CE. The intensity values for water use were assigned 0.0 for the latter CE type. Most of the water use impacts occur across the valley floors and along alluvial bottoms, while this CE occurs at higher elevations. In particular, this CE is not significantly affected by groundwater pumping from basin fill valley-bottom alluvial aquifers, where most groundwater withdrawals take place.

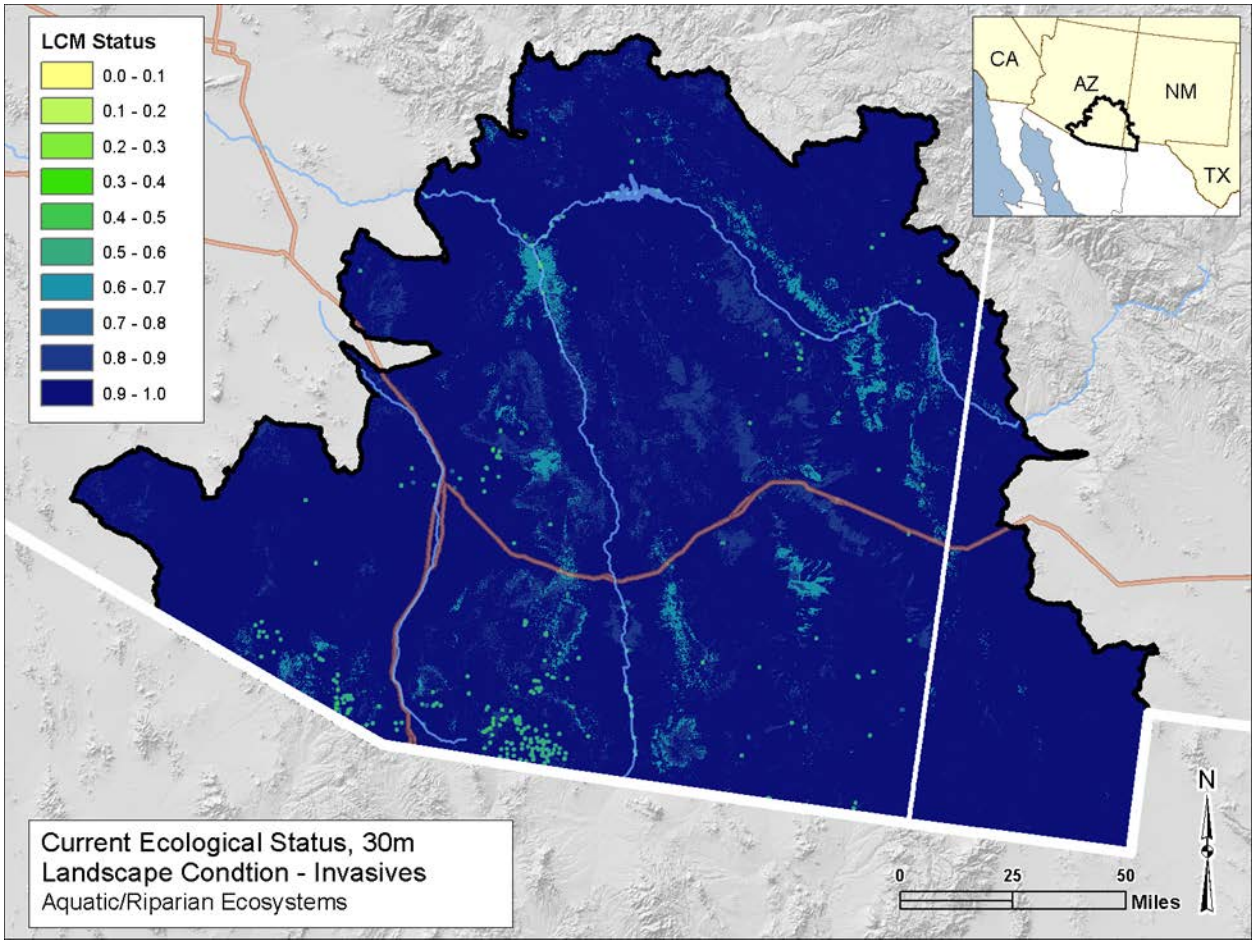
Figure E-3. Water use scenario by spatial reporting unit (groundwater basins (uppercase) in AZ; counties (lowercase) in NM), displayed for the entire MAR ecoregion. This map is for illustrative purposes only and the data will not be delivered. Individual CE data have been delivered.



Region-Wide Invasives Scenario

The invasive species data consisted of known locations of tamarisk (*Tamarix* spp.), percent cover of non-native herbaceous plant species, and known locations of invasive aquatic plant and animal species. Aquatic animals were categorized as high impact (non-native aggressive frogs, crayfish, and fish) and low impact (non-native salamanders, mammals, mollusks, plants and reptiles). Based on the site intensity values assigned in the aquatic CE response model for the various categories of aquatic invasive species, areas of high impact and greater cover of invasive species received higher indicator scores than low impact and low cover areas, while areas with no known records where not scored (see Table E-**3** for scores used). Further details on the methods and rational behind the invasive species indicator and scenario are available in Appendices B and C. **Figure E-4** shows the locations of riparian corridors with non-native fish and tamarisk, tributaries full of bullfrogs and crayfish, and where on the upland landscape non-native herbaceous species are concentrated. The lighter colors indicate greater numbers or higher abundances of invasive species; darker colors indicate fewer or no known invasives.

Figure E-4. Invasive species scenario, displayed for the entire MAR ecoregion. Lighter colors indicate greater concentrations of invasive species, darker colors indicate few to no known invasive species. Blue lines for major rivers obscures some color ramp results. This map is for illustrative purposes only and the data will not be delivered. Individial CE data have been delivered.



Overall Ecological Status Scoring

An overall "full" scenario (all KEA indicator scenarios combined into one) and associated overall ecological status map were also generated for each CE to provide overall CE status; however, such products typically beg the question of which indicators are driving the status at different locations. Therefore, as described above, the individual KEA indicator scenarios that represent relevant indicators were also assessed individually to illuminate their effects and inform understanding and potential management action.

Considerations, Limitations and Data Gaps

The aquatic conservation elements are small scale items. At the scale of a regional ecoregion assessment (REA) this can be very challenging. Several assumptions were made. Firstly, each change agent is assumed to have the same type and intensity of impact on each CE as described, even though there is diversity within each CE. Second, the purpose of the REA is to give an ecoregional scale assessment of how the aquatic CEs are doing. This assessment is not a comparison of upstream vs. downstream reaches, or one spring to be compared to another. Here the purpose is to assess the entire occurrence of each CE across the ecoregion. The most detailed results offered is to compare watersheds, if they differ in stress levels, across the ecoregion. In the aquatic realm, researchers and practitioners often do not think about the watershed scale, let alone the ecoregional scale. To this end, the analyses were conducted at the 30 m pixel level, so they are sensitive at a fine scale (if the data are fine scale), but results are reported at watershed scales, in order to answer ecoregional scale questions such as what is the status of each aquatic CE across the ecoregion.

Water Use relative impact is scored the same for every pixel within a groundwater basin or county (**Figure E-3**); it is a very coarse-scaled indicator. Therefore this indicator shows the relative water use as a stressor among groundwater basins (AZ) and counties (NM) in the assessment area. It cannot compare the impact of water use for CEs located near active groundwater wells or dams (for example) against CE locations further upstream from such impacts within the same groundewater basin or county.

The Native Biotic Integrity indicator is a direct measure of a CE's ecological health. Careful consideration needs to be applied when interpreting the scores, as the scores are relative to the negative impact scores such as development. Low scores indicate that surveys found no native fish; none to only a few (relative to expected) endangered species; and/or registered a low benthic macro-invertebrate score. High scores indicate high numbers of expected native fish or endangered species were confirmed or the bentic macro-invertebrate index scored very high. Unfortunately, areas of the CEs where surveys have not occurred also show high integrity (i.e no score) for this indicator as a lack of data means there is no indication of reduced integrity. While this indicator is clearly limited in its ability to give an ecoregion-wide picture of ecological integrity, it does serve the purpose of showing direct measure results that can be compared to indirect, stressor based results.

A data gap for this assessment is the Bureau of Land Management PFC data. The BLM has carried out many surveys of stream and riparian corridor condition using its "Proper Functioning Condition" protocol, for example, but the data from these surveys were not available in an integrated digital database for use in the present assessment (Masters, E., personal communication 2014).

Another data gap was the numerous bird surveys (amateur and professional) similarly were not evenly available or integrated in a form that could be used.

Numerous ecological studies have focused on the North American Warm Desert Riparian Woodland, Shrubland, Mesquite Bosque and Stream CE in the ecoregion. In fact, the San Pedro River has served as a research laboratory for a wide range of studies on southwestern riparian-stream ecosystems, their hydrology and ecology – particularly riparian ecology. Concerns about the impacts of groundwater pumping on baseflow along the San Pedro River have also resulted in detailed groundwater models of the San Pedro River Basin. Nevertheless, data on biological and habitat conditions are only unevenly available across the entire ecoregion – particularly data on aquatic conditions.

Relatively few ecological studies have focused on the higher elevation North American Warm Desert Montane and Foothill Riparian Woodland, Shrubland and Stream CE in the ecoregion. The most intensive studies arise from the fact that perennial streams are an important focus of water quality monitoring by the Arizona Department of Environmental Quality. As a result, several stream reaches of this CE type have been surveyed using methods that result in data on stream macroinvertebrates and habitat quality. However these data are extremely limited within the context of the entire CE distribution.

Many of the ciénegas used for this analysis occur on private land, and their specific locations could not be shown (and these data will not be made available to BLM). However, the analyses were conducted at 30 m scale, so the results are as robust as for the other aquatic CEs. The data is delivered to the BLM and is reported visually at 12th level HUCs in order to obscure exact locations. While the BLM has collected extensive PFC data at ciénega locations, these data were not available in a readily available digital format for this assessment (Masters, E., personal communication 2014).

Few ecological studies have focused on the playas of the ecoregion; and much of the Willcox Playa remains closed to the public as a military reservation. Their hydrology and the history of the glacial lakes from which they descend are better known than their hydrochemistry, biology, or ecology. They warrant systematic biological study, to better assess their importance for migratory birds and to assess the status of their known but poorly understood assemblages of rare insects and plants.

References for Appendix Overview

Anderson, L. E. 1990. A checklist of *Sphagnum* in North America north of Mexico. The Bryologist 93:500-501.

Anderson, L. E., H. A. Crum, and W. R. Buck. 1990. List of mosses of North America north of Mexico. The Bryologist 93:448-499.

Comer, P. and D. Faber-Langendoen. 2013. Assessing Ecological Integrity of Wetlands from National to Local Scales: Exploring the Predictive Power, and Limitations, of Spatial Models. National Wetlands Newsletter Special Issue on Wetland Mapping and Assessment. Environmental Law Institute. Washington DC. Vol. 35 No. 3 May/June 2013.

Comer, P. J., and J. Hak. 2009. NatureServe landscape condition model. Internal documentation for NatureServe Vista decision support software engineering, prepared by NatureServe, Boulder, CO.

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. Ecological systems of the United States: A working classification of U.S. terrestrial systems. NatureServe, Arlington, VA.

De Leo, G. A., and S. Levin. 1997. The multifaceted aspects of ecosystem integrity. Conservation Ecology [online]1(1): 3. Available from the Internet. URL: http://www.consecol.org/vol1/iss1/art3/

Egan, R. S. 1987. A fifth checklist of the lichen-forming, lichenicolous and allied fungi of the continental United States and Canada. The Bryologist 90:77-173.

Egan, R. S. 1989. Changes to the "Fifth checklist of the lichen-forming, lichenicolous and allied fungi of the continental United States and Canada," edition I. The Bryologist 92:68-72.

Egan, R. S. 1990. Changes to the "Fifth checklist of the lichen-forming, lichenicolous and allied fungi of the continental United States and Canada," edition II. The Bryologist 93:211-219.

Egan, R. S. 1991. Changes to the "Fifth checklist of the lichen-forming, lichenicolous and allied fungi of the continental United States and Canada," edition III. The Bryologist 94:396-400.

Esslinger, T. L., and R. S. Egan. 1995. A sixth checklist of the lichen-forming, lichenicolous, and allied fungi of the continental United States and Canada. The Bryologist 98:467-549.

Faber-Langendoen, D., J. Rocchio, M. Schafale, C. Nordman, M. Pyne, J. Teague, T. Foti, and P. Comer. 2006. Ecological Integrity Assessment and Performance Measures for Wetland Mitigation. Final Report to US EPA Office of Water and Wetlands. NatureServe, Arlington, VA.

Harkness, M., M. Reid, P. Crist, L. Misztal, T. Van Devender, G. Kittel, D. Braun, and R. Unnasch. 2013. Madrean Archipelago Rapid Ecoregional Assessment: Pre-Assessment Report. Prepared for the U.S. Department of the Interior, Bureau of Land Management. NatureServe, Boulder, CO.

Holling, C. S. 1973. Resilience and stability of ecological systems. Annual Review of Ecology and Systematics 4: 1-23.

Jenkins, R. E. 1976. Maintenance of natural diversity: approach and recommendations. In: K. Sabol (ed.) Transactions–Forty -first North American Wildlife and Natural Resources Conference. Washington, D. C. March 21-25, 1976. Pp. 441-451.

Kartesz, J. T. 1999. A synonymized checklist and atlas with biological attributes for the vascular flora of the United States, Canada, and Greenland. First edition. In: J. T. Kartesz and C. A. Meacham.

Synthesis of the North American Flora, Version 1.0. North Carolina Botanical Garden, Chapel Hill, NC.

Levine, C.M. and J.C. Stromberg. 2001. Effects of flooding on native and exotic plant seedlings: implications for restoring south-western riparian forests by manipulating water and sediment flows. Journal of Arid Environments 49:111-131.

Masters, Elroy H. 2014. Acting Branch Chief, Renewable Resources and Planning, BLM, Arizona State Office. Personal Communication via e-mail dated May 2nd, 2014.

Nachlinger, J., K. Sochi, P. Comer, G. Kittel, and D. Dorfman. 2001. Great Basin: an ecoregion-based conservation blueprint. The Nature Conservancy, Reno, NV. 160 pp. + appendices.

Noss, R. F. 1987. From plant communities to landscapes in conservation inventories: A look at The Nature Conservancy (USA). Biological Conservation 41:11-37.

Noss, R. F., C. Carroll, K. Vance-Borland, and G. Wuerthner. 2002. A multicriteria assessment of the irreplaceability and vulnerability of sites in the Greater Yellowstone Ecosystem. Conservation Biology 16(4): 895-908.

Parrish, J. D., D. P. Braun, and R.S. Unnasch. 2003. Are we conserving what we say we are? Measuring ecological integrity within protected areas. Bioscience 53(9): 851-860.

Rood, Stewart B., Jeffrey H. Braatne and Francine M. R. Huges. 2003. Ecophysiology of riparian cottonwoods: stream flow dependency, water relations and restoration. Tree Physiology 23:1113-1124

Stotler, R., and B. Crandall-Stotler. 1977. A checklist of liverworts and hornworts of North America. The Bryologist 80:405-428.

Unnasch, R.S., D. P. Braun, P. J. Comer, G. E. Eckert. 2009. The ecological integrity assessment framework: A framework for assessing the ecological integrity of biological and ecological resources of the National Park System**.** Report to the National Park Service.

Aquatic/Wetland/Riparian Ecological Systems: Conceptual Models and Ecological Status

Connected Stream and Wetland Division

Basin River and Riparian

E-1 North American Warm Desert Riparian Woodland and Shrubland, Mesquite Bosque and Stream

E-1.1 Conceptual Model

E-1.1.1 Classification

The ecosystem conservation elements for the MAR REA were selected from NatureServe's classification of terrestrial ecological systems (Comer et al. 2003). Over three dozen ecological systems occur in the MAR, but only a select subset were chosen for the REA. The CE concept provided in this conceptual model includes these NatureServe ecological system types:

- North American Warm Desert (NAWD) Riparian Woodland and Shrubland (CES302.753)
- NAWD Riparian Mesquite Bosque (CES302.752)

There are other terrestrial ecological systems in the NatureServe classification that also occur in the MAR, or in adjacent ecoregions, which are similar to this CE concept but are not included in this conservation element. These are listed here to help the reader understand what is not included in this conceptual model; each of these other ecological systems has information that can be searched for and reviewed on NatureServe's on-line Explorer website.

- Chihuahuan-Sonoran Desert Bottomland and Swale Grassland (CES302.746) - Tobosa/Sacaton swale (intermittently flooded)
- North American Arid West Emergent Marsh (CES302.747)
- NAWD Cienega (CES302.747)
- NAWD Lower Montane Riparian Woodland and Shrubland (CES302.748)

E-1.1.2 Summary

This ecological system consists of riparian corridors and perennial and seasonally-flowing streams (**Figure E-5**) along canyons and across desert valleys generally at low-elevations (< 1200 m, ~4000 ft.)[1] with variation due to hydrogeologic setting, found in southwestern United States and adjacent Mexico (Comer et al. 2003) (**Figure E-6**). Mesquite-dominated sites can also occur along intermittent streams, where higher groundwater levels permit. The vegetation is a mix of riparian woodlands and shrublands. Dominant native trees include box elder (*Acer negundo*), velvet ash (*Fraxinus velutina*), Fremont's cottonwood (*Populus fremontii*), honey mesquite (*Prosopis glandulosa*), velet mesquite (*Prosopis velutina*), Gooding's willow (*Salix gooddingii*), arroyo willow (*Salix lasiolepis*), netleaf hackberry (*Celtis laevigata var. reticulata*), sycamore (*Platanus racemosa*), and Arizona walnut (*Juglans major*). Native shrub dominants include mulefat (*Baccharis salicifolia*), arrowweed (*Pluchea sericea*), Geyer's willow

[1] Tentative proposed elevation break, specific to the MAR.

(*Salix geyeriana*), and coyote or sandbar willow (*Salix exigua*) (Comer et al. 2003, Robinett 2005b, Stromberg et al. 2009).

This ecosystem covers woody vegetated riparian areas typical of the Sandy Bottom Ecological Site Description (Robinett 2005b). This CE does not include the Loamy Bottom Ecological Site where giant sacaton (*Sporobolus wrightii*) dominates, as described by NRCS (Robinett 2005a, Wright 2002) and Stromberg et al. (2009). Giant sacaton stands may be adjacent to woody riparian ecosystems.

The aquatic fauna and flora vary depending on flow characteristics: perennial or intermittent; the frequency, intensity, seasonal timing, and duration of high-flow pulses, low-flows, and dry conditions; the relative contributions of rainfall/runoff and groundwater discharges to flow, including discharges from discrete springs; water temperature and chemistry; channel substrate and form, including the distribution of shaded pools; the extent of the hyporheic zone; and drainage network connectivity.

Perennial flow and spring flooding are an important part of the hydrology for communities along perennial reaches, such as cottonwood. Cottonwood communities are of special concern in the region, in part because they provide critical habitat for Western yellow-billed cuckoo, currently up for review to be listed as threatened by the USFWS (see http://www.fws.gov/sacramento/outreach/Public-Advisories/WesternYellow-BilledCuckoo/outreach_PA_Western-Yellow-Billed-Cuckoo.htm). In addition perennial flow and floods are critical for cottonwood regenerateion see Levine and Stromberg 2002 Journal of Arid Environments 49:111-131; Rood et al. 2003 Tree Physiology 23:1113-1124.

As with all warm desert streams and rivers, this ecosystem supports a unique range of aquatic species adapted to the overall scarcity and irregular availability of water over space and time, and the frequent isolation of perennial reaches by dry conditions across the rest of the drainage network. These factors result in a high degree of endemism among the aquatic biota, including species adapted to using pools or the hyporheic zone as their main habitat or as refuge during periods with low, intermittent, or no flow.

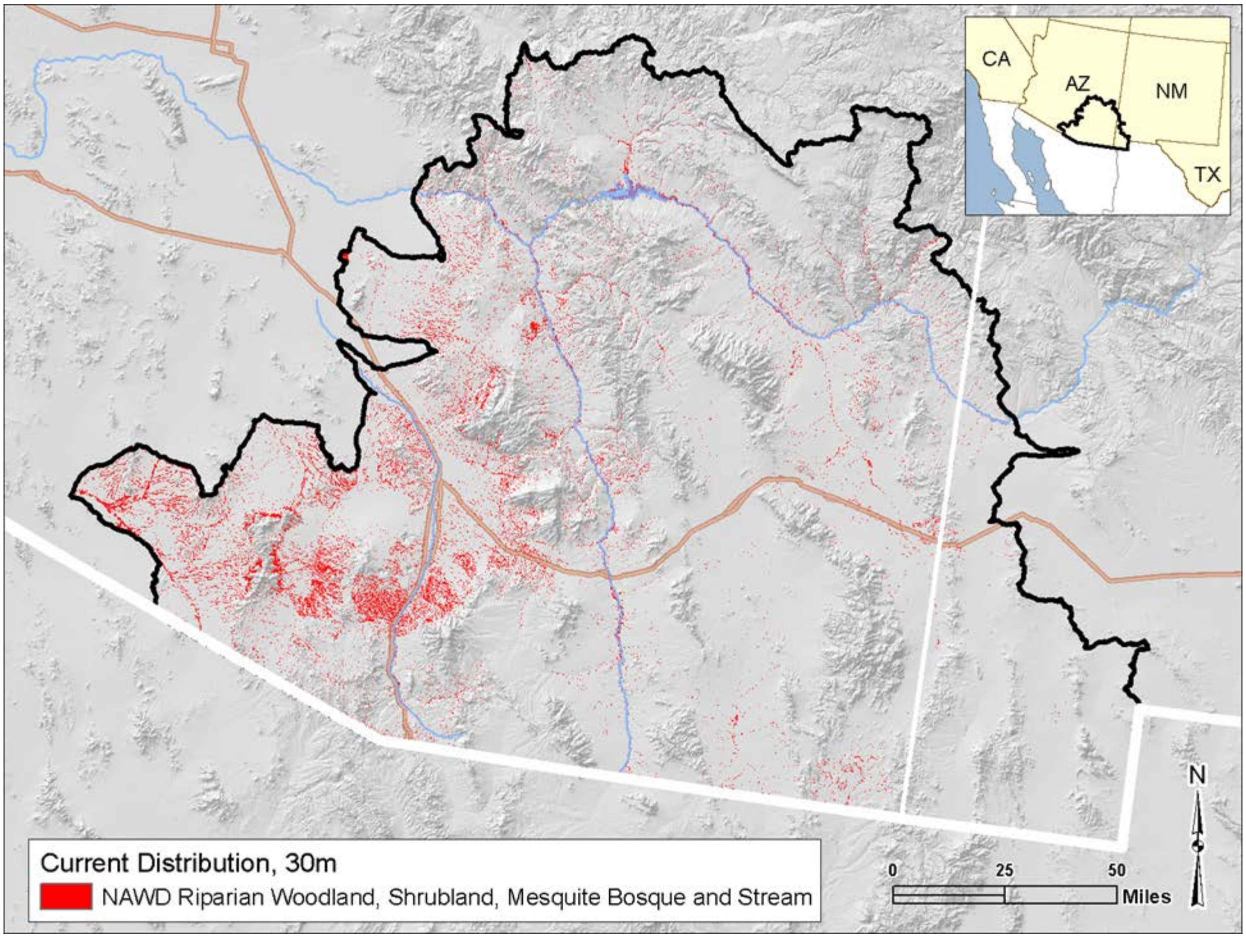
These factors select for a unique spectrum of aquatic species in this ecosystem. For example, benthic macroinvertebrate assemblages generally consist of highly tolerant, short-lived, fast-reproducing individuals with broad ecological tolerances, with an emphasis on collectors/gatherers and grazers. Vertebrate and invertebrate species able to use the hyporheic zone as their main habitat or as a refuge during periods without flow or during extreme flow pulses occur in this system type (e.g., Del Rosario and Resh 2000, Levick et al. 2008), as do aquatic species tolerant of higher water temperatures and salinity. Disturbances caused by intermittent flows may actually facilitate high food quality and consequently high levels of insect production (Fisher and Gray 1983, Grimm and Fisher 1989, Huryn and Wallace 2000, Jackson and Fisher 1986).

Figure E-5. Photos of North American Warm Desert Riparian Woodland and Shrubland, Mesquite Bosque and Stream CE along the San Pedro River, AZ.

E-1.1.3 Current Distribution

Figure E-6 shows the current distribution of the CE, by 30m pixel. The pixels are represented to scale, and so appear very small on a map compressed to fit on a printed page. As a result, it is difficult to discern the overall pattern of distribution in **Figure E-6.** Only clusters of adjacent pixels for the CE stand out. However, the distribution is fully apparent when viewed directly in a GIS. The CE occurs in two types of settings – directly along stream corridors, and along dry washes across adjacent foothills and terraces where shallow groundwater conditions permit the growth of mesquite bosques.

Figure E-6. Current distribution of North American Warm Desert Riparian Woodland, Shrubland and Mesquite Bosque and Stream CE within the MAR.



E-1.1.4 Species of Conservation or Management Concern

Below are listed some species of concern associated with this ecological system CE. Sources include the Gila Ecoregion in Freshwater Ecoregions of North America (Abell et al. 2000), and Stefferud et al. (2009).

Reptiles and Amphibians: Mexican garter snake, lowland leopard frog.

Birds: Gray hawk, yellow-billed cuckoo, Southwestern Willow Flycatcher (*Empidonax trailii extimus*), Lucy's warbler, and many other migratory and breeding species.

Fish: Spikedace (*Meda fulgida*) (Gila R), loach minnow (*Tiaroga cobitis*) (Gila & San Francisco R.), Gila trout (*Oncorhynchus gilae*), Longfin dace (*Agosia chrysogaster*) and Gila topminnow (*Poeciliopsis occidentalis*) endemic to Gila R., Gila chub (*Gila intermedia*), Colorado Squawfish (*Ptychocheilus lucius*) and Razorback sucker (*Xyrauchen texanus*) endemic to Colorado River Basin and the Gila R., and Roundtail chub (*Gila robusta*) Gila R. Additional fishes include the Sonora sucker (*Catostomus insignis*) and the Desert Sucker (*Pantosteus clarki*)

Mammals: Beaver (*Castor canadensis*)

E-1.1.5 Natural Dynamics

The hydrologic regime of North American Warm Desert Riparian Woodland and Shrubland, Mesquite Bosque, and Stream ecosystem is naturally highly variable temporally and spatially among the streams of this ecosystem.

Faunal and floral composition and dynamics – both terrestrial and aquatic – are shaped by episodic flooding and associated sediment scour and deposition, and by the rise and fall of the alluvial water table. Vegetation is relatively dense, especially when compared to drier washes. Woody vegetation, especially the mesquites, cottonwoods, and willows, rely on groundwater recharged to the alluvial soils either by seasonal runoff along the channel or by deeper groundwater connections. In turn vegetation can affect the velocity of surface flows (Hereford 1993, Webb et al. 2007, Stromberg et al. 2009). Locally, bedrock formations may force groundwater to the surface – either along diffuse gaining reaches or at discrete springs – where it supports the alluvial water table and channel baseflow. Historically, areas of surface water-groundwater connection sometimes supported extensive open wetland complexes without significant woody vegetation (e.g., Calamusso 2005, Eby et al. 2003, Horton et al. 2001, Katz et al. 2009, Leenhouts et al. 2006, Lite and Stromberg 2005, Propst et al. 2008, Shafroth et al. 2000, Shafroth et al. 2010, Snyder and Williams 2000, Stromberg 1998, Stromberg 2001, Stromberg et al. 1996, Stromberg et al. 2005, Stromberg et al. 2006, Stromberg et al. 2007, USFWS 1999, Webb and Leake 2006).

Stream depth and discharge vary widely in where they occur, at what magnitudes, and when and how often, as a result of the wide variation in where and when precipitation takes place as well as the result of other factors such as slope, vegetation, channel characteristics and subsurface properties (e.g., Abell et al. 2000, Eby et al. 2003, Shafroth et al. 2010, Stromberg 2001, Stromberg et al. 2007). Intense runoff can be highly erosive, resulting in rapid reconfiguration of aquatic and riparian macrohabitats, particularly along reaches with sand and gravel substrates. As a result of this intense regime of fluvial disturbance, occurrences of this ecosystem often contain a mix of early-, mid- and late-seral riparian plant associations. They may also contain non-obligate riparian species. Mesquite is a facultative phreatophyte and can tolerate significant drops in the water table in low-flow years. Cottonwood communities are early-, mid- or late-seral, depending on the age-class of the trees and the associated species of the occurrence (Kittel et al. 1999b). Cottonwoods, however, do not reach a climax stage as defined by Daubenmire (1952). Mature cottonwood occurrences do not regenerate in place, but regenerate by "moving" up and down a river reach. Over time, a healthy riparian area supports all stages of cottonwood communities (Kittel et al. 1999b).

This riparian and aquatic ecosystem has high spatial and temporal variation that is driven by many abiotic factors. The timing, duration, temperature range of perennial flow (from groundwater dynamics) and flow pulses (from watershed runoff) - are shaped by the warm, arid climate with large contrast between daytime and nighttime temperatures (>60 degrees F). Spatial extent of perennial flow is controlled by the many factors such as distribution of bedrock and clay layers that can force alluvial groundwater flow to the surface, by the distribution of buried channel gravels, and by the distribution of springs from deeper aquifers with sufficient discharge to support streamflow. The limited precipitation is concentrated at higher elevations mostly as rainfall but sometimes also as snow, and substantial precipitation and/or snowmelt events are necessary to produce runoff that reaches the low-elevation occurrences of this ecosystem (e.g., Price et al. 2005). Runoff can, however, be produced by precipitation over lower elevations particularly during summer convective storms and winter synoptic storms.

The presence and magnitude of such runoff events vary greatly from season to season, year to year, and decade to decade (e.g., Price et al. 2005, Serrat-Capdevila et al. 2007). The Madrean Archipelago ecoregion is the northern and western most arm of the Chihuahuan desert. This area receives about 14.7 inches of rain a year, most of that falling in the summer months, the monsoon. About 90% of the annual rainfall occurs between July and October, at least for the San Pedro Basin (Hirschboeck 2009). The summer monsoon is characterized by thunderstorms that build in the afternoon (Serrat-Capdevila et al. 2007). However winter storms deliver rain and snow, which can be significant as well. Evapotranspiration is lower in the winter, and the rainfall is of greater duration but lower intensity – and may be combined with snowfall at higher elevations. Consequently, more winter moisture soaks into soils and becomes a very important source of groundwater recharge in the mountains and along the mountain fronts (valley margins). Although winter rains are less than half the annual precipitation they are responsible for a major portion of the annual recharge (Eastoe et al.2004, Poole and Coes 1999, Serrat-Capdevila et al. 2007). The types of storms associated with different seasons and weather patterns also affect the types of fluvial erosion and deposition that take place (Price et al. 2005). Perennially-flowing reaches occur where groundwater discharge is sufficient to produce sustained surface flow. The groundwater discharge may occur as seepage or spring discharge from the surrounding alluvial aquifer or from an underlying basin-fill aquifer, water from which is forced to the surface by bedrock constrictions or fine-grained layers that create confining conditions.

Daily stream flows for rivers that originate mostly or entirely within the MAR ecoregion, such as the San Pedro River, typically have high flows during the summer monsoon. However, occasional years occur during which winter/spring flows exceeded monsoon flows, as illustrated in Stromberg et al. (2009).

Streams in this ecosystem include both "gaining" and "losing" reaches. Gaining reaches occur where groundwater flows into the stream. Losing reaches occur where surface water leaks into underlying aquifers, resulting in a reduced or complete cessation of flow. Alternating gaining and losing reaches can result in a naturally patchy distribution of aquatic, hyporheic, and riparian habitat as nutrient, chemical characteristics, and temperature vary. Evaporation and riparian transpiration also consume water seasonally, contributing to losses of flow along individual stream reaches during the growing season, with a proportionately smaller affect during runoff flow pulses. Riparian water table dynamics follow suit: the water table rises during high-flow events and falls between such events, unless the water table is controlled primarily by an upward leakage of groundwater from deeper aquifers (e.g., Webb and Leake 2006). However, large intense storms can also cause dynamic response in groundwater table, regardless of stream flow characteristics.

Average concentrations of particulate organic matter can be higher during runoff pulses, as are concentrations of suspended and re-suspended sediment through dilution. In contrast, concentrations of particulate organic matter are lower during baseflow, as are concentrations of suspended and re-suspended sediment. One important characteristic of groundwater inputs to streamflow is that groundwater temperatures tend to be stable over the longterm.

Fire can also play an important role in shaping the vegetation along streams. Very hot fires can kill cottonwood trees and in drier reaches may stimulate growth of already present salt cedar (*Tamarix*) (Stromberg et al. 2009). Fires cause less mortality along wetter and regularly flooded reaches, probably due to the removal of woody debris by floods, the more open stature of the trees, and higher moisture of vegetation. Fire in adjacent sacaton grasslands maintain grass dominance and reduced woody growth such as mesquite (Stromberg et al. 2009, Wright 2002). Fires can also destabilize channels until vegetation reestablishes, as well as greatly increase sediment and debris transport which can substantially affect aquatic ecosystems in the short term.

E-1.1.6 Change Agent Effects on the CE

This section of the conceptual model presents a narrative description of the primary change agents and current knowledge of their effects on North American Warm Desert Riparian Woodland, Shrubland and Mesquite Bosque / Stream ecosystems. The section contains two sub-sections: (1) A list of primary change agents identified for the CE; and (2) a discussion of altered dynamics caused by these agents.

E-1.1.6.1 List of Primary Change Agents

Occurrences of this ecosystem – both their riparian areas and aquatic communities – are directly affected by concentrated grazing, cutting of woody vegetation, land development, river channelization including channel dredging and bank armoring, diversion of flows, withdrawals of groundwater, wildfire suppression, colonization by non-native terrestrial and aquatic plants and animals, unregulated recreation (both motorized and non-motorized), roadways and railways that cut through/along riparian corridors, mining, point-source and diffuse (runoff) pollution, and fragmentation by dams. Occurrences are also indirectly affected by climate change and by human activities across the surrounding watersheds that alter watershed runoff and groundwater recharge/discharge by altering ground cover and through water diversions and withdrawals; or that result in point and non-point-source pollution, including from abandoned and active mines, septic tanks, effluent from wastewater treatment plants, and possibly from atmospheric deposition.

E-1.1.6.2 Altered Dynamics

Table E-4 identifies the most likely impacts associated with each of the stressors identified in Section E-1.1.6.1. Change agents, and the specific stressors they generate, which can cause alteration to the key ecological attributes (KEAs) for individual occurrences of this ecosystem type. Some stressors directly remove the conservation element, such as new rural or urban development. Other stressors such as roads and other infrastructure corridors (e.g. railroads, power lines, solar arrays, oil pumping platforms and the like) cause fragmentation in the distribution or connectivity of the conservation element (Debinski and Holt 2001). Irrigated agriculture, in addition to completely removing portions of a conservation element, can also cause downstream alteration to a riparian/stream ecosystem through polluted runoff and return flow and through flow alteration (e.g., Boody and DeVore 2006, Chipps et al. 2006, Pimentel et al. 2004). Water development projects can have a double effect on aquatic CEs, as they can change the amount and timing of flow, and also can fragment the network of flow (Poff et al. 2010). Aquatic invasive species can have profound effects on the amount of oxygen available; can introduce toxins; can prey on, infect, or directly compete with native species; and have been shown to completely replace the native ecosystem habitat (e.g. tamarisk) (USGS 2011).

Stressors can cause different degrees of alteration to an individual KEA, i.e., different degrees of stress; and the degree of alteration to a KEA will depend on the cumulative effects of all stressors acting on it. Responses to stress in key ecological attributes of biotic condition for riparian/stream ecosystems may include a reduction in species taxonomic and genetic diversity due to fragmentation and loss of habitat at the scale of the ecoregion (Vranckx et al. 2011). Individual species can become less abundant as their habitats become fragmented or continually disturbed such that reproduction is less successful, causing alteration to functional diversity and food web structure (Calamusso et al. 2005). As native species become stressed, other more tolerant and opportunistic species may increase in abundance, causing additional changes to functional diversity and food web structure. Shifts in species abundance and composition can also alter abiotic dynamics. For example, changes in vegetation can alter nutrient cycling or cause changes in vegetation on stream banks that affect bank and channel stability; and changes in beaver populations can change hydrology and nutrient cycling. **Figure E-7** and **Figure E-8** capture these interactions and the use of indicators to track them.

Table E-4. Stressors and their likely impacts on the North American Warm Desert Riparian Woodland and Shrubland, Mesquite Bosque, and Stream ecosystem type in the Madrean Archipelago ecoregion (with representative citations specific to impacts to aquatic resources in general, within the ecoregion, or in the western US, but not an exhaustive literature review of the wide literature on each stressor).

Stressor	Impacts
Land Use	
Concentrated grazing	Removal of native vegetation, changes to native composition and structure, possibly favoring invasion of non-native vegetation (Patten 1998); loss of regenerating native cottonwoods and willows (Robinett 2005b) thus altering native vegetation assemblage and overall ecological function (Faber-Langendoen et al. 2008); erosion of stream banks and channel; stream pollution (sediment, manure) (Robinett 2005b), which can degrade fish habitats (Calamusso 2005).
Unregulated recreation	Elimination and fragmentation of riparian habitat; increased soil erosion; point and non-point source pollution, cutting of woody vegetation, (Debinski and Holt 2000).
Cutting of woody vegetation	Removal of native vegetation, possibly favoring invasion of non-native vegetation (Patten 1998, Stromberg et al. 2009), thus altering native vegetation assemblage and overall ecological function (Faber-Langendoen et al. 2008), which can impact the amount of woody debris important for fish habitat (Calamusso 2005).
Development	
Roadways/railways	Elimination and fragmentation of riparian habitat; altered longitudinal surface flow paths in alluvial aquifer; non-point source pollution (Comer and Faber-Langendoen 2013, Comer and Hak 2009).
Mining within riparian zone	Elimination and fragmentation of riparian habitat; altered alluvial/channel geomorphic dynamics; altered longitudinal groundwater flow paths in alluvial aquifer; point source pollution (Berkman and Rabeni 1987, Mol and Ouboter 2004).
Altered watershed ground cover	Alteration of runoff and recharge at both the watershed scale and immediately along the riparian/stream corridor; altered sediment inputs from watershed during runoff events; altered non-point source pollution (Anning et al. 2009, Poff et al. 2010, Webb and Leake 2006).
Land development	Elimination and fragmentation of riparian habitat; reduced alluvial recharge during rainfall/runoff; increased soil erosion; non-point source pollution (McKinney and Anning 2009).
Fragmentation by dams	Fragmentation of riparian habitat and aquatic connectivity very important to fish habitat (Calamusso 2005)

Stressor	Impacts
Hydrologic Alterations	
River channelization	Elimination of natural geomorphic dynamics; elimination of bank and over-bank recharge to alluvial aquifer during runoff pulses; elimination of groundwater discharge along armored reaches; channel entrenchment resulting in lowered groundwater table (Hereford 1993, Webb et al. 2007), which degrades fish habitat (Calamusso 2005).
Diversion of flows	Loss of surface flows, both baseflow and runoff, with consequent loss of natural alluvial groundwater recharge/discharge dynamics, disconnect with the floodplain which can increase sediment transport and change the aquatic habitat (Calamusso 2005, Poff et al. 2010, Shafroth et al. 2010, Theobald et al. 2010), causing loss to flora and faunal ecology (Faber-Langendoen et al. 2008, Patten 1998, Stromberg et al. 2007).
Point-source pollution along riparian zone	Direct alteration of surface water and potentially also groundwater quality which can lead to poor water quality detrimental to fish habitats.
Point-source pollution, watershed	Alteration of water quality in flows arriving from upstream and tributaries which can lead to poor water quality detrimental to fish habitats (Calamusso 2005).
Non-point-source pollution	Alteration of water quality in flows arriving from upstream and tributaries as well as in surface runoff along/within the riparian zone itself Abell et al. 2000) which can lead to poor water quality detrimental to fish habitats (Calamusso 2005).
Withdrawals of groundwater	Loss of baseflow (magnitude and spatial extent) and lowering of alluvial water table (Calamusso 2005, Poff et al. 2010, Stromberg et al. 1996). Changes in flow can cause increased channel incision and down cutting of the stream bed (Hereford et al. 1993, Webb et al. 2007), and cause severe habitat changes such as loss of mature trees, bank erosion and widened channel and wetland grassed and forbs are replaced by annuals (Falke et al. 2011, Robinett 2005b).
Changes to natural Wildfire regime	Change in vegetation succession dynamics, such as the encroachment and increase density of native and non-native woody species, such as tamarisk , and hot fires that change soil characteristics (Stromberg et al. 2009, Stromberg and Rychener 2010, U.S. Fish and Wildlife Service 2002).
Invasive Species	
Non-native terrestrial plants and animals	Replacement of native vegetation, altering riparian habitat suitability for terrestrial fauna; alteration of shading of channel affecting water temperature and habitat quality;, alteration of fire risk; alteration of soil and channel stability either through an increase (such as tamarisk thickets) or decrease (annuals replacing perennial graminoid species); alteration of ground-litter chemistry; alteration of evapotranspiration rates and timing (Robinett 2005b, Stromberg 1998).

Stressor	Impacts
Non-native aquatic plants and animals	Removal or reduction of native aquatic species due to competition, predation, alteration of water quality (Calamusso 2005, Rinne 1996, USEPA 2005).
Climate change	Alteration of precipitation and evapotranspiration rates and timing, resulting in direct alteration of runoff and recharge at both the watershed scale and immediately along the riparian/stream corridor. Impacts may also occur through changes in human consumption of surface water and groundwater in response to climate change (Price et al. 2005).

E-1.1.7 Ecological Status: Key Ecological Attributes and Indicators

This section of the conceptual model addresses key ecological attributes and their potential indicators. "Ecological status" is a way of describing the current status of a CE via key ecological attributes and their indicators, asking if the indicators are within their normal ranges of variation.

E-1.1.7.1 Key Ecological Attributes

Table E-5 identifies the key ecological attributes for the CE within the Madrean Archipelago ecoregion. A **key ecological attribute** of a focal ecological resource is a characteristic of the resource's biology, ecology, or physical environment that is critical to the resource's persistence in the face of both natural and human-caused disturbance. Alteration of such a characteristic beyond some critical range of variation will lead to the degradation or loss of the resource within decades or less. The KEAs table lists the identified key ecological attributes, with a brief definition, a rationale for why it is important for the CE, and a listing of stressors or change agents that might be affecting the key attribute.

Table E-5. Key ecological attributes (KEA) of North American Warm Desert Riparian Woodland and Shrubland, Mesquite Bosque, and Stream ecosystem.

KEA Class: Name	Definition	Rationale	Stressors
Landscape Context: **Landscape Cover**	The extent of natural ground cover for the watershed containing the riparian/stream ecosystem occurrence, versus the extent of different kinds of modifications to the watershed surface for human use.	Surrounding watershed cover in unaltered landscapes helps determine the rates of precipitation runoff versus infiltration, evapotranspiration, soil erosion (both "sheet" and "channel" erosion), and transport of sediment, dissolved and suspended nutrients to the riparian/stream location from the watershed as a whole and from its immediate "near-stream" buffer zone. Surrounding watershed cover also shapes the connectivity between the riparian/stream corridor and the surrounding landscape for fauna that move between the two settings; and the longitudinal connectivity of the buffer zone alongside the corridor within which additional wildlife movement takes place. (Comer and Faber-Langendoen 2013, Comer and Hak 2009)	Stressors to landscape cover include watershed development and/or excessive grazing, which can alter the rates of runoff versus infiltration from precipitation, evapotranspiration, soil erosion (both "sheet" and "channel" erosion), and transport of sediment, dissolved and suspended nutrients to the riparian/stream location from the watershed as a whole and from its immediate "near-stream" buffer zone. Development and excessive grazing also can introduce pollutants and cause fragmentation (reduce connectivity) between the riparian/stream corridor and the surrounding landscape and along the buffer zone surrounding the corridor. Climate change also has the potential to cause additional change in landscape cover.
Size/Extent: **Vegetation Corridor Extent**	The longitudinal extent of uninterrupted (unfragmented) native vegetation patches along the riparian corridor.	Unfragmented riparian corridors support individual animal movement; gene flow; and natural flooding, sediment deposition, and scour processes upon which aquatic and wetland species depend. More extensive and highly connected riparian corridors are ecologically more resistant and resilient, for example by providing refugia and movement routes that support recovery following disturbance or incursions by non-native species (Faber-Langendoen et al. 2012b). Within the MAR, streams were naturally patterned perennial and intermittent, making for naturally patchy corridors, so the degree of fragmentation change from historic would require accurate maps showing the distribution prior to European influence. At the time of this assessment, such a map was not available.	Stressors to vegetation corridor extent include development on/in the riparian corridor itself, including: conversion to agriculture, excessive grazing, commercial/industrial/residential use; construction of transportation infrastructure; and dams/impoundments. These changes can alter the movement of water, nutrients, animals, and sediment. Lateral constrictions can lead to increased velocity of flows, contributing to increased erosion and down-cutting. Climate change also has the potential to cause additional change in vegetation corridor extent, through its impacts on hydrology (see Hydrologic Regime).

KEA Class: **Name**	**Definition**	**Rationale**	**Stressors**
Size/Extent: **Aquatic Corridor Extent**	The longitudinal extent of the stream channel network, uninterrupted by barriers or reaches including those with naturally seasonal or intermittent flow.	Unfragmented aquatic corridors support up- and downstream movement and gene flow for aquatic animal species, natural downstream transport of larvae and seeds, and natural downstream transport of sediment and both dissolved and suspended nutrient matter -- all processes crucial to sustaining the aquatic food web, aquatic and riparian species populations, and succession and recovery from disturbances. More extensive and highly connected aquatic corridors are ecologically more resistant and resilient, for example by providing refugia and movement routes that support recovery following disturbance. Within the MAR, streams naturally contained mixes of perennial and intermittent reaches, making for naturally patchy corridors, so the degree of fragmentation change from historic cannot be used as a measure of health.	Stressors affecting aquatic corridor extent include dams and diversions, riparian corridor development (see Vegetation Corridor Extent), surface- and groundwater use (see Hydrologic Regime), channelization (see Geomorphology), and concentrated contamination such as from mine waste (see Water Chemistry). Climate change also has the potential to cause additional change in aquatic corridor extent, through its impacts on hydrology (see Hydrologic Regime).
Biotic Condition: **Riparian Fauna**	The taxonomic and functional (e.g., guild) composition of the native faunal assemblage of the riparian corridor including birds, mammals, reptiles and amphibians, and invertebrates; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The taxonomic and functional composition of riparian faunal assemblage are important aspects of the ecological integrity of a riparian ecosystem. Numerous native species of birds, mammals, reptiles and amphibians, and invertebrates use riparian habitat for feeding, resting, breeding, and movement; and their patterns of use vary over time (seasonal, annual, longer-term). These species vary in their sensitivity to different stresses such as alterations to riparian vegetation composition, riparian corridor connectivity, soil moisture, and the availability of surface water. Alterations in the taxonomic and functional composition of the terrestrial faunal assemblage beyond their natural ranges of variation therefore strongly indicate the types and severities of stresses imposed on the riparian ecosystem.	Stressors to the taxonomic and functional composition of the riparian faunal assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, floral composition, and abiotic condition of the riparian/stream ecosystem; and incursions of non-native species that alter the food web or directly compete with or prey on the native fauna.

KEA Class: Name	Definition	Rationale	Stressors
Biotic Condition: **Riparian & Aquatic Flora**	The taxonomic composition of the native floral assemblage of the riparian corridor including woody and non-woody vegetation - terrestrial, wetland, and aquatic - and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The taxonomic composition of the riparian & aquatic floral assemblage is an important aspect of the ecological integrity of a riparian/aquatic ecosystem. Numerous native species of woody and non-woody plants occur preferentially or exclusively in riparian habitats, from floodplain terraces to stream banks and perennial pools; and occur in different successional settings following disturbance. These species vary in their sensitivity to different stresses such as alterations to riparian corridor hydrology (e.g., water table and flood dynamics), aquatic and riparian corridor connectivity (affecting availability of seed for recolonization following disturbance), and altered water quality. Alterations to the taxonomic composition of the riparian floral assemblage beyond its natural range of variation strongly indicates the types and severity of stresses imposed on the riparian ecosystem.	Stressors to the taxonomic composition of the riparian native floral assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, and abiotic condition of the riparian/stream ecosystem, including altered wildfire and excessive grazing; and incursions of non-native species that alter the habitat (e.g., alter soils) or directly compete with the native flora.
Biotic Condition: **Aquatic Fauna**	The taxonomic and functional (e.g., guild) composition of the native faunal assemblage of the stream, including fishes, reptiles and amphibians, and invertebrates; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The taxonomic and functional composition of the aquatic faunal assemblage are important aspects of the ecological integrity of a stream ecosystem. Aquatic species - as especially well studied for fishes and macroinvertebrates - vary in their roles in the aquatic food web and in their sensitivity to different stresses such as alterations to stream hydrology, habitat quality, water quality, and nutrient inputs. Alterations in the taxonomic and functional composition of the aquatic faunal assemblage beyond their natural ranges of variation therefore strongly indicate the types and severities of stresses imposed on the aquatic ecosystem.	Stressors affecting the taxonomic and functional composition of the aquatic faunal assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, and abiotic condition of the riparian/stream ecosystem; and incursions of non-native species that alter the food web or directly compete with or prey on the native fauna.

KEA Class: Name	Definition	Rationale	Stressors
Abiotic Condition: **Hydrologic Regime**	The pattern of surface flow in the stream channel and surface-groundwater interaction along the riparian corridor - as characterized by, for example, the frequency, magnitude, timing, and duration of extreme flow conditions and extreme water table elevations; the magnitude and timing of seasonal and annual baseflow and total discharge; and the magnitude of seasonal and annual water table mean elevation.	The surface flow regime determines which aquatic species can persist in a stream system through their requirements for or tolerances of different flow conditions at different times of the year; shapes sediment transport and geomorphology and therefore aquatic habitat distributions and quality; and determines the pattern of flood disturbance. In turn, interactions between the surface flow regime and underlying aquifer conditions shape the pattern of baseflow and the pattern of water table variation along the riparian corridor. The surface flow regime and surface-groundwater interactions thereby together strongly influences both aquatic and riparian habitat and biological diversity (e.g., Poff et al. 1997; Poff et al. 2010).	Stressors affecting the hydrologic regime include watershed development that alters runoff, infiltration (recharge), sediment and debris transport and deposition and evapotranspiration rates; surface water diversions, transfers, and use; groundwater withdrawals from basin-fill and alluvial aquifers; return flows of municipal and agricultural wastewater; dams, dam operations, and impoundment evaporation; riparian corridor development; and alterations to the riparian floral assemblage including invasions of non-native flora with high water consumption. Climate change also has the potential to cause additional change in the hydrologic regime, through its effects on precipitation form (snow vs. rain), spatial distribution, magnitude, and timing; and through its effects of evapotranspiration rates both within the riparian zone and across the surrounding watershed. Climate change may also cause changes in human water use.
Abiotic Condition: **Geomorphology**	The geomorphology of the stream channel, banks, and floodplain, including channel steepness, cross-sectional form, sediment size distributions, and geomorphic stability/turnover.	Channel and floodplain geomorphology, shaped by watershed runoff (sediment and water) and surface flows in the stream, create the habitat template for both riparian and stream flora and fauna. Altered channel substrate and geomorphology strongly affect aquatic faunal assemblage composition, sediment and debris transport and deposition, and complexity and both stream-floodplain and surface-groundwater interactions along riparian corridors.	Stressors affecting the geomorphology of the stream channel, banks, and floodplain include the cumulative effects of alterations to watershed cover, riparian and aquatic corridor connectivity, riparian flora, sediment and debris transport and deposition and hydrology; the effects of bank and channel trampling from excessive use by livestock; and the effects of direct channel and floodplain modifications such as channelization and gravel mining. Climate change also has the potential to cause additional change in stream channel morphology through its impacts on watershed cover (see Landscape Cover) and hydrology (see Hydrologic Regime).

KEA Class: Name	Definition	Rationale	Stressors
***Abiotic Condition:* Water Chemistry**	The chemical composition of the water moving into the riparian corridor water table and along the stream channel, including the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The chemistry of the water flowing into and through riparian and stream habitat strongly determine which plant and animal species can persist in these habitats through their requirements for or tolerances of different soil and stream water chemistries. Stream fauna, for example, vary in their requirements for or tolerances of variation in salinity, dissolved oxygen, temperature, turbidity, and the presence/absence of different dissolved and suspended constituents including anthropogenic pollutants.	Stressors affecting water quality include effects of single catastrophic high or low concentration perturbation such as low oxygen, high temp, or heavy metals can be devastating to aquatic ecosystems. Additionaly, the cumulative effects of non-point source pollution from watershed development, point-source pollution those that are not catastrophic (e.g., municipal, industrial, mining wastewater), atmospheric deposition, excessive use of riparian zones as pasturing areas for livestock, and altered groundwater discharge (see Hydrologic Regime). Climate change has the potential to exacerbate these impacts through changes in watershed runoff and water use.
***Abiotic Condition:* Fire**	The pattern of fire occurrence (fire regime) within the riparian corridor, as characterized by its frequency, intensity, and spatial extent.	Fire is a natural agent of disturbance in riparian vegetation communities, where it helps shape community succession, triggers reproductive activity, and shapes the cycling of soil nutrients.	Stressors affecting the fire regime include ecologically incompatible fire management practices, and changes in landscape and riparian corridor vegetation due to other factors.

E-1.1.8 Relationship of KEAs to Fundamentals of Rangeland Health

The key ecological attributes and stressors listed in **Table E-5** also encompass the four fundamentals of rangeland health (USDI BLM 2006), as shown in **Table E-6.** The KEA for Landscape Cover specifically refers to watershed conditions; all other KEAs refer specifically to Ecological Processes and Habitat. However, many of the Indirect Indicators for the KEAs for abiotic condition focus on stressors that arise as a result of modifications to the watershed or modifications to water quality. These relationships are also indicated in **Table E-6**. Further information about interpretation and assessment of these fundamentals of rangeland health is found in Pellant et al. (2005).

Table E-6. Relationship of key ecological attributes (KEA) for the North American Warm Desert Riparian Woodland and Shrubland, Mesquite Bosque, and Stream ecosystem to fundamentals of rangeland health.

Key Ecological Attribute	Watersheds	Ecological Processes	Water Quality	Habitat
Landscape Cover	X		X	
Vegetation Corridor Extent		X		X
Aquatic Corridor Extent		X		X
Biotic Condition: Riparian Fauna		X		X
Biotic Condition: Riparian and Aquatic Flora		X		X
Biotic Condition: Aquatic Fauna		X		X
Abiotic Condition: Hydrologic Regime	X	X	X	X
Abiotic Condition: Geomorphology	X	X	X	X
Abiotic Condition: Water Chemistry	X	X	X	X
Abiotic Condition: Fire	X	X	X	X

E-1.1.9 Conceptual Model Diagrams

Figure E-7. Conceptual model diagram for North American Warm Desert Riparian Woodland and Aquatic Stream Ecosystem This diagram describes the structural components and functional relationships that characterize this system. Ovals represent key ecological attributes and Ecosystem Drivers. Arrows indicate functional relationships among components. Line weights indicate relative importance. The model is constrained by global climatic and atmospheric conditions, topography, parent material and potential biota.

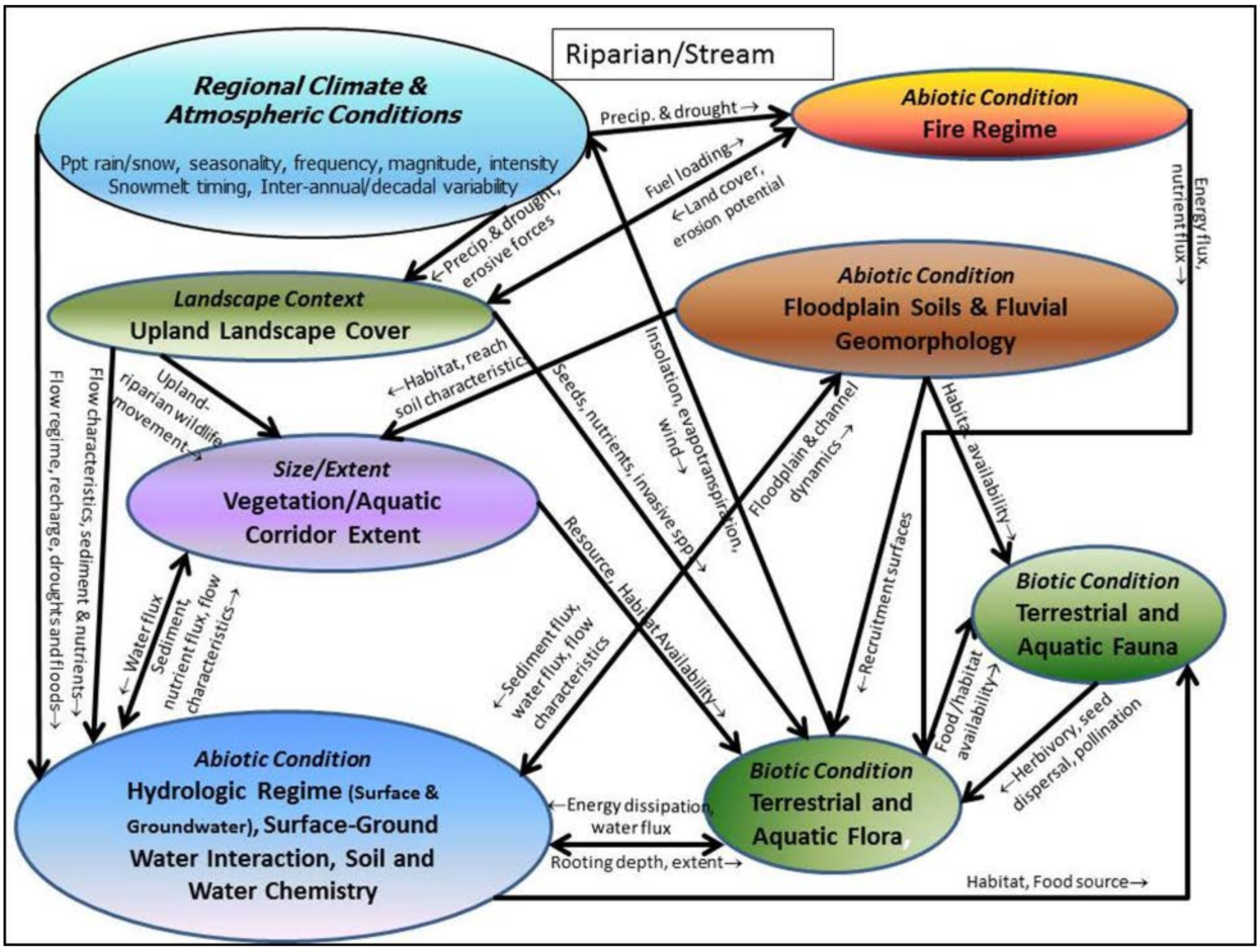
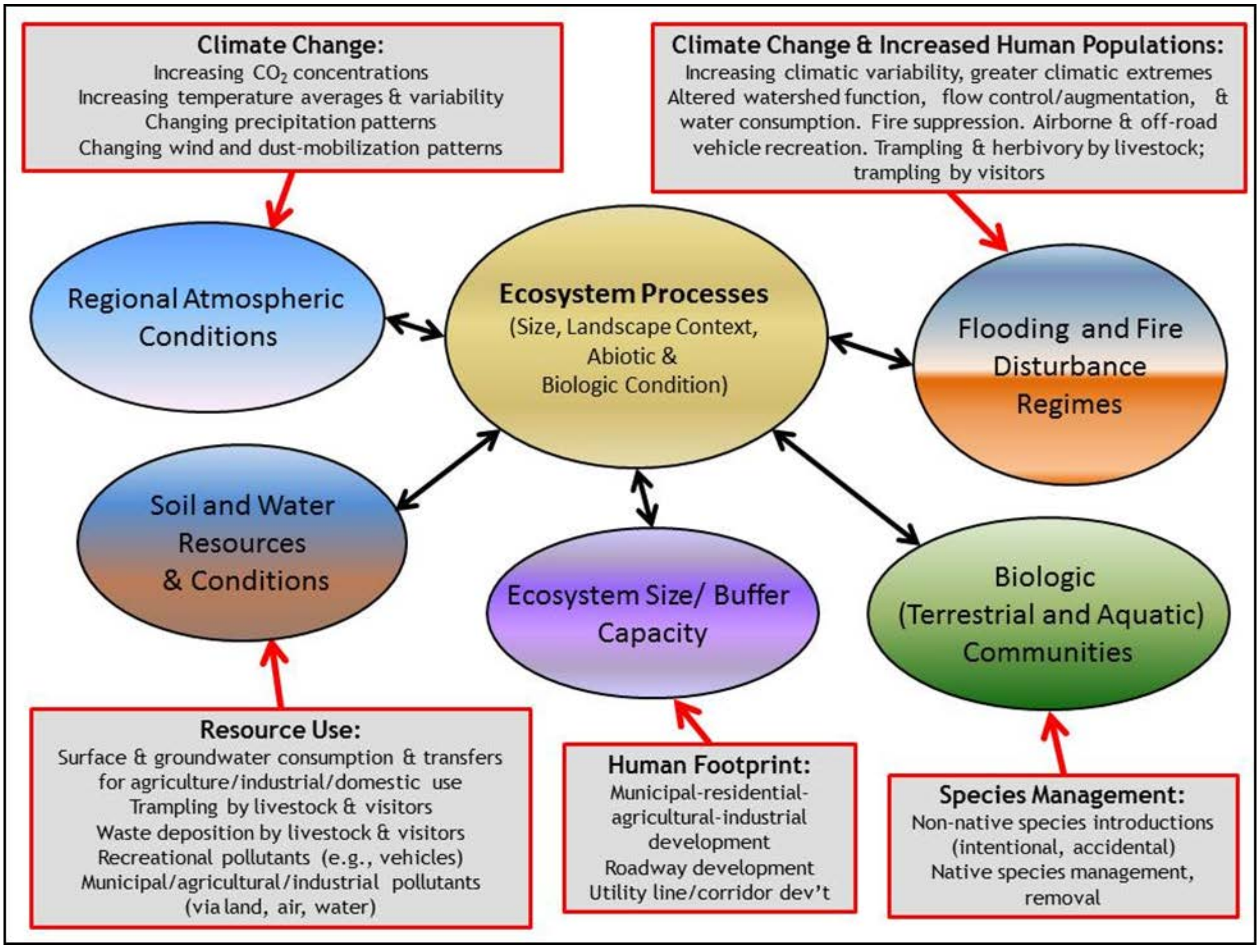


Figure E-8. Some of the major stressors affecting riparian ecosystem's key ecological attributes.



E-1.2 Ecological Status Assessment Results and Interpretation

This section of the appendix presents and discusses the results of the ecological status assessment for the North American Warm Desert Riparian Woodland, Shrubland, Mesquite Bosque & Stream CE. The presentation addresses each indicator separately, and then addresses the overall assessment, which integrates the results of all individual indicators. The results are presented using a common framework, in which the status of an indicator – or the combination of all indicator – is scored on a scale from 0.0 to 1.0, where 0.0 indicates a condition of complete replacement of reference ecological conditions due to the impacts of stressors, and 1.0 indicates a condition of no alteration of reference ecological conditions. The same color ramp is used for all results, yellow to dark blue, where yellow equals low scores, green moderate scores and dark blues high scores.

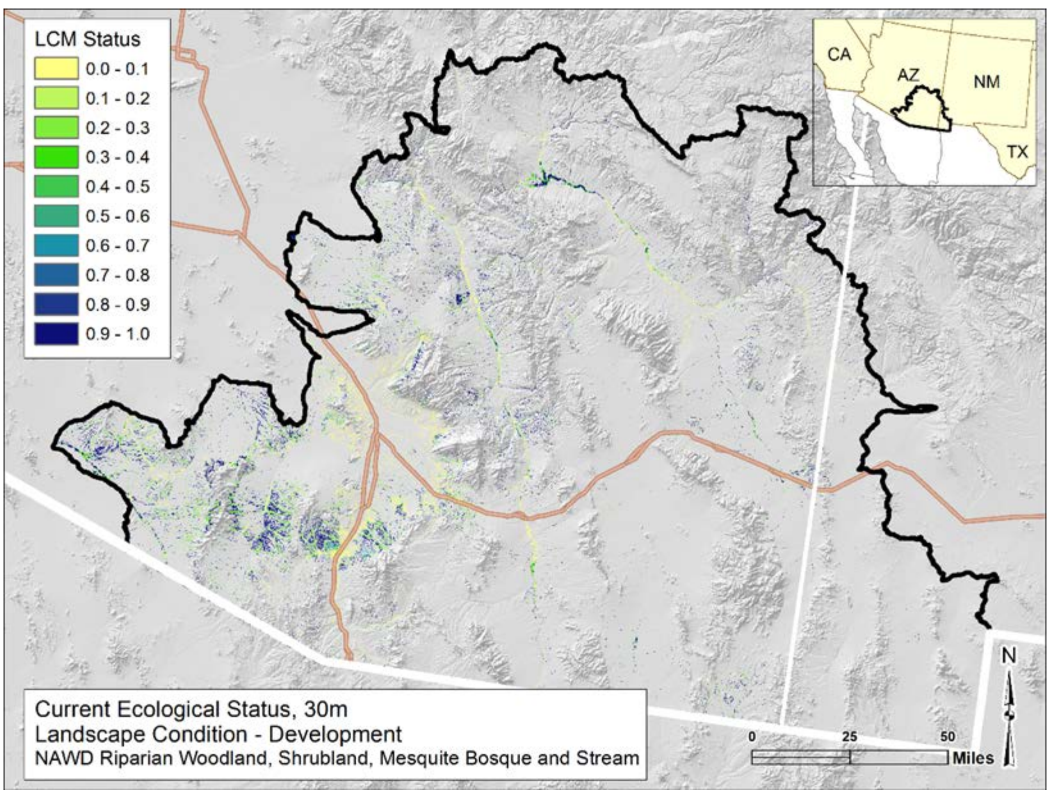
E-1.2.1 Development Indicator

Development is a stressor-based indicator of the spatial extent and intensity of human modifications to the land surface that alter land cover and watershed functions crucial to the ecological integrity of aquatic and wetland conservation elements in the MAR ecoregion. The indicator takes into account the density of urban development; infrastructure such as above- and below-ground distribution corridors, communication towers, and border barriers; a wide range of transportation features; mines and landfills; dams; recreational development; agriculture; and energy development. The scoring is on a continuous scale, from 1.0 indicating no ecologically relevant modifications to 0.0 indicating modifications that essentially eliminate all natural cover and natural watershed functions.

The results across the whole ecoregion (shown in **Figure** E-1 in the earlier **KEA Indicator Scenarios** section) show several large areas and corridors of intense development throughout the ecoregion, representing areas of municipal and agricultural development. Development impacts are especially noticeable in the Tucson metropolitan area; in and around every residential community in the ecoregion; and along corridors associated with Interstate highways 10 and 19, US highway 70 and 191, and many other larger roads. Smaller roads lie along almost all larger riparian corridors in the ecoregion, where they result in lower scores as well. This is the case even in relatively protected riparian areas such as along the Upper San Pedro River.

As a result, as seen in **Figure E-9** , the majority of pixels in the distribution of the North American Warm Desert Riparian Woodland, Shrubland, Mesquite Bosque & Stream CE register status scores below 0.5 for landscape condition. The few pixels with status scores above 0.5 mostly represent mesquite bosques located away from the main riparian corridors. However, most mesquite bosques located away from the main riparian corridors are impacted by development; only a minority in remote locations is unaffected. (As noted above, the CE pixels are represented to scale, and so appear very small on a map compressed to fit on a printed page, making isolated pixels difficult to discern in this format).

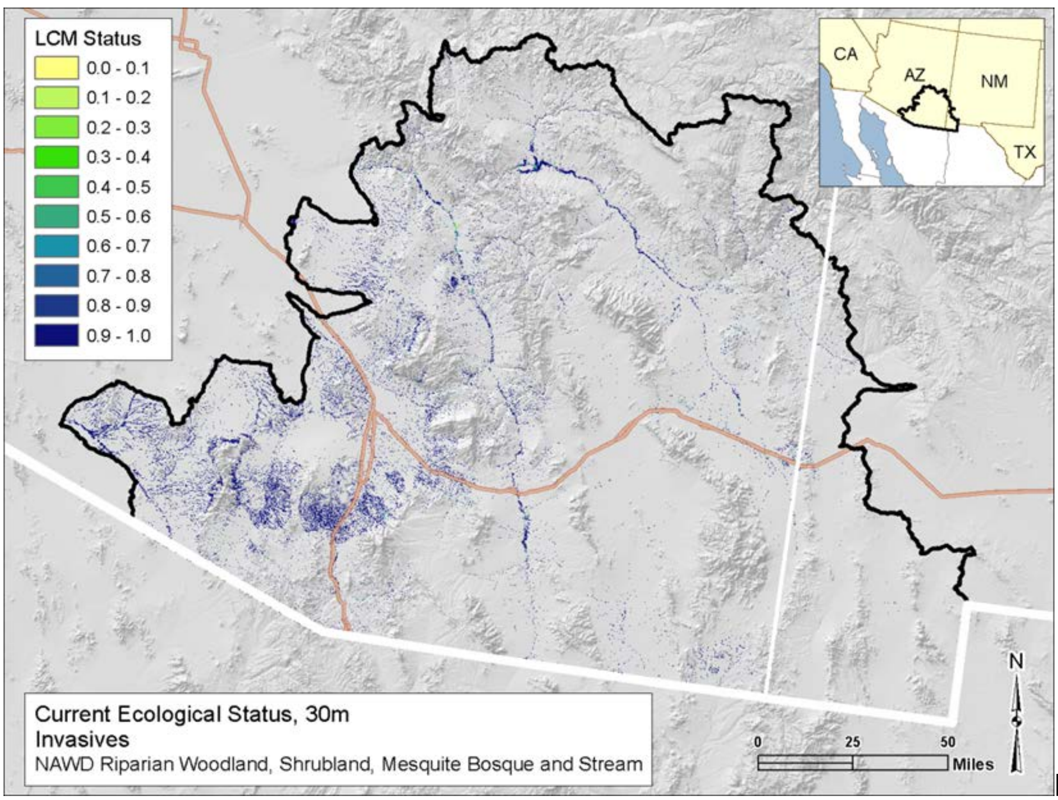
Figure E-9. Scores for the development indicator for the North American Warm Desert Riparian Woodland, Shrubland, Mesquite Bosque & Stream CE.



E-1.2.2 Aquatic and Terrestrial Invasives Species Indicator

Figure E-10 shows the scores for the invasives indicator. This is a stressor-based indicator of the presence of non-native invasive species including terrestrial woody and herbaceous plants such as tamarisk and cheat grass (*Bromus tectorum*) and aquatic invasive animals and aquatic plants (such as bullfrogs, crayfish, non-native fish, and pondweed). Status scores for invasive species mean the following: a score of 0.35 indicates a combination of aggressive aquatic animals and abundance of terrestrial plant species, 0.5 indicates the presence of highly aggressive aquatic species such as bullfrogs or crayfish, a score of 0.7 the presence of less aggressive aquatic species such as non-native salamanders, OR high abuncance (>25% cover) of non-native terrestrial plant species. There are numerous stretches of the Gila and San Pedro River that have scores <0.4 due to aggressive non-native fish and tamarisk invasions, and certain reaches with very low scores of 0.10 where several invasive species are found. The lighter colors may be difficult to see against the hillshade backdrop. Specific areas will be more apparent in a GIS application. In addition, note that much of the distribution of this CE has not yet been surveyed for non-native invasive species.

Figure E-10. Scores for the invasive species indicator for North American Warm Desert Riparian Woodland, Shrubland, Mesquite Bosque & Stream CE. It is recommended to view this data with a GIS application to see the patterns of high infestations.

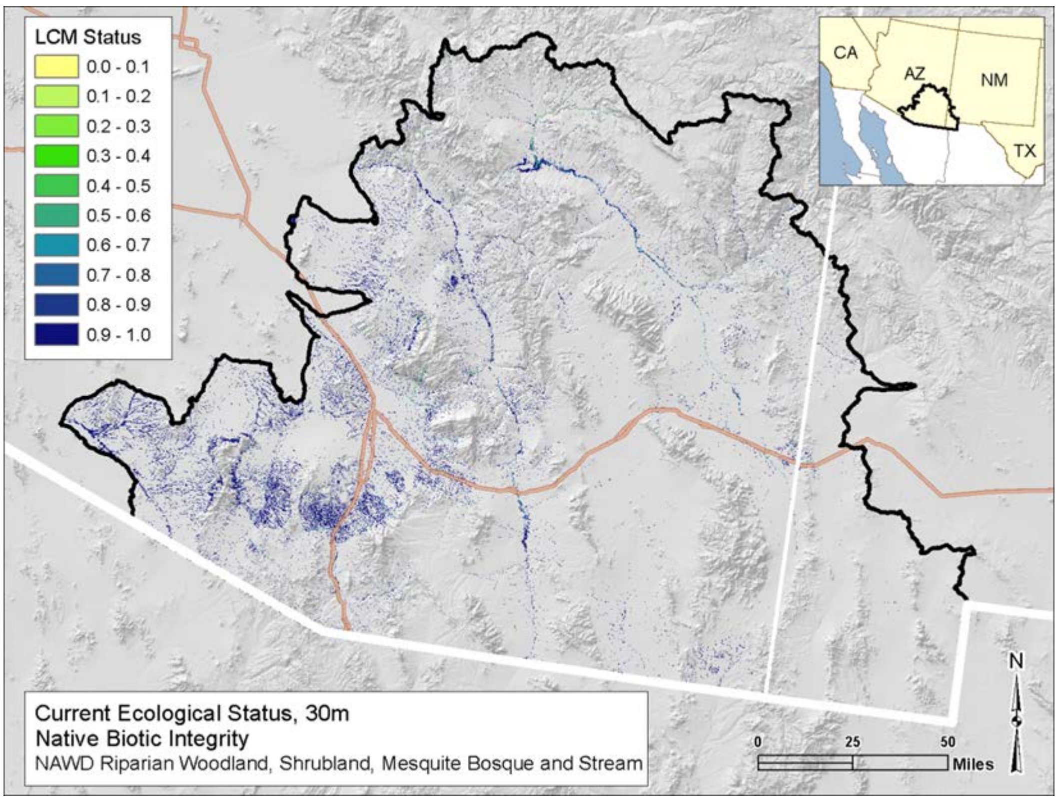


Native Biotic Integrity Indicator

Figure E-11 shows the scores for Native Biotic Integrity. This indicator is a direct measure of integrity (a combination of information on native fish, endangered species, and a benthic macro-invertebrate Index) and shows how many of the expected native species are present. While this is a limited data set, the data points are well distributed throughout the major rivers and tributaries of the Arizona portion of the REA. Of the 287 sample points across all aquatic CEs, 17% scored highly, 47% scored moderately, and

36% scored poorly. Stream reaches with null data were not scored. An absence of data does not mean that the stream has high or low native biotic integrity; it means only that no one has looked. This indicator is different from all other indicators in that it tracks a positive response rather than a negative one. The scores for native biotic integrity are relative to the high status scores such as development. Scores of 0.35 indicate that surveys turned up no native fish and few endangered species, and registered a low benthic macro-invertebrate score. Only a few pixels received such a low score, as it was rare to have all three sources of native biotic integrity measured at the same sampling location. A score of 0.5 means no native fish occur or the benthic macro-invertebrate index score was poor; a score of 0.7 indicates 1-3 native fish were present or 1-4 endangered species were recorded.

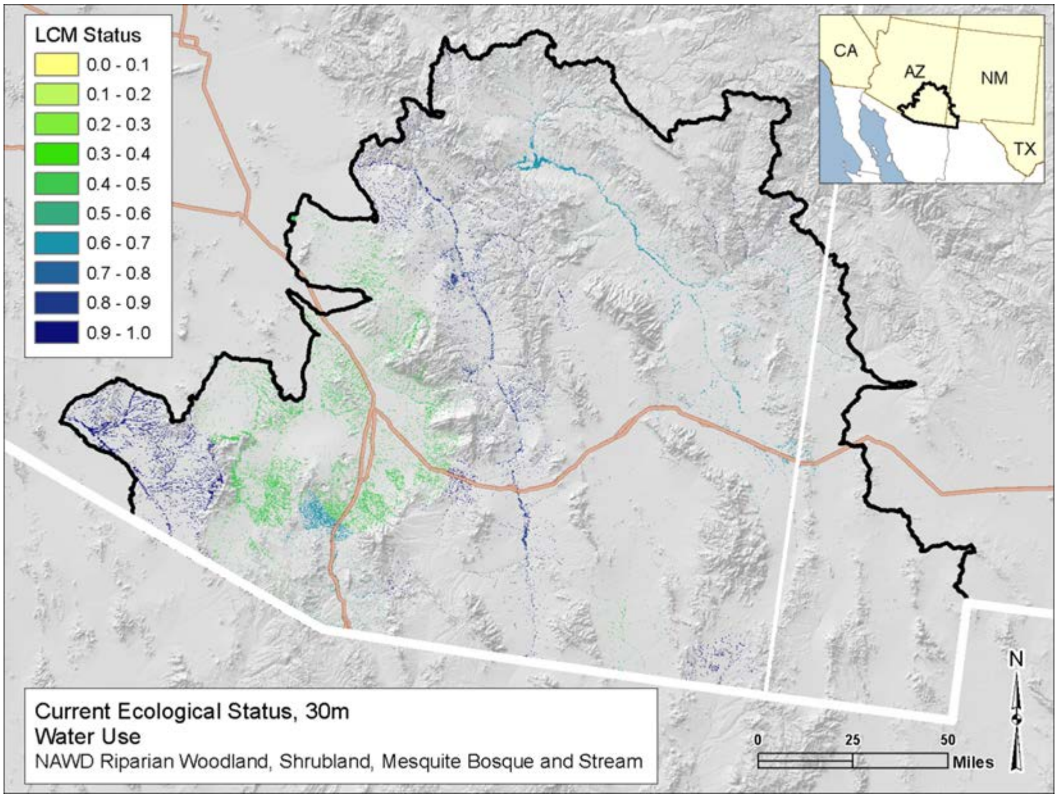
Figure E-11. Scores for the native biotic integrity indicator for North American Warm Desert Riparian Woodland, Shrubland, Mesquite Bosque & Stream CE. Native Biotic Integrity is a combination of native fish, endangered species, and benthic macro-invertebrates; scores are for each pixel of the distribution.



E-1.2.4 Water Use Indicator

Water use is a stressor-based indicator of the intensity of consumption of surface and ground water from within-ecoregion sources (discussed above, see page 20 of this Appendix). Each pixel in the map shows the score of the Arizona groundwater basin or New Mexico County in which the pixel lies. Thus, as in **Figure E-2** and **Figure E-3,** above, the results (**Figure E-12**) indicate high rates of water use in the Pinal AMA, Willcox, Tucson AMA, and Douglas groundwater basins; medium-high in the Safford, Duncan Valley, and Santa Cruz AMA basins, AZ, and Hidalgo County, NM; medium in the Upper and Lower San Pedro and Morenci groundwater basins, AZ, and Grant County, NM; and low in the Aravaipa Canyon, Cienega Creek, San Simon Wash, San Rafael, Donnelly Wash, San Bernardino, Dripping Springs Wash, and Bonita Creek groundwater basins, AZ. The areas of high rates of water use are all basins in Arizona with either dense municipal development (Tucson AMA) or large areas of intensive irrigation (Pinal AMA, Douglas and Willcox basins).

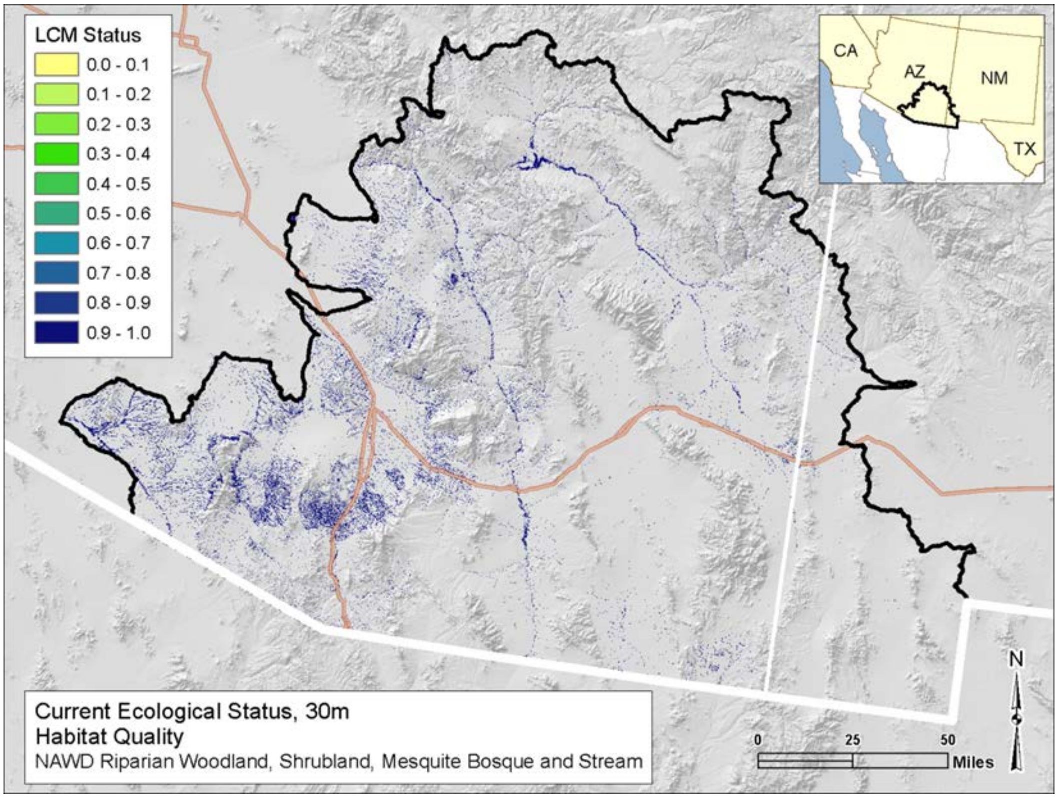
Figure E-12. Scores for the water use indicator for North American Warm Desert Riparian Woodland, Shrubland, Mesquite Bosque & Stream CE.



E-1.2.5 Habitat Quality Indicator

Figure E-13 shows the scores for Habitat Quality. This indicator is a direct measure of abiotic integrity and combines Proper Functioning Condition (PFC) Scores and Aquatic Habitat Scores. It shows how well channel bed, banks and floodplain soils may hold up during rainfall and runoff events. This is a spatially extremely limited data set and while the data points are distributed throughout the Arizona portion of the REA, there are not many points. BLM does collect PFC data within this REA, but those data were not available in a comprehensive, standardized, ecoregion wide format (Masters, E., personal communication 2014). Of the 118 sample points across all CEs, 50% scored highly, 49% scored moderately, and 1% scored poorly. Stream reaches with null data were not scored. A lack of data does not mean the stream is in good ecological heath but rather it means no one has looked. This indicator was included to compare direct measures against indirect, stressor measures. High scores indicate Proper Functioning Condition or high Aquatic Assessment scores, where there is vegetative cover and proper ratios of pool to riffles. Lowest scores (0.49) are places where both PFC and Aquatic habitat scored poorly.

Figure E-13. Scores for the habitat quality indicator for North American Warm Desert Riparian Woodland, Shrubland, Mesquite Bosque & Stream CE. Very few individual pixels scored low.

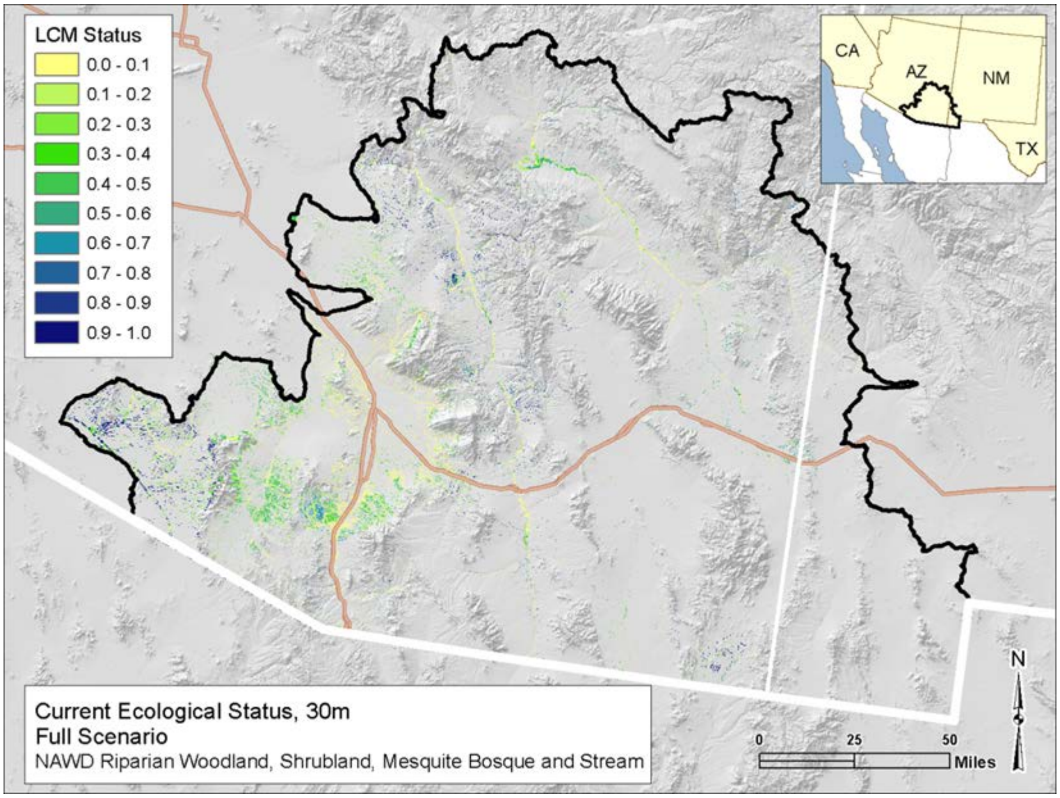


E-1.2.6 Current Ecological Status: Full Scenario

Figure E-14 shows the overall status of the North American Warm Desert Riparian Woodland, Shrubland, Mesquite Bosque & Stream CE. The upper panel shows the results by 30m pixel; the lower panel, by HUC10. The overall assessment takes into account the stressor-based indicators for landscape development, aquatic and terrestrial invasive species, and water use; and the direct indicators of ecological condition focused on native biotic integrity and habitat quality. The results are dominated by the stressor-based indicators, which together produce status scores < 0.5 for most pixels. At the HUC scale, 58 HUCs have status scores < 0.4, including four HUCs with status scores < 0.1. These contrast with only 20 HUCs with status scores > 0.4, including five with impacts scores 0.4-0.5, eight with status scores 0.5-0.6, seven with status scores 0.6-0.7, and none with status scores > 0.7. The majority of the distribution of this CE is in moderate to poor condition (**Figure E-15**).

The Gila River corridor downstream from the San Simon River confluence, most of the San Pedro River corridor, and most of the Santa Cruz River corridor south of Tucson show high levels of impact from development, water use, and invasive species. A few pixels with moderate or high scores represent riparian communities that have emerged around San Carlos Lake, a reservoir on the Gila River, and mesquite bosques located away from the main riparian corridors. The four most altered watersheds containing this CE type are located in the areas of Animas, NM; and the areas of Safford, Wilcox, and the Tucson metropolis, AZ. The seven least altered watersheds containing this CE type occur in the far west-southwestern corner of the ecoregion west and south of Sells, AZ; in the northern third of the lower San Pedro River basin; in the lower San Francisco River basin; and surrounding San Bernardino National Wildlife Refuge.

Figure E-14. Scores for overall status of the North American Warm Desert Riparian Woodland, Shrubland, Mesquite Bosque & Stream CE. – all indicators combined – for each pixel (upper map) and all 5th-level HUCs (lower map) containing occurrences of the distribution.



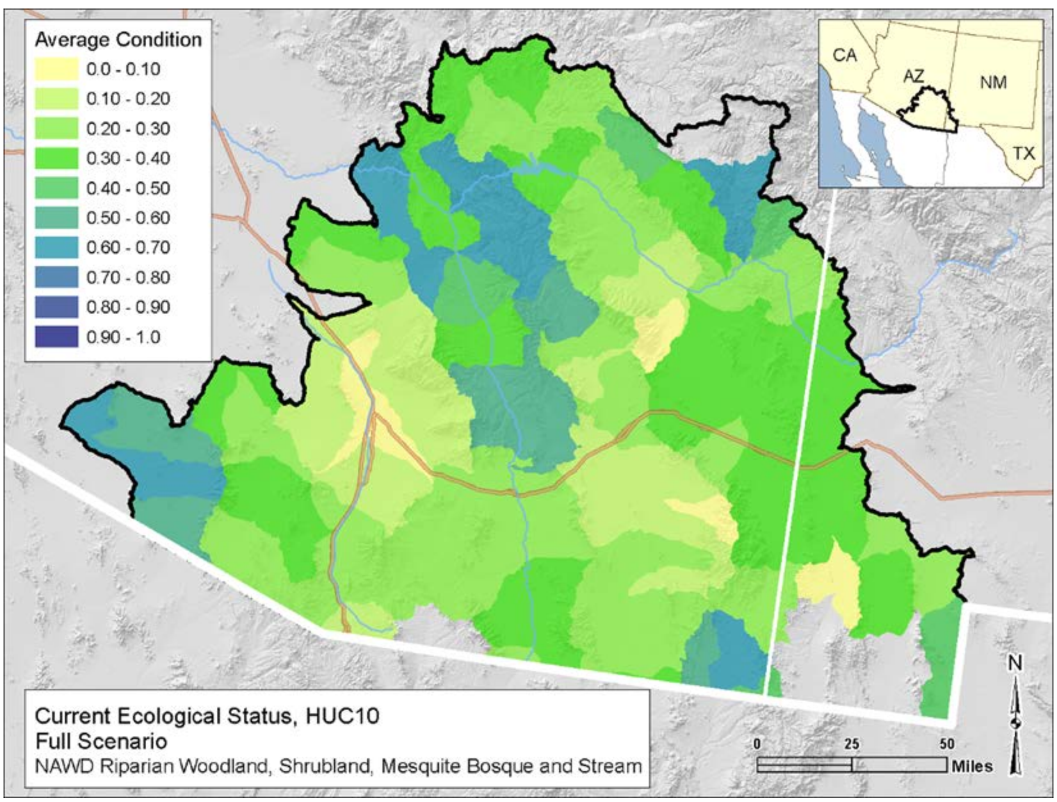
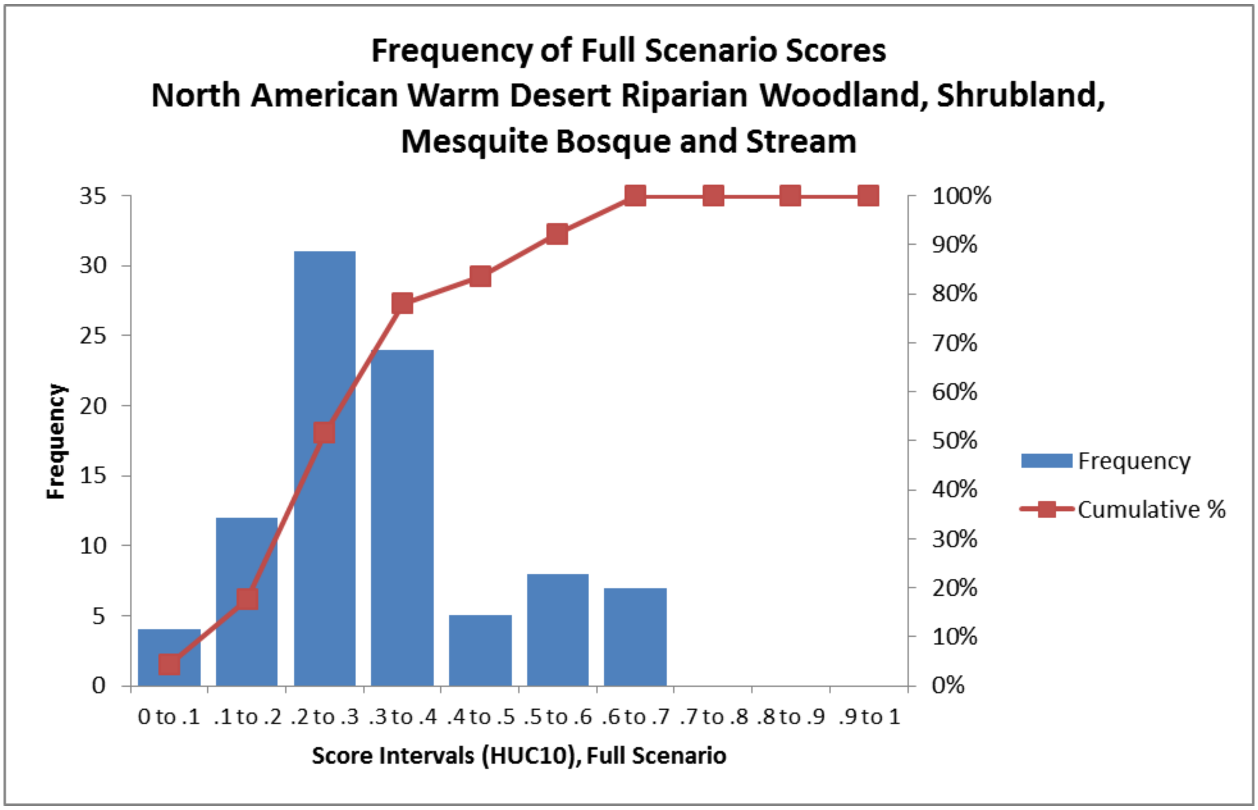


Figure E-15. Frequency distribution of the overall ecological status scores (by 5th-level HUC) with a running cumulative percent. The x-axis represents the 0.1 increment scoring intervals, while the y-axis shows the number of HUCs in each interval (left) and the cumulative percentage of the HUCs in each interval (right).



E-1.3 References for the CE

Abell, R., D. Olson, E. Dinerstein, P. Hurley, J. Diggs, W. Eichbaum, S. Walters, W. Wetterngel, T. Allnutt, C. Loucks, and P. Hedao. 2000. Freshwater Ecoregions of North America: A conservation assessment. Island Press, Washington, DC.

Anning, D.W., S.A. Thiros, L.M. Bexfield, T.S. McKinney, and J.M. Green. 2009. Southwest Principal Aquifers Regional Ground-Water Quality Assessment. U.S. Department of the Interior, U.S. Geological Survey Fact Sheet 2009-3015. http://water.usgs.gov/nawqa/studies/praq/swpa.

Berkman, H.E. and C.F. Rabeni. 1987. Effect of siltation on stream fish communities. Environmental Biologi of Fishes 18:285-294

Boody, G., and B. Devore. 2006. Redesigning agriculture. BioScience 56(10):839-845. [http://dx.doi.org/10.1641/0006-3568(2006)56[839:RA]2.0.CO;2]

Calamusso, B. 2005. Fishes of Southwestern Grasslands-Ecology, Conservation, and Management. In Finch, Deborah M., Editor, Assessment of grassland ecosystem conditions in the Southwestern United States, Volume 2: Wildlife and Fish, pp. 141-168. Rocky Mountain Forest and Range Experiment Station, General Technical Report RMRS-GTR-135-vol. 2. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Chipps, S. R., D. E. Hubbard, K. B. Werlin, N. J. Haugerud, K. A. Powell, J. Thompson, and T. Johnson. 2006. Association between wetland disturbance and biological attributes in floodplain wetlands. Wetlands 26(2):497-508.

Comer, P. and D. Faber-Langendoen. 2013. Assessing Ecological Integrity of Wetlands from National to Local Scales: Exploring the Predictive Power, and Limitations, of Spatial Models. National Wetlands Newsletter Special Issue on Wetland Mapping and Assessment. Environmental Law Institute. Washington DC. Vol. 35 No. 3 May/June 2013.

Comer, P. J., and J. Hak. 2009. NatureServe landscape condition model. Internal documentation for NatureServe Vista decision support software engineering, prepared by NatureServe, Boulder, CO

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. Ecological systems of the United States: A working classification of U.S. terrestrial systems. NatureServe, Arlington, VA.

Daubenmire, R. 1952. Forest vegetation of northern Idaho and adjacent Washington, and its bearing on concepts of vegetation classification. Ecological Monographs 22(4):301-330.

Debinski, D. M., and R. D. Holt. 2000. A survey and overview of habitat fragmentation experiments. Conservation Biology 14(2):342-355.

Del Rosario, R. B., and V. H. Resh. 2000. Invertebrates in intermittent and perennial streams: Is the hyporheic zone a refuge from drying? Journal of the North American Benthological Society 19(4):680-696.

Eastoe, C.J., Gu, A., Long, A., 2004. The origins, ages and flow paths of groundwater in Tucson Basins: results of a study of multiple isotope systems. In: Hogan, J.F., Philips, F.M., Scanlon, B.R. (Eds.), Groundwater Recharge in a Desert Environment: The Southwestern United States, Water Science Applied Series, vol. 9. AGU, Washington, DC, pp. 217–234.

Eby, L.A., W.F. Fagan, and W.L. Minckley. 2003. Variability and dynamics of a desert stream community. Ecological Applications, 13(6): 1566-1579.

Faber-Langendoen, D., G. Kudray, C. Nordman, L. Sneddon, L. Vance, E. Byers, J. Rocchio, S. Gawler, G. Kittel, S. Menard, P. Comer, E. Muldavin, M. Schafale, T. Foti, C. Josse, and J. Christy. 2008. Ecological Performance Standards for Wetland Mitigation: An Approach Based on Ecological Integrity Assessments. NatureServe, Arlington, VA.

Faber-Langendoen, D., J. Rocchio, S. Thomas, M. Kost, C. Hedge, B. Nichols, K. Walz, G. Kittel, S. Menard, J. Drake, and E. Muldavin. 2012b. Assessment of wetland ecosystem condition across landscape regions: A multi-metric approach. Part B. Ecological Integrity Assessment protocols for rapid field methods (L2). EPA/600/R-12/021b. U.S. Environmental Protection Agency Office of Research and Development, Washington, DC.

Falke, J. A., K. D. Fausch, R. M. A. A. D. S. Durnford, L. K. Riley, and R. Oad. 2011. The role of groundwater pumping and drought in shaping ecological futures for stream fishes in a dryland river basin of the western Great Plains, USA. ECOHYDROLOGY 4:682-697.

Fisher, S. G., and L. J. Gray. 1983. Secondary production and organic matter processing by collector macroinvertebrates in a desert stream. Ecology 64:1217-1224.

Grimm, N. B., and S. G. Fisher. 1989. Stability of periphyton and macroinvertebrates to disturbance by flash floods in a desert stream. Journal of the North American Benthological Society 8:293-307.

Hereford, R. 1993. Entrenchment and widening of the upper San Pedro River, Arizona. Geological Society of America Special Paper 282. 46 pp.

Horton, J.L., T.E. Kolb, and S.C. Hart. 2001. Responses of riparian trees to interannual variation in ground water depth in a semi-arid river basin. Plant, Cell and Environment 24: 293-304.

Huryn, A. D., and J. B. Wallace. 2000. Life history and production of stream insects. Annual Review of Entomology 45:83-110.

Jackson, J. K., and S. G. Fisher. 1986. Secondary production, emergence, and export of aquatic insects of a Sonoran Desert stream. Ecology 67:629-638.

Katz, G.L., J.C. Stromberg, and M.W. Denslow. 2009. Streamside herbaceous vegetation response to hydrologic restoration on the San Pedro River, Arizona. Ecohydrology 2: 213–225. DOI: 10.1002/eco.62.

Kittel, G., E. Van Wie, M. Damm, R. Rondeau, S. Kettler, A. McMullen, and J. Sanderson. 1999b. A classification of riparian and wetland plant associations of Colorado: A user's guide to the classification project. Colorado Natural Heritage Program, Colorado State University, Fort Collins CO. 70 pp. plus appendices.

Leenhouts, J.M., J.C. Stromberg, and R.L. Scott, eds. 2006. Hydrologic requirements of and consumptive ground-water use by riparian vegetation along the San Pedro River, Arizona. U.S. Geological Survey Scientific Investigations Report 2005–5163.

Levick, L., J. Fonseca, D. Goodrich, M. Hernandez, D. Semmens, J. Stromberg, R. Leidy, M. Scianni, D. P. Guertin, M. Tluczek, and W. Kepner. 2008. The ecological and hydrological significance of ephemeral and intermittent streams in the arid and semi-arid American Southwest. EPA/600/R-08/134, ARS/233046. U.S. Environmental Protection Agency and USDA/ARS Southwest Watershed Research Center. 116 pp.

Lite, S.J. and J.C. Stromberg. 2005. Surface water and ground-water thresholds for maintaining *Populus–Salix* forests, San Pedro River, Arizona. Biological Conservation 125: 153–167. DOI:10.1016/j.biocon.2005.01.020

Masters, Elroy H. 2014. Acting Branch Chief, Renewable Resources and Planning, BLM, Arizona State Office. Personal Communication via e-mail dated May 2nd, 2014.

McKinney, T.S. and D.W. Anning. 2009. Geospatial data to support analysis of water-quality conditions in basin-fill aquifers in the southwestern United States. U.S. Geological Survey Scientific Investigations Report 2008-5239. http://pubs.er.usgs.gov/sir/2008/5239.

Mol, Jan H. and Paul E. Outboter. 2004. Downstream Effects of Erosion from small-scale Gold mining on the instream habitat and fish community of a small Neotropical Rainforest Stream. Conservation Biology v18,n1:201-214

Patten, D. 1998. Riparian ecosystems of semi-arid North America: Diversity and human impacts. Wetlands 18:498-512. http://dx.doi.org/10.1007/BF03161668. ^10.1007/BF03161668.

Pellant, M., P. Shaver, D.A. Pyke, and J.E. Herrick. 2005. Interpreting indicators of rangeland health, version 4. Technical Reference 1734-6. BLM/WO/ST-00/001+1734/REV05. U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center, Denver, CO. 122 pp.

Pimentel, D., B. Berger, D. Filiberto, M. Newton, B. Wolfe, E. Karabinakis, S. Clark, E. Poon, E. Abbett, and S. Nandagopal. 2004. Water resources: Agricultural and environmental issues. BioScience 54(10):909-918.

Poff, N. L., J. D. Allan, M. B. Bain, J. R. Karr, K. L. Prestegaard, B. D. Richter, R. E. Sparks, and J. C. Stromberg. 1997. The natural flow regime-a paradigm for river conservation and restoration. BioScience 47(11):769-784.

Poff, N. L., B. D. Richter, A. H. Arthington, S. E. Bunn, R. J. Naiman, E. Kendy, M. Acreman, C. Apse, B. P. Bledsoe, M. C. Freeman, J. Henriksen, R. B. Jacobson, J. G. Kennen, D. M. Merritt, J. H. O'Keeffe, J. D. Olden, K. Rogers, R. E. Tharme, and A. Warner. 2010. The ecological limits of hydrologic alteration (ELOHA): A new framework for developing regional environmental flow standards. Freshwater Biology 55:147-170.

Pool, D.R., Coes, A.L., 1999. Hydrologic investigations of the Sierra Vista subwatershed of the Upper San Pedro River Basin, Cochise County, southeastern Arizona. U.S. Geological Survey Water Resources Scientific Investigation Report, 99-4197.

Price, J., C.H. Galbraith, M. Dixon, J. Stromberg, T. Root, D. MacMykowski, T. Maddock, III, and K. Baird. 2005. Potential Impacts of Climate Change on Ecological Resources and Biodiversity in the San Pedro Riparian National Conservation Area, Arizona. Report to U.S. EPA from the American Bird Conservancy. http://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=468326.

Propst, D.L., K.B. Gido, and J.A. Stefferud. 2008. Natural flow regimes, nonnative fishes, and native fish persistence in arid-land river systems. Ecological Applications 18(5): 1236–1252.

Rinne, J.N. 1996. The effects of introduced fishes on native fishes: Arizona, Southwestern United States. In Phillips et al., ed., Protection of Aquatic Biodiversity: Proceedings of the World Fisheries Congress, Theme 3, pp. 149-159.

Robinett, D. 2005a. Ecological Site Description: Sandy Bottom PLWR2-POFR2 F041XA113AZ. United States Department of Agriculture, Natural Resources Conservation Service.

Robinett, D. 2005b. Ecological Site Description: Sandy Bottom POFR2-SAGO F041XC317AZ. United States Department of Agriculture, Natural Resources Conservation Service.

Serrat-Capdevila, Aleix, Juan B. Valde´s , Javier Gonza´lez Pe´rez, Kate Baird, Luis J. Mata, Thomas Maddock III. 2007. Modeling climate change impacts – and uncertainty – on the hydrology of a riparian system: The San Pedro Basin (Arizona/Sonora). Journal of Hydrology, volume 347, pp 48–66.

Shafroth, P.B., A.C. Wilcox, D.A. Lytle, J.T. Hickey, D.C. Andersen, V.B. Beauchamp, A. Hautzinger, L.E. McMullen, A. Warner. 2010. Ecosystem effects of environmental flows: modeling and experimental floods in a dryland river. Freshwater Biology 55: 68–85. DOI:10.1111/j.1365-2427.2009.02271.x 1.

Shafroth, P.B., J.C. Stromberg, and D.T. Patten. 2000. Woody riparian vegetation response to different alluvial water table regimes. Western North American Naturalist 60(1): pp. 66–76.

Snyder, K.A. and D.G. Williams. 2000. Water sources used by riparian trees varies among stream types on the San Pedro River, Arizona. Agricultural and Forest Meteorology 105: 227–240.

Stefferud, J. A., P. C. Marsh, S. E. Stefferud, and R. W. Clarkson. 2009. Chapter 10: Fishes: Historical Changes and an Imperiled Native Fauna.in J. C. Stromberg and B. Tellman, editors. Ecology and Conservation of the San Pedro River. University of Arizona Press, Tucson.

Stromberg, J.C. 1998. Dynamics of Fremont cottonwood (*Populus fremontii*) and saltcedar (T*amarix chinensis*) populations along the San Pedro River, Arizona. Journal of Arid Environments 40: 133-155.

Stromberg, J.C. 2001. Restoration of riparian vegetation in the southwestern United States: importance of flow regimes and fluvial dynamism. Journal of Arid Environments 49: 17-34. DOI:10.1006/jare.2001.0833.

Stromberg, J.C., K.J. Bagstad, J.M. Leenhouts, S.J. Lite, and E. Makings. 2005. Effects of stream flow intermittency on riparian vegetation of a semiarid region river (San Pedro River, Arizona). River Research and Applications 21: 925–938. DOI: 10.1002/Rra.858.

Stromberg, J. C., S. J. Lite, M. D. Dixon, and R. L. Tiller. 2009. Chapter 1-Riparian Vegetation: Pattern and Process.in J. C. Stromberg and B. Tellman, editors. Ecology and Conservation of the San Pedro River. University of Arizona Press, Tucson.

Stromberg, J.C., R. Tiller, and B. Richter. 1996. Effects of groundwater decline on riparian vegetation of semiarid regions: the San Pedro, Arizona. Ecological Applications 6(1): 113-131.

Stromberg, J.C., S.J. Lite, T.J. Rychener, L.R. Levick, M.D. Dixon, and J.M. Watts. 2006. Status of the riparian ecosystem in the Upper San Pedro River, Arizona: Application of an assessment model. Environmental Monitoring and Assessment 115: 145–173. DOI: 10.1007/s10661-006-6549-1.

Stromberg, J.C., V.B. Beauchamp, M.D. Dixon, S.J. Lite, and C. Paradzick. 2007. Importance of low-flow and high-flow characteristics to restoration of riparian vegetation along rivers in arid south-western United States. Freshwater Biology 52: 651–679. DOI:10.1111/j.1365-2427.2006.01713.x.

Stromberg, J., and T. Rychener. 2010. Effects of Fire on Riparian Forests Along a Free-Flowing Dryland River. Wetlands 30:75-86.

Theobald, D. M., D. M. Merritt, and J. B. Norman, III. 2010. Assessment of threats to riparian ecosystems in the western U.S. Prepared for the Western Environmental Threats Assessment Center, Prineville, OR, by the Department of Human Dimensions of Natural Resources and the Natural Resource Ecology Lab, Colorado State University and USDI Forest Service Watershed, Fish, Wildlife, Air and Rare Plants Staff, Natural Resource Research Center, Ft. Collins, CO. 56 pp.

U.S. Environmental Protection Agency (USEPA). 2005. Use of Biological Information to Better Define Designated Aquatic Life Uses in State and Tribal Water Quality Standards: Tiered Aquatic Life Uses. EPA-822-R-05-001, DRAFT, August 10, 2005.

USDI BLM [U.S. Bureau of Land Management]. 2006. 43CFR4180.1 Fundamentals of Rangeland Health. Code of Federal Regulations and Federal Register, Accessed February 2013 http://federal.eregulations.us/cfr/section/2006/04/18/43-cfr-4180.1

U.S. Fish and Wildlife Service (USFWS). 1999. Designation of Critical Habitat for the Huachuca Water Umbel, a Plant. Department of the Interior Fish and Wildlife Service, 50 CFR Part 17 RIN 1018–AF37, Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Huachuca Water Umbel, a Plant, Final rule. Federal Register /Vol. 64, No. 132 /Monday, July 12, 1999 /Rules and Regulations 37441-37453.

U.S. Fish and Wildlife Service (USFWS). 2002. Southwestern Willow Flycatcher Recovery Plan. Albuquerque, New Mexico.

U.S. Geological Survey (USGS). 2011. Non-indigenous aquatic species. [http://nas.er.usgs.gov/] (Accessed December 2001).

Unnasch, R.S., D. P. Braun, P. J. Comer, G. E. Eckert. 2008. The Ecological Integrity Assessment Framework: A Framework for Assessing the Ecological Integrity of Biological and Ecological Resources of the National Park System. Report to the National Park Service.

Vranckx, G., H. Jacquemyn, B. Muys, and O. Honnay. 2011. Meta-analysis of susceptibility of woody plants to loss of genetic diversity through habitat fragmentation. Conservation Biology, November 2011. Early on-line publication. [10.1111/j.1523-1739.2011.01778.x]

Webb, R.H. and S.A. Leake. 2006. Ground-water surface-water interactions and long-term change in riverine riparian vegetation in the southwestern United States. Journal of Hydrology 320: 302–323. DOI:10.1016/j.jhydrol.2005.07.022.

Webb, R.H., R.M. Turner and S.A. Leake 2007. The Ribbon of Green. University of Arizona Press. Tucson, 480 pp.

Wright, E. 2002. Ecological Site Description: Loamy Bottom R041XA006NM. United States Department of Agriculture, Natural Resources Conservation Service.

Desert Marshes and Ciénegas

E-2 North American Warm Desert Ciénega, Marsh and Pond Ecological System

E-2.1 Conceptual Model

E-2.1.1 Classification

The ecosystem conservation elements for the MAR REA were selected from NatureServe's classification of terrestrial ecological systems (Comer et al. 2003). Over three dozen ecological systems occur in the MAR, but only a subset were chosen for the REA. The CE concept provided in this conceptual model includes these NatureServe ecological system types:

- North American Arid West Emergent Marsh (CES300.729)
- North American Warm Desert Cienega (CES302.747)

There are other terrestrial ecological systems in the NatureServe classification that also occur in the MAR, or in adjacent ecoregions, which are similar to this CE concept but are not included in this conservation element. These are listed here to help the reader understand what is not included in this conceptual model; each of these other ecological systems has information that can be searched for and reviewed on NatureServe's on-line Explorer website.

- Chihuahuan-Sonoran Desert Bottomland and Swale Grassland (CES302.746) Tobosa/Sacaton swale (intermittently flooded)
- North American Warm Desert Lower Montane Riparian Woodland and Shrubland (CES302.748)
- North American Warm Desert Riparian Woodland and Shrubland (CES302.753)
- Chihuahuan-Sonoran Desert Bottomland and Swale Grassland (CES302.746) - Tobosa/Sacaton swale (intermittently flooded)Summary

This spring-fed marsh ecosystem (**Figure E-16**) occurs at mid to low elevations (<2000 m, 6562 feet) across the warm deserts of western North America (**Figure E-17**). "Ciénegas" are freshwater, spring-fed wetlands, characterized by non-fluctuating shallow surface water (PAG 2001, Stromberg et al. 2009); the term ciénega was applied to riparian marshlands by Spanish explorers. These wetlands are found embedded in landscapes dominated by semi-desert grasslands and Madrean evergreen woodlands. The Ciénega, Marsh and Pond CE is characterized by permanently saturated, highly organic, reducing soils and a relatively simple flora dominated by low stature herbaceous hydrophytes (water loving plants), patches of taller emergent vegetation (marshes) and open water (ponds) with only occasional patches of trees (Hendrickson and Minckley 1984, Stevens et al. 2012, Stromberg et al. 2009,). The term "ciénega" is used throughout this report as a short hand for the Ciénega, Marsh and Pond ecosystem. Historically, ciénegas were much more abundant within the MAR, and were persistent part of the landscape with infrequent cycles of incision, such that they are considered a type of climax vegetation (Hendrickson and Minckley 1984). After 1870 and the influx of European setters, their livestock and coincidental drought cycle, severe changes occurred in the hydrology and plant cover with ciénega wetlands, causing arroyo formation (**Figure E-16**) and the loss of many ciénegas (Hendrickson and Minckley 1984, Hereford 1993, Webb et al. 2007). Today ciénegas are very rare (Stefferud et al. 2009) and are generally isolated from direct stream flow (that is, outside of active channels but still adjacent to them), although they can be hydrologically connected through the interaction of surface flow and groundwater sources such as shallow aquifers, as shown to be the source of water for the Bingham Ciénega (PAG 2001).

Figure E-16. Photos of North American Warm Desert Ciénega, Marsh and Pond CE. Left—St. David Ciénega, San Pedro River (Stevens et al. 2012). Right—Arroyo where a ciénega once stood, created by severe down cutting flooding caused by drought and loss of vegetative cover (Hendrickson and Minckley 1984, Hereford 1993, Webb et al. 2007).

Ciénegas in the MAR occurred historically at low and mid-elevations along stream channels with perennial springs. Ciénegas are perpetuated by permanent, minimally fluctuating sources of water that, when they were abundant, experienced low probabilities of scouring from floods (Hendrickson and Minckley 1984). Today they occur along small, low-energy rivers and streams, have low frequencies of scouring floods, and are typically sustained by groundwater inflow (Hendrickson and Minckley 1984, Stromberg et al. 2009). The hydrology is controlled by permanently saturated hydrosols, with reducing conditions limiting the type of plant life that may grow. Soils can have many meters of organic deposition (Stromberg et al. 1996). Plant life is limited to low shallow-rooted semi-aquatic sedges such as spike-rush (*Eleocharis* spp.), rushes *(Juncus* spp.), sedges (*Carex* spp.) a few grasses, and more rarely, cattails (*Typha spp*.) (Stevens et al. 2012, Stromberg et al. 2009). Forbs include whorled marshpennywort (*Hydrocotyle verticillata*), and creeping primrose-willow (*Ludwigia natans*)*,* which can be rooted in patches of gravel below organic root zone in pool bottoms (Stevens et al. 2012, Stromberg et al. 2009). A few trees and shrubs may be present, such Godding's willow (*Salix gooddingii*), Fremont cottonwood (*Populus fremontii*), velvet ash (*Fraxinus velutina*), and common button bush (*Cephalanthus occidentalis*) (Stevens et al. 2012, Stromberg et al. 2009).

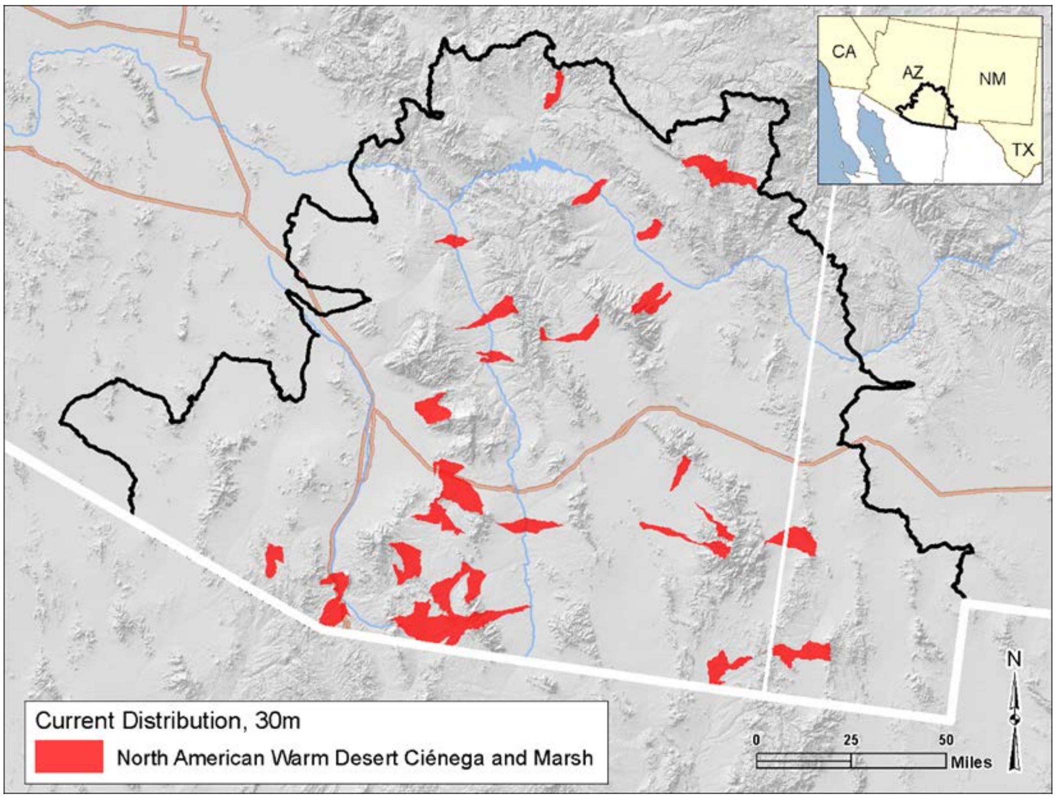
The type and pattern of vegetation depends on depth of water. In shallow pool margins, emergent plants include species of *Eleocharis, Carex, and Juncus*. Taller marsh vegetation can be found in adjacent deeper waters, such as cattails (*Typha*), bulrush (*Schoenoplectus*) and reed canary grass (*Phalaris*). Ciénegas may also include areas of relatively deep water with floating-leaved plants (*Lemna, Potamogeton*, *Polygonum* and *Brasenia*) and submergent and floating plants (*Myriophyllum, Ceratophyllum*, and *Elodea*).The outer margins of a ciénega may have saline soils due to capillary action and evaporation, where salt- tolerant species such as saltgrass (*Distichlis spicata*) and alkali sacaton (*Sporobolus airoides*) may be abundant (Stevens et al. 2012). Ciénegas tend to have deep organic soils and are very productive ecosystems.

Faults along mountain fronts provide for springs and deep alluvial soil serves as an aquifer for groundwater storage, as well as shallow aquifers and the interaction between surface water and groundwater, two important sources of water for ciénegas (PAG 2001, Mitsch and Gosselink 2000, Jolly et al. 2008).

E-2.1.2 Current Distribution

Figure E-17 shows the current distribution of occurrences of the CE. The distribution is represented by HUC12 watersheds rather than by 30m pixels at the request of the data providers, who promised landowners to protect the locational information on occurrences on their private lands. Each watershed identified in **Figure E-17** represents a watershed in which *one or more* current occurrences are known.

Figure E-17. Current distribution of North American Warm Desert Ciénega, Marsh and Pond CE within in the MAR. Each 6th level Huc colored red contains at least one occurrence. Specific locations of this CE are proprietary. For analysis, data were 30 m. For display results are shown as 6th level hucs.



E-2.1.3 Species of Conservation or Management Concern

Below are listed some species of concern associated with this ecological system CE.

Animals listed are from Stromberg et al. 2009.

Reptiles and Amphibians: Sonora Mud Turtle, Slevin's Bunchgrass Lizard, Desert Grassland Box Turtle, Madrean Alligator Lizard, Giant Spotted Whiptail (*Aspidoscelis burti stictogrammus*), Ring-necked Snake, Mexican garter snake, Woodhouse's Toad, Arizona Toad (*Anaxyrus microscaphus*), Narrow-headed Garter snake, Lowland leopard Frog.

Mollusks: Page springsnail (*Pyrgulopsis morrisoni*), *Tryonia* spp. and *Fontelicella* spp.

Invertebrates: Sunrise skipper (*Asopaeoides prittwitzi*)

Birds: Virginia rail, sora, , Common yellow throat, and waterfowl (especially for migration and winter habitat)

Fish: Desert pupfish (*Cyprinodon macularius)*, Gila topminnow (*Poeciliopsis occidentalis*, subspp *occidentalis*Yaqui or Sonora topminnow (*Poeciliopsis occidentalis*, subspp *sonoriensis*), Gila Chub (*Gila intermedia),* and Yaqui Chub *(Gila purpurea*)

Mammals: white-footed mouse, beaver.

Plants: Canelo Hills ladies tresses (*Spiranthes delitescens*)

E-2.1.4 Natural Dynamics

The Ciénega, Marsh and Pond ecosystem within the MAR are mostly isolated spring-fed wetlands found at the outer edge of floodplains and valley floors. Therefore they have relatively stable surface hydrologic dynamics. As such they are entirely dependent on groundwater flow, and are very sensitive to changes in groundwater levels (Bagstad et al. 2005, Hendrickson and Minckley 1984, Hereford 1993, Webb et al. 2007, Stromberg et al. 1996, Stromberg et al. 1997, Stromberg et al. 2009). Overland surface flow from intense rains in the summer may deliver sediments into the ciénega, depending on the amount of vegetation and exposed soils on hill slopes above. Winter storms are less intense and are more likely to result in soil moisture absorption, ground water recharge, and less surface runoff. Groundwater level stability is key to maintaining ciénegas (Bagstad et al. 2005, Hendrickson and Minckley 1984, Hereford 1993, Webb et al. 2007, Stromberg et al. 1996, Stromberg et al. 1997, Stromberg et al. 2009). Springs and associated marsh plant communities that occur within an active steam channel are subject to the dynamics of high and low channel flows, and are treated as part of the North American Warm Desert Riparian/Stream and North American Warm Desert Lower Montane Riparian/Stream conservation elements for the MAR assessment.

In the past, ciénegas were more extensive and different cienegas could be dependent on different factors such as low gradient channels, high water tables, fine sediments, and dense vegetation that could slow in-channel surface water flows as well as being surrounded by low-relief rolling terrain or alluvial plains that absorbed rains, where dense upland grassland vegetation, low slope gradients and deep soils slowed overland runoff (Hendrickson and Minckley 1984). When drought arrived (around 1870), the surrounding landscape changed with a decrease in the amount of vegetation, exposing soils, resulting in much more erosive runoff during monsoons (Hereford 1993, Webb et al. 2007). The erosive power of runoff and subsequent channel flows caused massive downcutting of channel floors, dropping the groundwater table, changing the low gradient, high water table mid- elevation stream channel into dry, deep arroyos,, with larger more coarse sediments, completely eliminating or significantly reducing the ciénega ecosystem footprint (Hendrickson and Minckley 1984, Hereford 1993, Webb et al. 2007, Stromberg et al. 2009).

It is possible and has been observed that in certain locations with a period of flow stability wetland plants will invade saturated streambeds in arroyos and begin organic deposition (Hereford 1993, Webb et al. 2007). Vegetation development will continue to build under continued stable flow regimes. These newly formed wetlands may be washed away by subsequent floods, but with enough time, may develop enough to withstand some flooding (Hendrickson and Minckley 1984, Hereford 1993, Webb et al. 2007, Stromberg et al. 1997). However at some locations thresholds can be exceeded that do not allow this in the short term. For instance, if a wetland is dependent on a clay layer that is eroded to expose underlying sands and channel slopes increase beyond a certain point natural restoration may be unlikely (J. Callegary, pers. comm. 2014). As organic materials accumulate, water levels rise and soil moisture storage increases. Once matured, ciénegas can act as climax communities that are self-protecting and water-storage systems, that is once they are large enough they are better at buffering once destructive high flows (Hendrickson and Minckley 1984). Flows downstream from ciénegas are less variable and of greater permanence than flows in streams without them. The large storage capacity and slow release of water can dampen and attenuate flood peaks. This is conducive to the establishment and growth of ciénegas downstream, and the increase in vegetation can cause deposition of additional clays and silts, allowing for upstream development (Hendrickson and Minckley 1984). Increased water storage and sediment trapping means flows downstream have less sediment and increased erosive power, causing downcutting and deep pool formation. Thus it may be quite possible to restore ciénegas in mid-elevation arroyos (Hereford 1993, Webb et al. 2007, Stromberg 2001, Stromberg et al. 1997, Stromberg et al. 2007).

Therefore the perpetuation of ciénega habitat requires maintenance of permanent high groundwater levels and a balance between sedimentation and flushing flows (Hendrickson and Minckley 1984).

E-2.1.5 Change Agent Effects on the CE

This section of the conceptual model presents a narrative description of the primary change agents and current knowledge of their effects on North American Warm Desert Ciénega, Marsh and Pond ecosystem. The section contains two sub-sections: (1) A list of primary change agents identified for the CE; and (2) a discussion of altered dynamics caused by these agents.

E-2.1.5.1 List of Primary Change Agents

Occurrences of this ecosystem are directly affected by concentrated grazing on site, land development, withdrawals of groundwater, wildfire suppression, non-native terrestrial and aquatic plants and animals, unregulated recreation (both motorized and non-motorized). Occurrences are also indirectly affected by climate change and by human activities across the surrounding watersheds that alter watershed runoff and groundwater recharge/discharge by altering ground cover.

E-2.1.5.2 Altered Dynamics

Table E-7 identifies the most likely impacts associated with each of the stressors identified. Change agents, and the specific stressors they generate, cause alteration to the key ecological attributes (KEAs) for individual occurrences of this ecosystem type. Some stressors directly remove the conservation element, such as active downcutting and lowering of groundwater, or new rural or urban development. Irrigated agriculture, in addition to complete removing portions of a conservation element, can also cause downstream alteration to a ciénega, marsh and pond ecosystem through polluted runoff and return flow and through flow alteration (e.g., Boody and DeVore 2006, Chipps et al. 2006, Pimentel et al. 2004). Aquatic invasive species can have profound effects on the amount of oxygen available, can directly compete with native species, and have been shown to completely replace the native ecosystem habitat (e.g. tamarisk) (USGS 2011).

Stressors can cause different degrees of alteration to an individual KEA, i.e., different degrees of stress; and the degree of alteration to a KEA will depend on the cumulative effects of all stressors acting on it. Responses to stress in key ecological attributes of biotic condition for ciénega,marsh and pond ecosystems may include a reduction in species taxonomic and genetic diversity due to fragmentation and loss of habitat at the scale of the ecoregion (Vranckx et al. 2011). Individual species can become less abundant as their habitats become fragmented (Calamusso et al. 2005) As native species become stressed more tolerant and opportunistic species may increase in abundance, causing additional changes to functional diversity and food web structure (Stromberg 2001). Shifts in species abundance and composition can also alter abiotic dynamics. For example, changes in vegetation can alter nutrient cycling (Tabacchi et al. 1998) or cause changes in vegetation on stream banks that affect bank and channel stability (Micheli and Kirchner 2002); and changes in beaver populations can change hydrology

(Lewis et al. 2009, Naiman et al. 1988, Rosell et al. 2005) and nutrient cycling (Lewis et al. 2009). **Figure E-18** and **Figure E-19** capture these interactions, and the use of indicators to track them.

Table E-7. Stressors and their likely impacts on the North American Warm Desert Ciénega, Marsh and Pond ecosystem type in the Madrean Archipelago ecoregion (with representative citations specific to impacts to aquatic resources in general, within the ecoregion, or in the western US, but not an exhaustive literature review, of which there are many for each stressor).

Stressor	Impacts
Land Use	
Continuous Heavy Livestock grazing	Removal of native vegetation, possibly favoring invasion of non-native vegetation; disruption of spring structure, associated pools and outflow channels; (Stevens and Meretsky 2008) increase water pollution (sediment, manure), which is detrimental to fish habitat (Calamusso 2005,).
Recreation	Elimination and disturbance of ciénega, marsh and pond habitat; increased soil erosion; soil compaction, non-point source pollution, reduction spring-upland trophic linkage, potential fire starts (Debinski and Holt 2000, Stevens and Meretsky 2008).
Development	
Roadways/railways	Elimination and fragmentation of spring habitat; altered surface water flow paths; non-point source pollution (Comer and Faber-Langendoen 2013, Comer and Hak 2009).
Mining	Elimination of spring habitat; altered alluvial/channel geomorphic dynamics; altered longitudinal groundwater flow paths in alluvial aquifer; source of pollution and sedimentation (Berkman and Rabeni 1987, Mol and Ouboter 2004).
Altered watershed ground cover	Alteration of runoff and recharge at both the watershed scale and immediately surrounding the ciénega, marsh and pond buffer area; altered sediment inputs from watershed during runoff events; altered non-point source pollution (Anning et al. 2009, Poff et al. 2010, Webb and Leake 2006).
Land development	Reduced alluvial recharge during rainfall/runoff; increased soil erosion; non-point source pollution (McKinney and Anning 2009).
Hydrologic Alterations	
Spring Development /Alteration	Direct local elimination of natural spring geomorphic structure, reduction in soil moisture absorption, physical disruption of pool/bank ratio. (Stevens and Meretsky 2008) Post-orifice diversion is also common, particularly for livestock watering and development of ponds. Spring flows are commonly captured into open troughs or into covered tanks and then piped to troughs or ponds. These alterations often eliminate spring channel and ciénega (wet meadow) functions (Stevens and Meretsky 2008).

Stressor	Impacts
Diversion of flows	Loss of surface flows, both baseflow and runoff, with consequent loss of natural alluvial groundwater recharge/discharge dynamics, which can come from activities far removed from spring location (Poff et al. 2010, Shafroth et al. 2010, Theobald et al. 2010).
Point-source pollution, watershed	Alteration of water quality of groundwater sources (Anning et al. 2009). Groundwater and surface water pollution strongly alters ciénega ecosystem integrity and is a common phenomenon in agricultural and urban areas. Agricultural groundwater pollution may shift ecosystem nutrient dynamics to entirely novel trajectories creating conditions to which few native species may be able to adapt (Stevens and Meretsky 2008). Local contamination may also affect springs microhabitats by polluting surface waters. Such impacts are abundant at springs on the southern Colorado Plateau where springs sources are often fenced and concentrate ungulate use (Stevens and Meretsky 2008).
Non-point-source pollution	Alteration of water quality in surface storm runoff into the ecosystem itself, which can come from agricultural and urban areas within the watershed, which can be detrimental to fish habitat (Abell et al. 2000, Calamusso 2005).
Withdrawals of groundwater	Loss of baseflow (magnitude and spatial extent) and lowering of alluvial water table, adds stress to fish habitat (Calamusso 2005, Poff et al. 2010, Stromberg et al. 1996).
Wildfire suppression	Change in vegetation succession dynamics, possibly also favoring invasion of non-native vegetation (Unnash et al. 2008). Also, changes in land use by fire suppression can change the role of plant water use in a watershed and subsequently recharge to the aquifer (Stevens and Meretsky 2008)
Invasive Species	
Non-native terrestrial plants and animals	Replacement of native vegetation, altering ciénega, marsh and pond habitat suitability for terrestrial fauna; alteration of shading of channel affecting water temperature and habitat quality; alteration of fire risk; alteration of soil and ground-litter chemistry; alteration of evapotranspiration rates and timing (Stromberg 1998).
Non-native aquatic plants and animals	Removal or reduction of native aquatic species due to competition, predation, alteration of water quality (Calamusso 2005, Rinne 1996, USEPA 2005).
Climate change	Alteration of precipitation and evapotranspiration rates and timing, resulting in direct alteration of soil moisture, runoff (surface flows) and recharge (groundwater quantity) at both the watershed scale and immediately within the ecosystem and buffer. Impacts may also occur through changes in human consumption of surface water and groundwater in response to climate change (Price et al. 2005).

E-2.1.6 Ecological Status: Key Ecological Attributes and Indicators

This section of the conceptual model addresses key ecological attributes and their potential indicators. The ecological status is a way of describing current status via criteria, functionality, or levels of attributes and asks if they are within the normal range of variation.

E-2.1.6.1 Key Ecological Attributes

Table E-8 identifies the key ecological attributes for the CE within the Madrean Archipelago ecoregion. A **key ecological attribute** of a focal ecological resource is a characteristic of the resource's biology, ecology, or physical environment that is critical to the resource's persistence in the face of both natural and human-caused disturbance. Alteration of such a characteristic beyond some critical range of variation will lead to the degradation or loss of the resource within decades or less. The KEAs table lists the identified key ecological attributes, with a brief definition, a rationale for why it is important for the CE, and a listing of stressors or change agents that might be affecting the key attribute.

Table E-8. Key ecological attributes (KEAs) of North American Warm Desert Ciénega, Marsh and Pond ecosystem.

***KEA Class:* Name**	**Definition**	**Rationale**	**Stressors**
***Landscape Context:* Landscape Cover**	The extent of natural ground cover for the watershed containing the ecosystem occurrence, versus the extent of different kinds of modifications to the watershed surface for human use.	Surrounding watershed cover in unaltered landscapes helps determine the rates of precipitation runoff versus infiltration, evapotranspiration, soil erosion, and transport of sediment, dissolved and suspended nutrients to the ecosystem location from the watershed as a whole and from its immediate buffer zone. Surrounding watershed cover also influences groundwater recharge rates (Comer and Faber-Langendoen 2013, Comer and Hak 2009, Stevens and Meretsky 2008).	Stressors to landscape cover include watershed development and/or excessive grazing, which can alter the rates of runoff versus infiltration from precipitation, evapotranspiration, soil erosion (both "sheet" and "channel" erosion), and transport of sediment, dissolved and suspended nutrients to the ciénega location from the watershed as a whole and from its immediate buffer zone. Development and excessive grazing also can introduce pollutants and reduces connectivity between the ciénega and the surrounding landscape and along the buffer zone surrounding the ciénega. Climate change also has the potential to cause additional change in landscape cover.
***Size/Extent:* Relative Size**	The size of the ciénega, marsh and pond relative to historic extent.	Ciénegas can be naturally very small occurrences, so absolute size alone will not indicate the health of a spring system. However the historic extent of ciénegas was much more extensive than today. Larger more complex ciénega has higher habitat heterogeneity and greater buffer capacity. Understanding the degree of reduction in the footprint of ciénegas is critical to understand the loss of wetland habitat throughout the watershed. Knowledge of historic extent can also be very useful for understanding restoration potential (Hendrickson and Minckley 1984, Stevens and Meretsky 2008).	Stressors to ciénega size include development on top of the ciénega itself, including: conversion to agriculture, excessive grazing, commercial/industrial/residential use; construction of transportation infrastructure; and dams/impoundments. These changes can alter the movement of ground water, nutrients, animals, and sediment. Lateral constrictions can lead to increased velocity of flows, contributing to increased erosion and down-cutting. Climate change also has the potential to cause additional change in ciénega extent, through its impacts on hydrology (see Hydrologic Regime).

KEA Class: Name	Definition	Rationale	Stressors
Biotic Condition: **Aquatic Flora**	The taxonomic composition of the native floral assemblage of the ciénega, marsh and pond emergent vegetation - terrestrial, wetland, and aquatic - and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The taxonomic composition of the ciénega wetland floral assemblage is an important aspect of the ecological integrity. Numerous native species of woody and non-woody plants occur preferentially or exclusively in ciénega habitats, from floodplain terraces to stream banks and perennial pools; and occur in different successional settings following disturbance. These species vary in their sensitivity to different stresses such as alterations to ciénega hydrology (e.g., water table and spring flow dynamics), and altered water quality. Alterations in the taxonomic composition of the ciénega floral assemblage beyond its natural range of variation therefore strongly indicate the types and severities of stresses imposed on the ciénega ecosystem.	Stressors to the taxonomic composition of the ciénega native floral assemblage experiences include the cumulative impacts of all stressors affecting the landscape context, size/extent, and abiotic condition of the ciénega ecosystem, including altered wildfire and excessive grazing; and incursions of non-native species that alter the habitat (e.g., alter soils) or directly compete with the native flora.
Biotic Condition: **Aquatic Fauna**	The taxonomic and functional (e.g., guild) composition of the native faunal assemblage of the ciénega, marsh and pond, including fishes, reptiles and amphibians, and invertebrates; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The taxonomic and functional composition of the aquatic faunal assemblage is an important aspect of the ecological integrity of a ciénega ecosystem. Aquatic species - as especially well studied for fishes and macroinvertebrates - vary in their roles in the aquatic food web and in their sensitivity to different stresses such as alterations to ciénega hydrology, habitat quality, water quality, and nutrient inputs. Alterations in the taxonomic and functional composition of the aquatic faunal assemblage beyond their natural ranges of variation therefore strongly indicate the types and severities of stresses imposed on the ciénega, marsh and pond aquatic ecosystem.	Stressors affecting the taxonomic and functional composition of the aquatic faunal assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, and abiotic condition of the ciénega ecosystem; and incursions of non-native species that alter the food web or directly compete with or prey on the native fauna.

KEA Class: Name	Definition	Rationale	Stressors
Abiotic Condition: **Hydrologic Regime**	The pattern of ground water flow to the surface (source springs) and the surface-groundwater interaction along the valley floor - as characterized by, for example, the frequency, magnitude, timing, and duration of extreme flow conditions and extreme water table elevations; the magnitude and timing of seasonal and annual baseflow and total discharge; the magnitude of seasonal and annual water table mean elevation, and aquifer responsiveness.	The ground water outflow regime determines which aquatic species can persist in a ciénega system through their requirements for or tolerances of different flow rates at different times of the year; shapes downstream sediment transport and geomorphology and therefore aquatic habitat distributions and quality. Interactions between the surface flow regime and underlying aquifer conditions also shape the pattern of baseflow and the pattern of water table variation along the valley floor. The surface flow regime and surface-groundwater interactions thereby together strongly influences both aquatic and marsh habitat and biological diversity (e.g., Poff et al. 1997; Poff et al. 2010 Stevens and Meretsky 2008).	Stressors affecting the hydrologic regime include watershed development that alters runoff, infiltration (recharge), and evapotranspiration rates; surface water diversions, transfers, and use; groundwater withdrawals from basin-fill and alluvial aquifers; return flows of municipal and agricultural wastewater; dams, dam operations, and impoundment evaporation; ciénega development; and alterations to the ciénega floral assemblage including invasions of non-native flora with high water consumption. Climate change also has the potential to cause additional change in the hydrologic regime, through its effects on precipitation form (snow vs. rain), spatial distribution, magnitude, and timing; and through its effects of evapotranspiration rates both within the ciénega and across the surrounding watershed. Climate change may also cause changes in human water use.
Abiotic Condition: **Geomorphology**	The geology and geomorphology of the spring source and its immediate outflow pool / channel, cross-sectional form, sediment size distributions, and geomorphic stability/turnover.	Spring geology and geomorphology create the habitat template for aquatic and wetland flora and fauna. Altered spring substrate and geomorphology strongly affect aquatic faunal assemblage composition and complexity and both spring-wetland and surface-groundwater interactions within ciénegas.	Stressors affecting the geomorphology of the ciénega soils, pool depth, and surrounding buffer include the cumulative effects of alterations to watershed cover, flora, and hydrology; the effects of ciénega trampling from excessive use by livestock; and the effects of direct floodplain modifications such as channelization and gravel mining. Climate change also has the potential to cause additional change in ciénega morphology through its impacts on watershed cover (see Landscape Cover) and hydrology (see Hydrologic Regime).

KEA Class: Name	Definition	Rationale	Stressors
Abiotic Condition: **Water Chemistry**	The chemical composition of the water flowing into ciénega, marsh and pond ecosystems including the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The chemistry of the water flowing into and through ciénega habitat strongly determine which plant and animal species can persist in these habitats through their requirements for or tolerances of different soil and water chemistries. Ciénega fauna, for example, vary in their requirements for or tolerances of variation in salinity, dissolved oxygen, temperature, turbidity, and the presence/absence of different dissolved and suspended matter including anthropogenic pollutants.	Stressors affecting water quality include the effects of single catastrophic high or low concentration perturbation such as low oxygen, high temp, or heavy metals can be devastating to aquatic ecosystems. Additionaly, cumulative effects of non-point source pollution from watershed development, point-source pollution (e.g., municipal, industrial, mining wastewater), atmospheric deposition, excessive use of riparian zones as pasturing areas for livestock, and altered groundwater discharge (see Hydrologic Regime). Climate change has the potential to exacerbate these impacts through changes in watershed runoff and water use.
Abiotic Condition: **Fire**	The pattern of fire occurrence (fire regime) in the surrounding landscape, as well as in ciénega. Marsh and pond ecosystems, as characterized by its frequency, intensity, and spatial extent.	Fire is a natural agent of disturbance in wetland vegetation communities, where it helps shape community succession, triggers reproductive activity, and shapes the cycling of soil nutrients (Luce et al. 2012). More importantly for ciénegas, the surrounding landscape natural fire regime is an important regulator of fuel loads and subsequent intensity of fires which affect the likelihood of sediment input.	Stressors affecting the fire regime include ecologically incompatible fire management practices, and changes in landscape and ciénega vegetation due to other factors. Fires can mimic disturbance (Conway et al. 2010) to the benefit of disturbance adapted species. However fire in cienegas would remove vegetation and could reduce ability to slow surface waters in post-fire high flows. Another outcome of fire may be the removal of encroaching woody species, and can stimulate regrowth of native species, depending on the context (Stromberg and Rychener 2010).

E-2.1.7 Relationship of KEAs to Fundamentals of Rangeland Health

The key ecological attributes listed in **Table E-8** also encompass the four fundamentals of rangeland health (USDI BLM 2006), as shown in **Table E-9**. Here we try and relate those 4 fundamentals to the KEAs in this Conceptual Model. The KEA for Landscape Cover specifically refers to watershed conditions; all other KEAs refer specifically to Ecological Processes and Habitat. However, many of the Indirect Indicators for the KEAs for abiotic condition focus on stressors that arise as a result of modifications to the watershed or modifications to water quality. These relationships are also indicated in **Table E-9**. Further information about interpretation and assessment of these fundamentals of rangeland health can be found in Pellant et al. (2005).

Table E-9. Relationship of key ecological attributes (KEA) for the North American Warm Desert Ciénega, Marsh and Pond ecosystem to fundamentals of rangeland health.

Key Ecological Attribute	Watersheds	Ecological Processes	Water Quality	Habitat
Landscape Cover	X	X	X	
Size/ Extent Relative Size	X	X	X	X
Biotic Condition: Aquatic Fauna		X		X
Biotic Condition: Aquatic Flora		X		X
Abiotic Condition: Hydrologic Regime	X	X	X	X
Abiotic Condition: Geomorphology	X	X	X	X
Abiotic Condition: Water Chemistry	X	X	X	X
Abiotic Condition: Fire	X	X	X	X

E-2.1.8 Conceptual Model Diagrams

Figure E-18. Conceptual model diagram for North American Warm Desert Ciénega, Marsh and Pond Aquatic Ecosystem describing the structural components and functional relationships that characterize this system. Ovals represent key ecological attributes and ecosystem drivers. Arrows indicate functional relationships among components. Line weights indicate relative importance. The model is constrained by global climatic and atmospheric conditions, topography, parent material and potential biota.

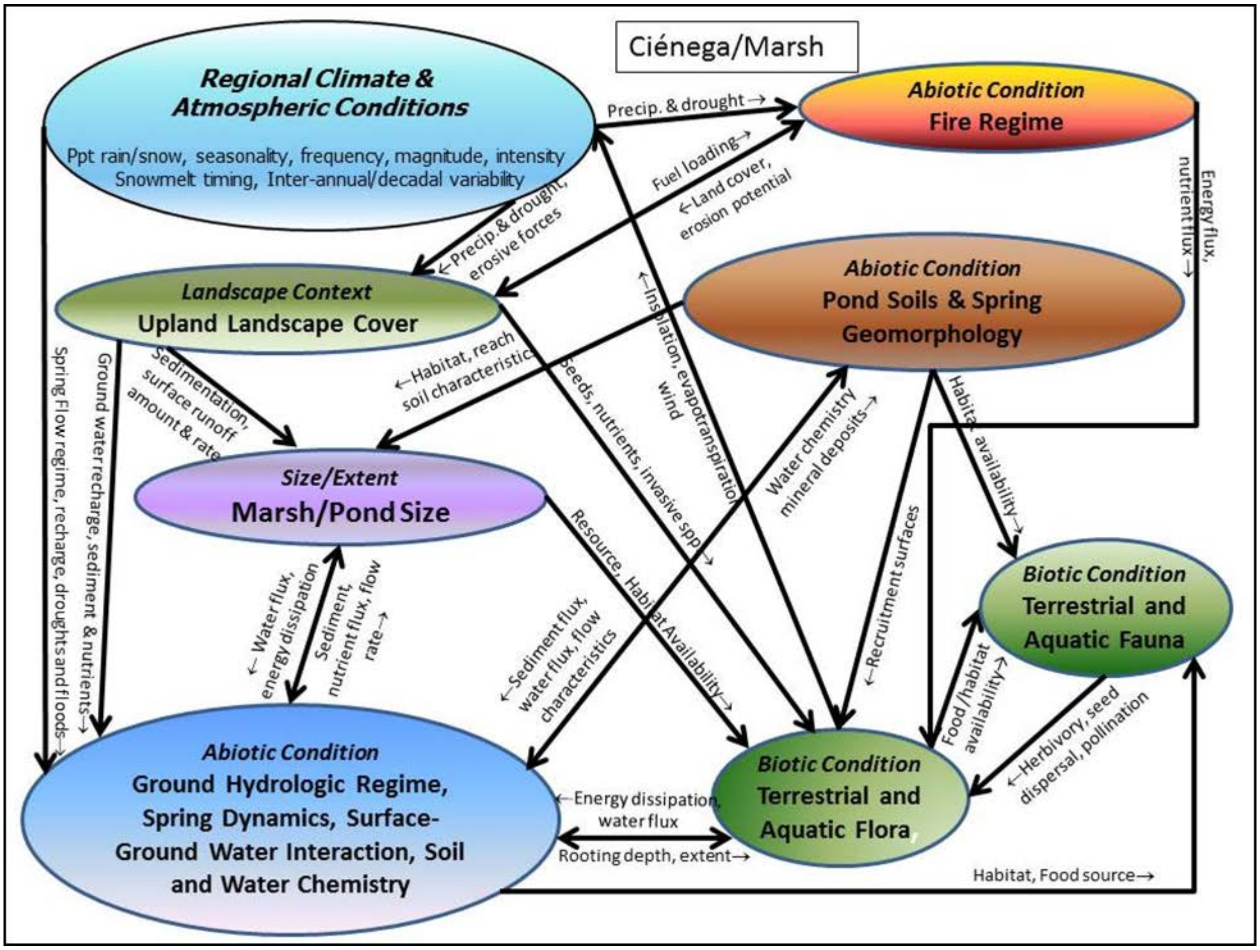
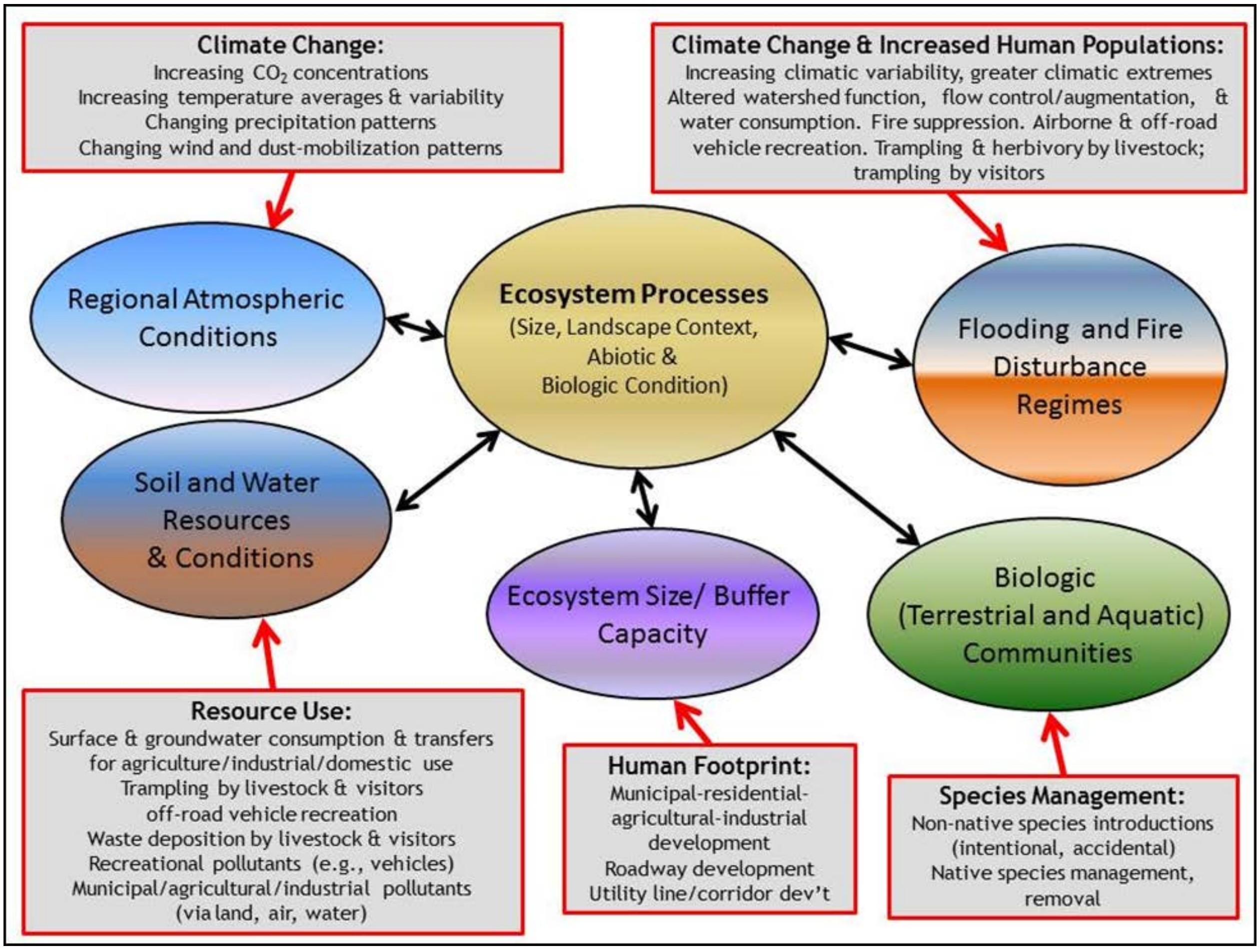


Figure E-19. Some of the greatest stressors affecting North American Warm Desert Ciénega, Marsh and Pond Ecosystem key ecological attributes.



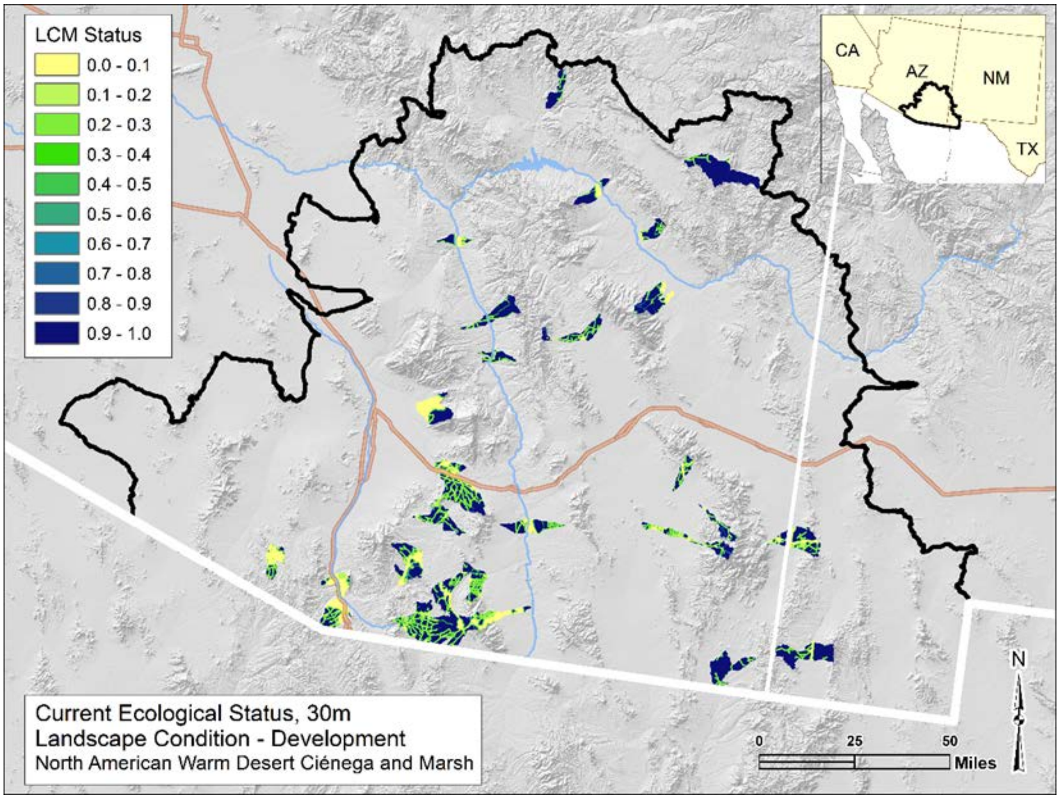
E-2.2 Ecological Status Assessment Results and Interpretation

This section of the appendix presents and discusses the results of the ecological status assessment for the North American Warm Desert Ciénega, Marsh and Pond CE. The presentation addresses each indicator separately, and then addresses the overall assessment, which integrates the results of all individual indicators. The results are presented using a common framework, in which the status of an indicator – or the combination of all indicator – is scored on a scale from 0.0 to 1.0, where 0.0 indicates a condition of complete replacement of reference ecological conditions due to the impacts of stressors, and 1.0 indicates a condition of no alteration of reference ecological conditions. The same color ramp is used for all results, yellow to dark blue, where yellow equals low scores, green moderate scores and blues high scores.

E-2.2.1 Development Indicator

Figure E-20 shows the impact of development on the HUC12 watersheds within which this CE currently occurs in the ecoregion. Each 30m pixel within each relevant watershed is colored according to its landscape condition (development) indicator score. The HUC12 watersheds that contain occurrences of this CE are affected to varying degrees by development, with watersheds closer to Tucson and the I-19 corridor most heavily affected.

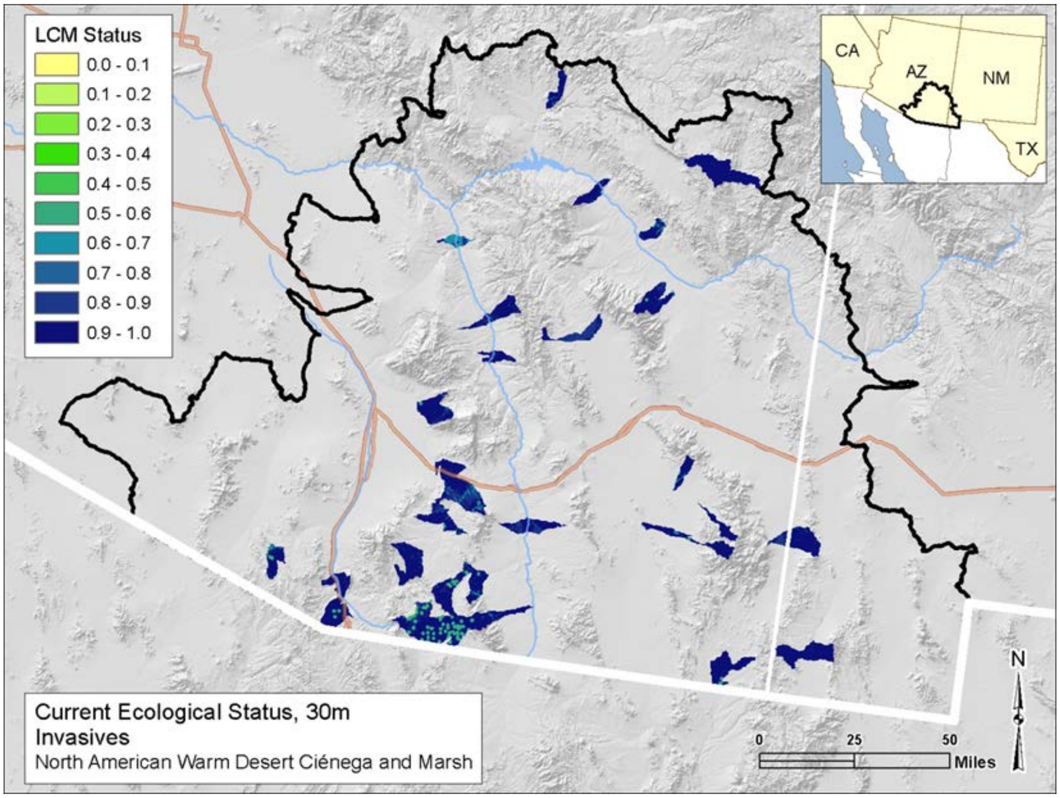
Figure E-20. Scores for the development indicator for North American Warm Desert Ciénega, Marsh and Pond CE Scores are for each pixel within HUC12 watersheds that contain at least one occurrence. The specific locations of this CE are proprietary.



E-2.2.2 Aquatic and Terrestrial Invasive Species Indicator

Figure E-21 shows the scores for the Invasives indicator. This is a stressor-based indicator of the presence non-native invasive species including terrestrial woody plants such as tamarisk and aquatic invasive animals and aquatic plants (such as bullfrogs, crayfish, non-native fish, and pondweed) and abundance of herbaceous plants such as cheatgrass (*Bromus tectorum*). Scores for invasives mean the following: a score of 0.35 indicates a combination of aggressive aquatic animals and abundance of terrestrial plant species, 0.5 indicates the presence highly aggressive aquatic species such as bullfrogs or crayfish of, a score of 0.7 the presence less aggressive aquatic species such as non-native salamanders, or >25% cover on non-native terrestrial plant species. Most of the heavily infested areas appear to be along the Lower San Pedro River and in the southern portion of the ecoregion.

Figure E-21. Scores for the invasive species indicator for North American Warm Desert Ciénega, Marsh and Pond CE. Invasive species include terrestrial plants, aquatic animals and aquatic plants. Scores are for each pixel within HUC12 watersheds that contain at least one occurrence. Specific locations of this CE are proprietary.

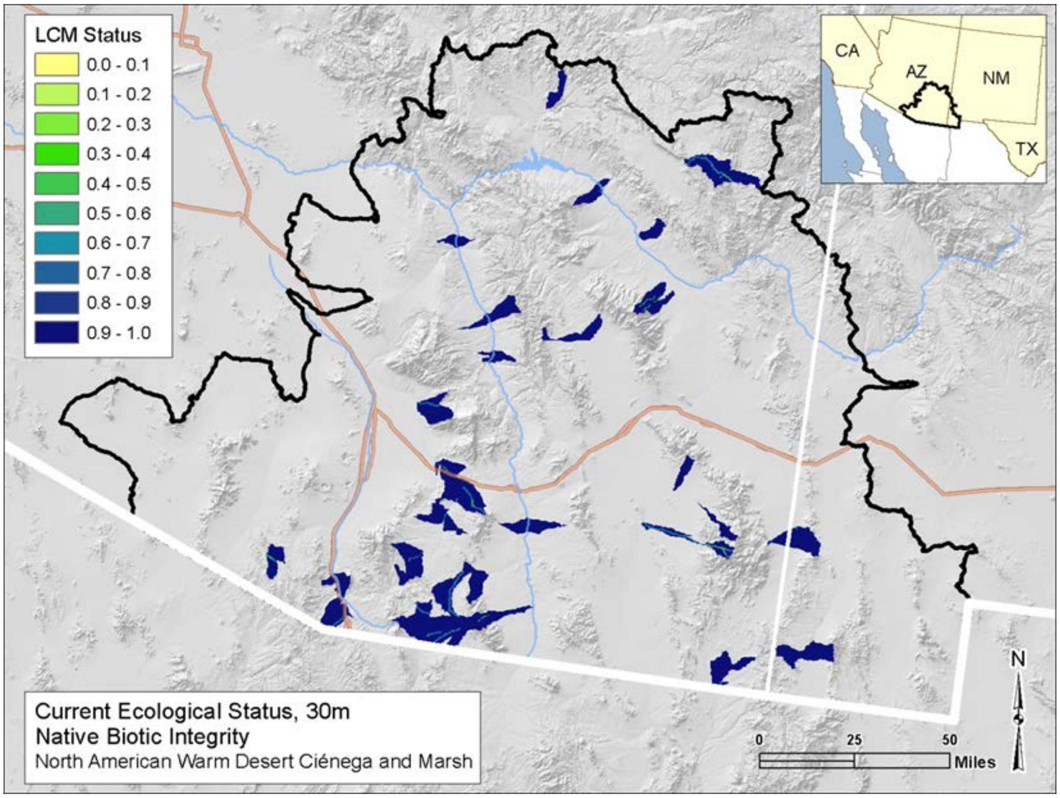


E-2.2.3 Native Biotic Integrity Indicator

Figure E-22 shows the scores for Native Biotic Integrity Status. This indicator is a direct measure of integrity (a combination of native fish, endangered species, and benthic macro-invertebrates) and shows how many of the expected native species are present. While this is a limited data set, the data points are well distributed throughout the major rivers, tributaries and ciénegas of the Arizona portion of the REA. Of the 287 sample points across all CEs, 17% scored highly, 47% scored moderately, and 36% scored poorly. Stream reaches or springs with null data were not scored. An absence of data does not mean that the CE has high or low native biotic integrity; it means only that no one has looked. This indicator is different from all other indicators in that it tracks a positive response rather than a negative one.

The scores for native biotic integrity are relative to the high status scores such as development. Scores of 0.35 indicate that surveys turned up no native fish and few endangered species, and registered a low benthic macro-invertebrate score. Only a few pixels received such a low score, as it was rare to have all three sources of native biotic integrity measured at the same sampling location. A score of 0.5 means no native fish occur or the benthic macro-invertebrate index score was poor; a score of 0.7 indicates 1-3 native fish were present or 1-4 endangered species were recorded. Very few sample locations coincided with ciénega locations, so this indicator does not discriminate integrity differences between ciénega-containing watersheds.

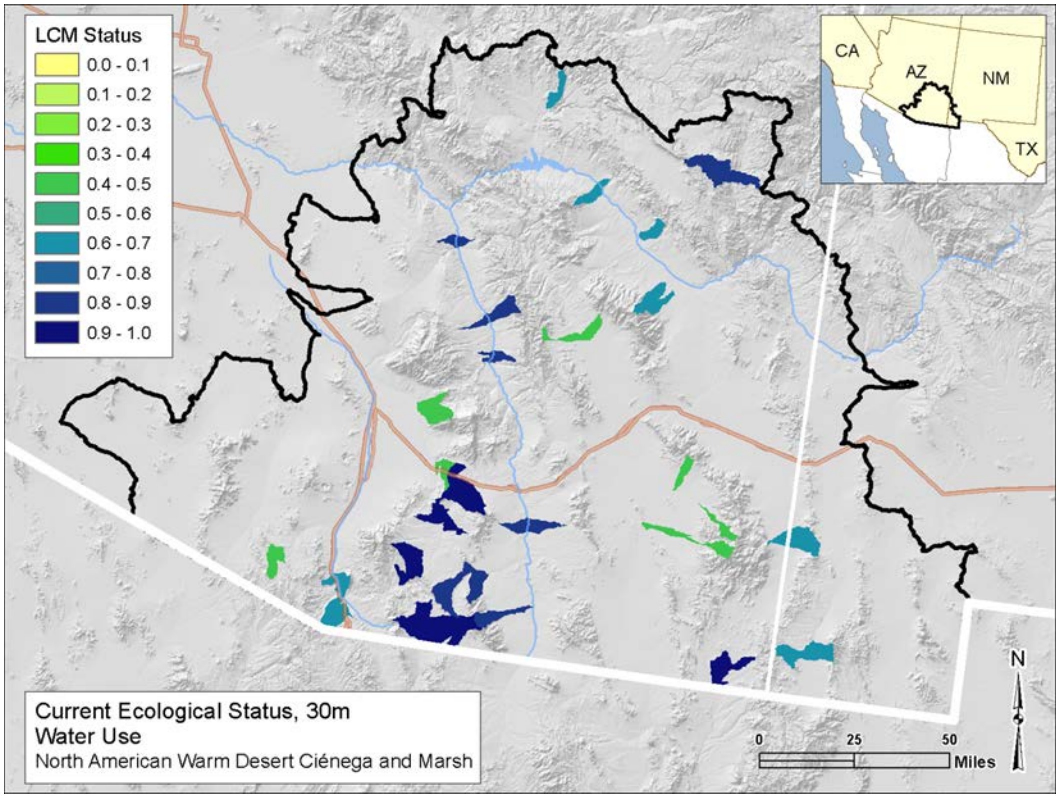
Figure E-22. Scores for the native biotic integrity indicator for North American Warm Desert Ciénega, Marsh and Pond CE. Native Biotic integrity is a combination of native fish, endangered species, and benthic macro-invertebrates for each pixel within HUC12 watersheds that contain at least one occurrence of the CE. Specific locations of this CE are proprietary.



E-2.2.4 Water Use Indicator

Figure E-23 shows the impact of water use on the HUC12 watersheds, within which are located one or more occurrences of the CE. As discussed earlier, the indicator for water use is a stressor-based indicator of the intensity of consumption of surface and ground water from within-ecoregion sources. As discussed above, the indicator is scored as follows: low water use, less than 0.0035 acre-feet per acre per year, status score = 1.0; medium water use, 0.01 – 0.0252 acre-feet per acre per year, status score = 0.8; medium-high water use, 0.0458 – 0.0583 acre-feet per acre per year, status score = 0.6; high water use, more than 0.0878 acre-feet per acre per year, status score = 0.5. Each HUC12 watershed in the map shows the score of the Arizona groundwater basin or New Mexico County in which the watershed lies (see **Figure E-2** and **Figure E-3**, above). Watersheds in the Willcox and Tucson AMA groundwater basins show the greatest impact; watersheds in the Cienega Creek, San Rafael, and San Bernardino groundwater basins show the least.

Figure E-23. Scores for the water use indicator for North American Warm Desert Ciénega, Marsh and Pond CE. Scores are for each pixel within HUC12 watersheds that contain at least one occurrence of. Specific locations of this CE are proprietary.



The Habitat Quality indicator (PFC and aquatic habitat assessment) was not applied to the ciénega, marsh and pond CE (**Table E-2**).

E-2.2.5 Current Ecological Status: Full Scenario

This is the result of all of the indicators combined together for a single score per pixel of CE distribution. The result is very similar to the development indicator alone, as this indicator has the greatest impact on ciénega, marsh and pond CEs (aka ciénega) and therefore the greatest spread of scores. The HUC12 watersheds containing occurrences of this CE also show the combined impacts of Landscape Condition, Water Use, Invasives, and Native Biotic Integrity scores. Ciénega CE distribution is shown by HUC 12 watersheds, so this full scenario shows the scores for all indicators multiplied together where they occurred together for each pixel within each HUC12. **Figure E-24** shows the individual pixel combined scores (upper panel) and the average of all scores across each HUC12 watershed (lower panel).

The results show that sections of the ecoregion with high development (e.g. near Tucson) and areas with high water use (for example within the Wilcox drainage) have the highest overall impact to ciénega ecological integrity overall.

Only about one-third of the ciénega, marsh and pond CE distribution scored well for ecological integrity (Figure E-25). Stressor-based indicators drive this result with those watersheds with heavy development or high water use causing the greatest impact to the CE.

Figure E-24. Overall ecological status scores for the North American Warm Desert Ciénega, Marsh and Pond CE. Upper Map --includes all indicators combined for each pixel within HUC12 watersheds that contain at least one occurrence of the CE. Lower Map-- The average of all pixels for a single, combined integrity score for each HUC12 watershed with the CE present.

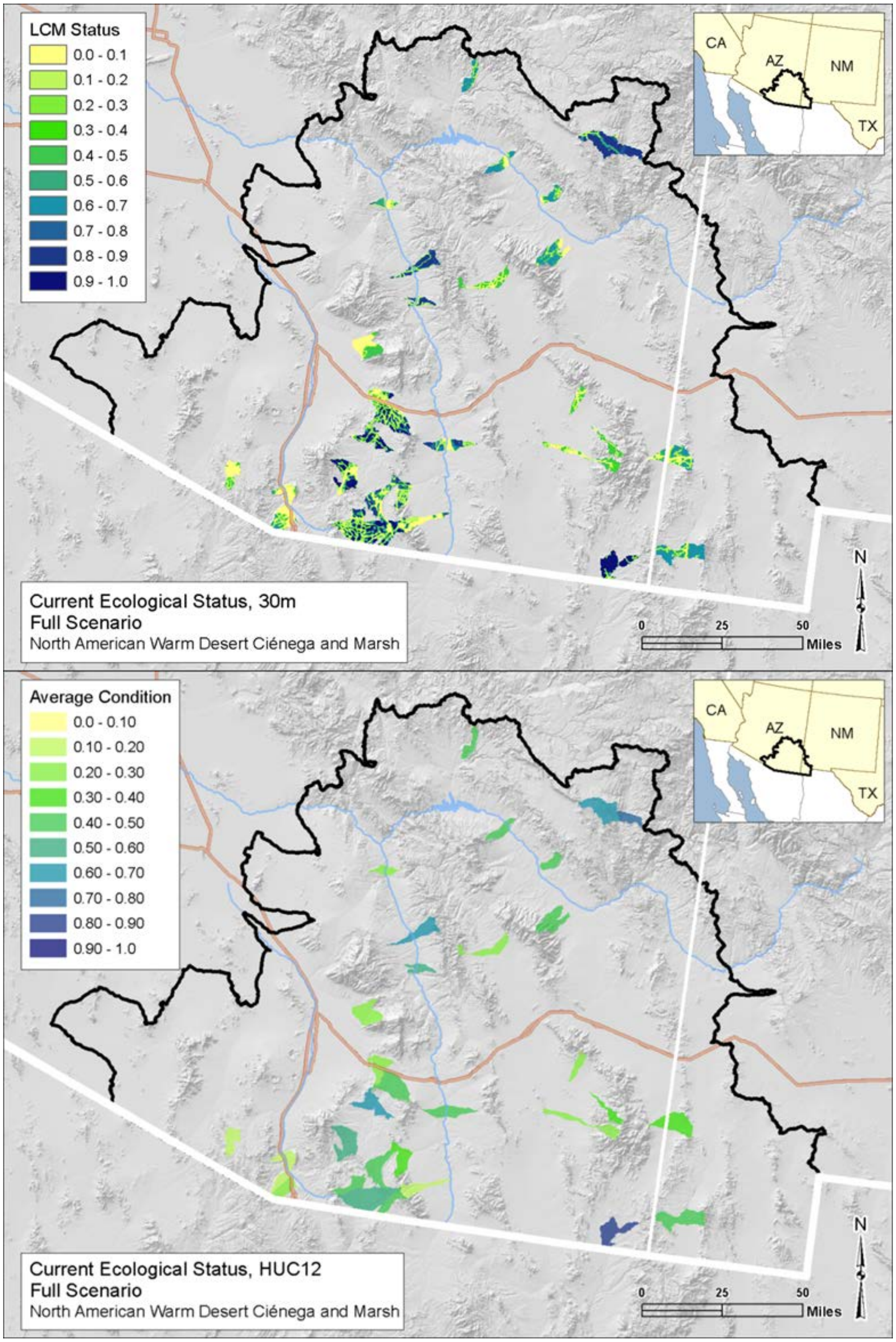
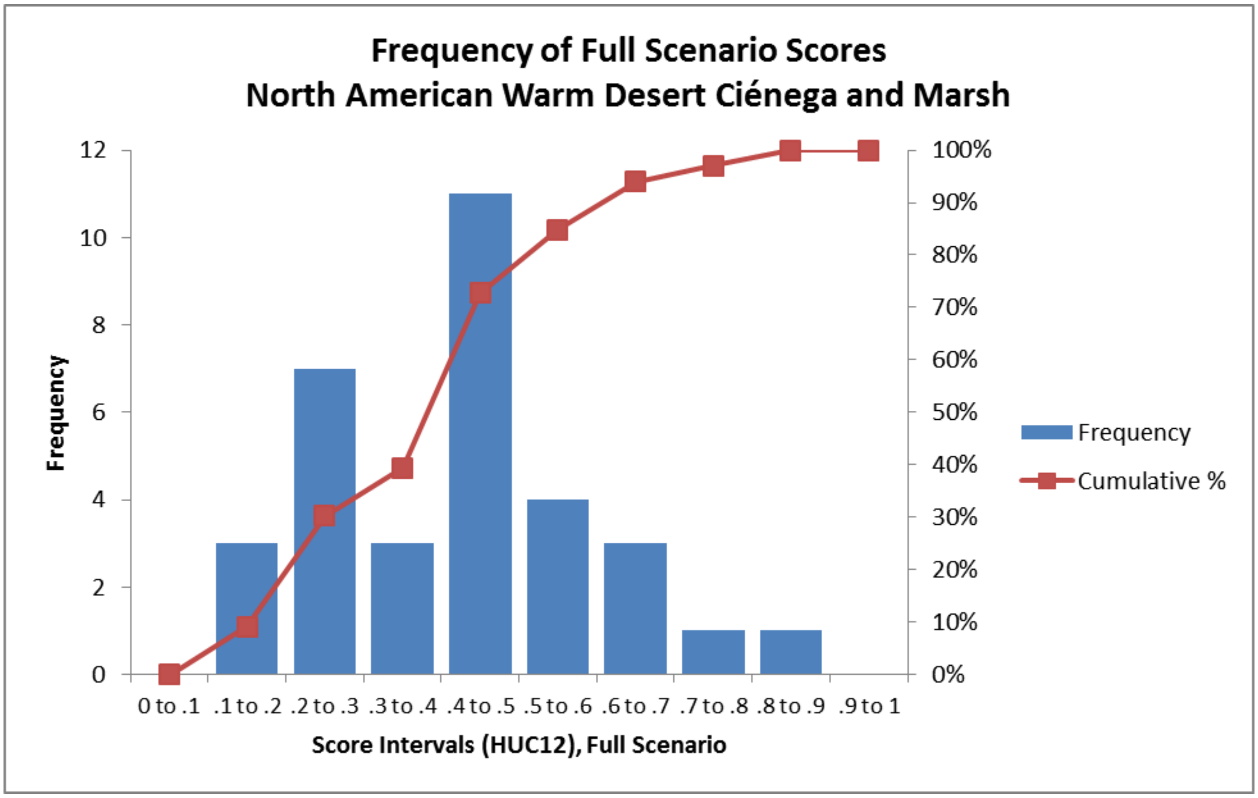


Figure E-25. Frequency distribution of the overall ecological status scores (by 6th-level HUC) with a running cumulative percent. The x-axis represents the 0.1 increment scoring intervals, while the y-axis shows the number of HUCs in each interval (left) and the cumulative percentage of the HUCs in each interval (right).



E-2.3 References for the CE

Abell, R., D. Olson, E. Dinerstein, P. Hurley, J. Diggs, W. Eichbaum, S. Walters, W. Wetterngel, T. Allnutt, C. Loucks, and P. Hedao. 2000. Freshwater Ecoregions of North America: A conservation assessment. Island Press, Washington, DC.

Anning, D.W., S.A. Thiros, L.M. Bexfield, T.S. McKinney, and J.M. Green. 2009. Southwest Principal Aquifers Regional Ground-Water Quality Assessment. U.S. Department of the Interior, U.S. Geological Survey Fact Sheet 2009-3015. http://water.usgs.gov/nawqa/studies/praq/swpa.

Bagstad, K., J. Stromberg, and S. Lite. 2005. Response of herbaceous riparian plants to rain and flooding on the San Pedro River, Arizona, USA. Wetlands 25:210-223.

Barbour, M. G., and J. Major, editors. 1988. Terrestrial vegetation of California: New expanded edition. California Native Plant Society, Special Publication 9, Sacramento. 1030 pp.

Berkman, H.E. and C.F. Rabeni. 1987. Effect of siltation on stream fish communities. Environmental Biology of Fishes 18:285-294

Boody, G., and B. Devore. 2006. Redesigning agriculture. BioScience 56(10):839-845. [http://dx.doi.org/10.1641/0006-3568 (2006)56[839:RA]2.0.CO;2]

Calamusso, B. 2005. Fishes of Southwestern Grasslands-Ecology, Conservation, and Management. In Finch, Deborah M., Editor, Assessment of grassland ecosystem conditions in the Southwestern United States, Volume 2: Wildlife and Fish, pp. 141-168. Rocky Mountain Forest and Range Experiment Station, General Technical Report RMRS-GTR-135-vol. 2. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Callegary, J. Personal communication. Hydrologist, U.S. Geological Survey, Tucson, AZ

Chipps, S. R., D. E. Hubbard, K. B. Werlin, N. J. Haugerud, K. A. Powell, J. Thompson, and T. Johnson. 2006. Association between wetland disturbance and biological attributes in floodplain wetlands. Wetlands 26(2):497-508.

Comer, P. and D. Faber-Langendoen. 2013. Assessing Ecological Integrity of Wetlands from National to Local Scales: Exploring the Predictive Power, and Limitations, of Spatial Models. National Wetlands Newsletter Special Issue on Wetland Mapping and Assessment. Environmental Law Institute. Washington DC. Vol. 35 No. 3 May/June 2013.

Comer, P. J., and J. Hak. 2009. NatureServe landscape condition model. Internal documentation for NatureServe Vista decision support software engineering, prepared by NatureServe, Boulder, CO

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. Ecological systems of the United States: A working classification of U.S. terrestrial systems. NatureServe, Arlington, VA.

Conway, C. J., C. P. Nadeau, and L. Piest. 2010. Fire helps restore natural disturbance regime to benefit rare and endangered Marsh birds endemic to the Colorado River. Ecological Applications 20:2024-2035.

Debinski, D. M., and R. D. Holt. 2000. A survey and overview of habitat fragmentation experiments. Conservation Biology 14(2):342-355.

Hendrickson, D. A., and W. L. Minckley. 1984. Cienegas--Vanishing Climax Communities of the American Southwest. Desert Plants 6:129-176.

Hereford, R. 1993. Entrenchment and widening of the upper San Pedro River, Arizona. Geological Society of America Special Paper 282. 46 pp.

Jolly, Ian D., Kerryn L. McEwan and Kate L. Holland. 2008. A review of groundwater–surface water interactions in arid/semi-arid wetlands and the consequences of salinity for wetland ecology. Ecohydrology vol 1 issue 1 pages 43-58. DOI: 10.1002/eco.6

Lewis, D. B., T. K. Harms, J. D. Sarge, and N. B. Grimm. 2009. Biogeochemical Function and Heterogeneity in Arid-region Riparian Zones.in J. C. Stromberg and B. Tellman, editors. Ecology and Conservation of the San Pedro River. University of Arizona Press, Tucson.

Luce, C., P. Morgan, K. Dwire, D. Isaak, Z. Holden, and B. Rieman. 2012. Climate change, forests, fire, water, and fish: Building resilient landscapes, streams, and managers. Fort Collins, CO.

Masters, Elroy H. 2014. Acting Branch Chief, Renewable Resources and Planning, BLM, Arizona State Office. Personal Communication via e-mail dated May 2nd, 2014.

McKinney, T.S. and D.W. Anning. 2009. Geospatial data to support analysis of water-quality conditions in basin-fill aquifers in the southwestern United States. U.S. Geological Survey Scientific Investigations Report 2008-5239. http://pubs.er.usgs.gov/sir/2008/5239.

Micheli, E., and J. Kirchner. 2002. Effects of wet meadow riparian vegetation on streambank erosion. 1. Remote sensing measurements of streambank migration and erodibility. Earth Surface Processes and Landforms 27:627-639.

Mitsch, William J. and James G. Gosselink. 2000. Wetlands. Third Edition. Wiley and Sons, New York. 920 pp.

Mol, Jan H. and Paul E. Outboter. 2004. Downstream Effects of Erosion from small-scale Gold mining on the instream habitat and fish community of a small Neotropical Rainforest Stream. Conservation Biology v18:201-214

Naiman, R. J., C. A. Johnston, and J. C. Kelley. 1988. Alteration of North American streams by beaver. BioScience 38:753-762.

PAG (Pima Association of Governments). 2001. Bingham Cienega Source Water Study. Final Project Report. http://rfcd.pima.gov/reports

Pellant, M., P. Shaver, D.A. Pyke, and J.E. Herrick. 2005. Interpreting indicators of rangeland health, version 4. Technical Reference 1734-6. BLM/WO/ST-00/001+1734/REV05. U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center, Denver, CO. 122 pp.

Pimentel, D., B. Berger, D. Filiberto, M. Newton, B. Wolfe, E. Karabinakis, S. Clark, E. Poon, E. Abbett, and S. Nandagopal. 2004. Water resources: Agricultural and environmental issues. BioScience 54(10):909-918.

Poff, N. L., J. D. Allan, M. B. Bain, J. R. Karr, K. L. Prestegaard, B. D. Richter, R. E. Sparks, and J. C. Stromberg. 1997. The natural flow regime-a paradigm for river conservation and restoration. BioScience 47(11):769-784.

Poff, N. L., B. D. Richter, A. H. Arthington, S. E. Bunn, R. J. Naiman, E. Kendy, M. Acreman, C. Apse, B. P. Bledsoe, M. C. Freeman, J. Henriksen, R. B. Jacobson, J. G. Kennen, D. M. Merritt, J. H. O'Keeffe, J. D. Olden, K. Rogers, R. E. Tharme, and A. Warner. 2010. The ecological limits of hydrologic alteration (ELOHA): A new framework for developing regional environmental flow standards. Freshwater Biology 55:147-170.

Price, J., C.H. Galbraith, M. Dixon, J. Stromberg, T. Root, D. MacMykowski, T. Maddock, III, and K. Baird. 2005. Potential Impacts of Climate Change on Ecological Resources and Biodiversity in the San Pedro Riparian National Conservation Area, Arizona. Report to U.S. EPA from the American Bird Conservancy. http://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=468326.

Rinne, J.N. 1996. The effects of introduced fishes on native fishes: Arizona, Southwestern United States. In Phillips et al., ed., Protection of Aquatic Biodiversity: Proceedings of the World Fisheries Congress, Theme 3, pp. 149-159.

Rosell, F., O. Bozser, P. Collen, and H. Parker. 2005. Ecological impact of beavers Castor fiber and Castor canadensis and their ability to modify ecosystems. Mammal Review 35:248-276.

Shafroth, P.B., A.C. Wilcox, D.A. Lytle, J.T. Hickey, D.C. Andersen, V.B. Beauchamp, A. Hautzinger, L.E. McMullen, A. Warner. 2010. Ecosystem effects of environmental flows: modeling and experimental floods in a dryland river. Freshwater Biology 55: 68–85. DOI:10.1111/j.1365-2427.2009.02271.x 1.

Stefferud, J. A., P. C. Marsh, S. E. Stefferud, and R. W. Clarkson. 2009. Chapter 10: Fishes: Historical Changes and an Imperiled Native Fauna.in J. C. Stromberg and B. Tellman, editors. Ecology and Conservation of the San Pedro River. University of Arizona Press, Tucson.

Stevens, L. E., and V. J. Meretsky. 2008. Aridland springs in North America: ecology and conservation. University of Arizona Press and The Arizona-Sonora Desert Museum, Tucson. 432 pp.

Stevens, L. E., J. D. Ledbetter, and M. Hendrie. 2012. St. David Ciénega Ecological Inventory and Assessment. Draft Report November 30, 2012. Prepared by Springs Stewardship Institute, Museum of Northern Arizona. 329 pp.

Stromberg, J.C. 1998. Dynamics of Fremont cottonwood (*Populus fremontii*) and saltcedar (T*amarix chinensis*) populations along the San Pedro River, Arizona. Journal of Arid Environments 40: 133-155.

Stromberg, J.C. 2001. Restoration of Riparian vegetation in the southwestern United States: importance of flow regimes and fluvial dynamism. Journal of Arid Environments 49: 17-34. DOI:10.1006/jare.2001.0833.

Stromberg, J., and T. Rychener. 2010. Effects of Fire on Riparian Forests Along a Free-Flowing Dryland River. Wetlands 30:75-86.

Stromberg, J. C., J. Fry, and D. T. Patten. 1997. Marsh development after large floods in an alluvial, arid-land river. Wetlands 17:292-300.

Stromberg, J.C., R. Tiller, and B. Richter. 1996. Effects of groundwater decline on Riparian vegetation of semiarid regions: the San Pedro, Arizona. Ecological Applications 6(1): 113-131.

Stromberg, J. C., S. J. Lite, M. D. Dixon, and R. L. Tiller. 2009. Chapter 1-Riparian Vegetation: Pattern and Process.in J. C. Stromberg and B. Tellman, editors. Ecology and Conservation of the San Pedro River. University of Arizona Press, Tucson.

Stromberg, J.C., V.B. Beauchamp, M.D. Dixon, S.J. Lite, and C. Paradzick. 2007. Importance of low-flow and high-flow characteristics to restoration of Riparian vegetation along rivers in arid south-western United States. Freshwater Biology 52: 651–679. DOI:10.1111/j.1365-2427.2006.01713.x.

Tabacchi, E., D. L. Correll, R. Hauer, G. Pinay, A. M. Planty-Tabacchi, and R. C. Wissmar. 1998. Development, maintenance and role of riparian vegetation in the river landscape. Freshwater Biology 40:497-516.

Theobald, D. M., D. M. Merritt, and J. B. Norman, III. 2010. Assessment of threats to Riparian ecosystems in the western U.S. Prepared for the Western Environmental Threats Assessment Center, Prineville, OR, by the Department of Human Dimensions of Natural Resources and the Natural Resource Ecology Lab, Colorado State University and USDI Forest Service Watershed, Fish, Wildlife, Air and Rare Plants Staff, Natural Resource Research Center, Ft. Collins, CO. 56 pp.

U.S. Environmental Protection Agency (USEPA). 2005. Use of Biological Information to Better Define Designated Aquatic Life Uses in State and Tribal Water Quality Standards: Tiered Aquatic Life Uses. EPA-822-R-05-001, DRAFT, August 10, 2005.

USDI BLM [U.S. Bureau of Land Management]. 2006. 43CFR4180.1 Fundamentals of Rangeland Health. Code of Federal Regulations and Federal Register, Accessed February 2013 http://federal.eregulations.us/cfr/section/2006/04/18/43-cfr-4180.1

U.S. Geological Survey (USGS). 2011. Non-indigenous aquatic species. [http://nas.er.usgs.gov/] (accessed December 2001).

Unnasch, R.S., D. P. Braun, P. J. Comer, G. E. Eckert. 2008. The Ecological Integrity Assessment Framework: A Framework for Assessing the Ecological Integrity of Biological and Ecological Resources of the National Park System. Report to the National Park Service.

Vranckx, G., H. Jacquemyn, B. Muys, and O. Honnay. 2011. Meta-analysis of susceptibility of woody plants to loss of genetic diversity through habitat fragmentation. Conservation Biology, November 2011. Early on-line publication. [10.1111/j.1523-1739.2011.01778.x]

Webb, R.H. and S.A. Leake. 2006. Ground-water surface-water interactions and long-term change in riverine Riparian vegetation in the southwestern United States. Journal of Hydrology 320: 302–323. DOI:10.1016/j.jhydrol.2005.07.022.

Webb, R.H., R.M. Turner and S.A. Leake 2007. The Ribbon of Green. University of Arizona Press. Tucson, 480 pp.

Montane River and Riparian

E-3 North American Warm Desert Lower Montane and Foothill Riparian Woodland and Shrubland and Stream

E-3.1 Conceptual Model

E-3.1.1 Classification

The ecosystem conservation elements for the MAR REA were selected from NatureServe's classification of terrestrial ecological systems (Comer et al. 2003). Over three dozen ecological systems occur in the MAR, but only a subset were chosen for the REA. The CE concept provided in this conceptual model includes this NatureServe ecological system type:

- North American Warm Desert Lower Montane Riparian Woodland and Shrubland (CES302.748)

There are other terrestrial ecological systems in the NatureServe classification that also occur in the MAR, or in adjacent ecoregions, which are similar to this CE concept but are not included in this conservation element. These are listed here to help the reader understand what is not included in this conceptual model; each of these other ecological systems has information that can be searched for and reviewed on NatureServe's on-line Explorer website.

- Chihuahuan-Sonoran Desert Bottomland and Swale Grassland (CES302.746) - Tobosa/Sacaton swale (intermittently flooded)
- North American Arid West Emergent Marsh (CES300.729)
- North American Warm Desert Cienega (CES302.747)
- North American Warm Desert Riparian Mesquite Bosque (CES302.752)
- North American Warm Desert Riparian Woodland and Shrubland (CES302.753)

E-3.1.2 Summary

This ecological system (**Figure E-26)** occurs in foothill and mountain canyons and valleys of the warm desert regions of the southwestern U.S. and adjacent Mexico (**Figure E-27**). It consists of riparian corridors and along perennial and seasonally intermittent streams or rivers at lower montane elevations, generally between 4,000 and 7,000 ft. (1200-2150 m)[2] with variation due to hydrogeologic setting. Rivers include upper portions of the Gila, Santa Cruz, Salt, San Pedro, and their tributaries. The vegetation is a mix of riparian woodlands and shrublands. Dominant trees include narrow leaf cottonwood (*Populus angustifolia*), aspen (*Populus tremuloides*), box elder (*Acer negundo*), Rio Grande cottonwood (*Populus deltoides ssp. wislizeni*), Fremont's cottonwood (*Populus fremontii*), sycamore (*Platanus wrightii*), Arizona walnut (*Juglans major*), Arizona cypress (*Cupressus arizonica*), velvet ash (*Fraxinus velutina*), Gambel's oak (*Quercus gambelii*) and soapberry (*Sapindus saponaria*). Shrub dominants include coyote or sand willow (*Salix exigua*), cherry or plum (*Prunus* spp.), Arizona alder (*Alnus oblongifolia*), and mulefat (*Baccharis salicifolia*). Vegetation is dependent upon annual or periodic flooding and associated sediment scour and/or annual rise in the water table for growth and reproduction. In addition elevation is an important factor in determining the dominant species that characterize the riparian zone within this type. The Coronado National Forest has identified the

[2] tentative proposed elevation band, specific to the MAR

vegetated portions of this system as the “Mixed Broadleaf Deciduous Riparian Forest” and the “Montane Willow Riparian Forest” (CNF 2009). National Resource Conservation Service recognizes this ecosystem as the Sandy Bottom (PLWR2, POFR2) F041XA113AZ Ecological Site Description (Robinett 2005b).

The aquatic fauna and flora in this ecosystem type vary depending on whether flow is perennial or intermittent; the frequency, intensity, seasonal timing, and duration of high-flow pulses, low-flows, and dry conditions; the relative contributions to stream flow from runoff from rainfall and snowmelt versus from groundwater discharge, including discharge from discrete springs; water temperature and chemistry; channel substrate and form, including the distribution of shaded pools; the extent of the hyporheic zone; and drainage network connectivity.

As with all warm desert streams and rivers, this ecosystem supports a unique range of aquatic species adapted to the overall scarcity and irregular availability of water over space and time, and the frequent isolation of perennial reaches by dry conditions across the rest of the drainage network. These factors result in a high degree of endemism among the aquatic biota, including species adapted to using pools or the hyporheic zone as their main habitat or as refuge during periods with low, intermittent, or no flow. This ecosystem occurs at higher elevations than the North American Warm Desert Riparian Woodland and Shrubland, Mesquite Bosque and Stream ecosystem, and consequently has cooler water temperatures, typically steeper channel gradients, higher flow velocities, and a higher proportion of habitats with coarse (versus fine) substrate and bank sediments. This ecosystem also often occurs in canyons, where surrounding bedrock confines the channel both vertically and horizontally, and where debris from the surrounding slopes such as snags and large boulders contribute to habitat complexity.

These factors select for a unique spectrum of aquatic species in this ecosystem. For example, benthic macroinvertebrate assemblages generally consist of highly tolerant, short-lived, fast-reproducing individuals with broad ecological tolerances, with an emphasis on collectors/gatherers and grazers. Vertebrate and invertebrate species able to use the hyporheic zone as their main habitat or as a refuge during periods without flow or during extreme flow pulses occur in this system type (e.g., Del Rosario and Resh 2000, Levick et al. 2008). Disturbances caused by intermittent flows may actually facilitate high food quality and consequently high levels of insect production (Fisher and Gray 1983, Grimm and Fisher 1989, Huryn and Wallace 2000, Jackson and Fisher 1986,).

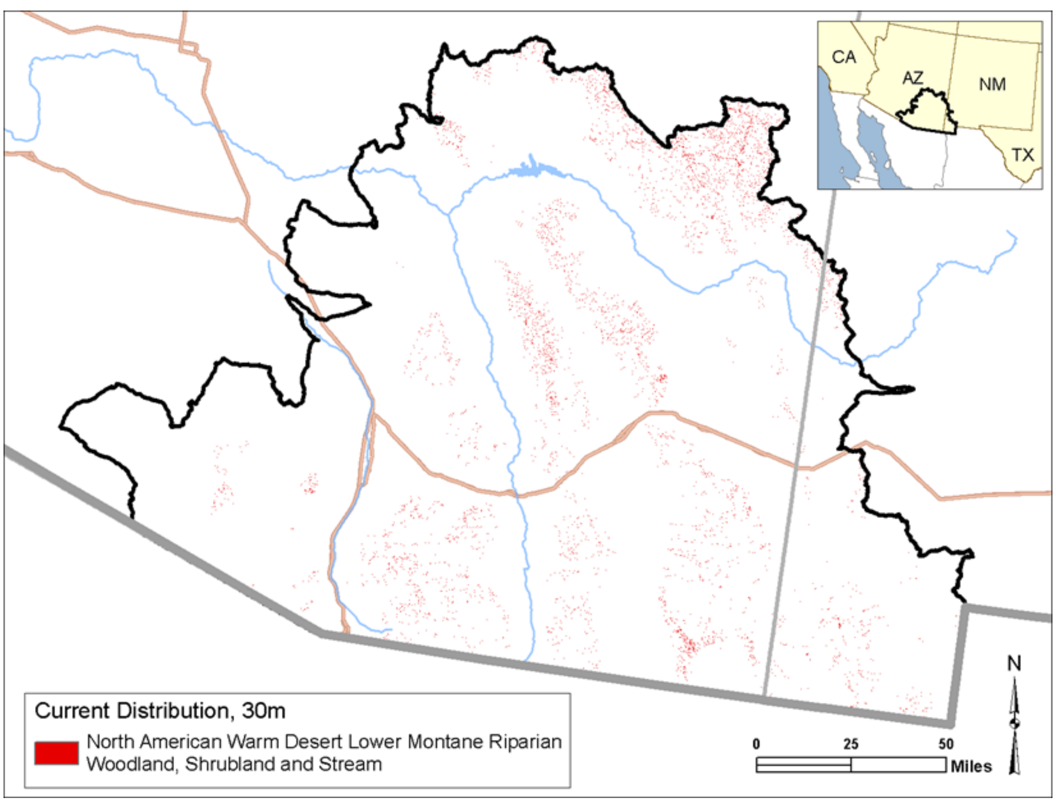
This CE does not include the Loamy Bottom Ecological Site where giant sacaton (*Sporobolus wrightii*) dominates, as described by NRCS (Robinett 2005a, Wright 2002) and Stromberg et al. (2009). Stands of giant sacaton may be adjacent to the woody riparian ecosystems or near-by within the same valley.

Figure E-26. Photos of North American Warm Desert Lower Montane Riparian Woodland and Shrubland and Stream in Bear Canyon (left) and Sycamore Canyon (right), Coronado National Forest

E-3.1.3 Current Distribution

Figure E-27 shows the current distribution of the CE by 30m pixel. The map omits the background topographic relief, because the pixels are so few and scattered that they become almost invisible when viewed with the background relief present. As would be expected given the elevational definition for the CE (see above), the pixels representing the distribution occur exclusively in a band of higher elevations across the mountain ranges of the ecoregion. However, not all mountain ranges have equally dense distributions; the Pedregosa, Galiuro, Pinaleño/ Pinal, and Gila Mountains have the highest densities.

Figure E-27. Current distribution of North American Warm Desert Lower Montane and Foothill Riparian Woodland and Shrubland and Stream CE within the MAR.



E-3.1.4 Species of Conservation or Management Concern

Below are listed some species of concern associated with this ecological system CE. Sources include the Gila Ecoregion in Freshwater Ecoregions of North America (Abell et al. 2000), and Stefferud et al. (2009).

Reptiles and Amphibians: Mexican garter snake, Chiricahua Leopard Frog *(Rana chiricahuensis)*

Mollusks: Wet Canyon Talussnail, Madera Talussnail, and Cave Creek Woodlandsnail

Invertebrates: caddisflies, damselflies, and stoneflies

Birds: Gray hawk, Western yellow-billed cuckoo, Southwestern Willow Flycatcher (*Empidonax trailii extimus*), and many other migratory and breeding species, including Bell's Vireo and Elegant Trogon. .

Fishes: Spikedace (*Meda fulgida*) (Gila R), loach minnow (*Tiaroga cobitis*) (Gila & San Francisco R.), Gila trout (*Oncorhynchus gilae*), Longfin dace (*Agosia chrysogaster*) and Gila topminnow (*Poeciliopsis occidentalis*) endemic to Gila R., Gila chub (*Gila intermedia*), Colorado Squawfish (*Ptychocheilus lucius*) and Razorback sucker (*Xyrauchen texanus*) endemic to Colorado River Basin and the Gila R., and Roundtail chub (*Gila robusta*) Gila R. [source: Abell et al. 2000]. Additional fishes include the Sonora sucker (*Catostomus insignis*) and the Desert Sucker (*Pantosteus clarki*) (Stefferud et al. 2009).

Mammals: Beaver (*Castor canadensis*)

Plants: Gentry's Indigo Bush, Chiricahua Mountain Alum-root, California Satintail, Southwest Monkeyflower, and Frog's-bit Buttercup.

E-3.1.5 Natural Dynamics

The hydrologic regime of North American Warm Desert Lower Montane Riparian Woodland and Shrubland and Stream ecosystem is naturally highly variable temporally and spatially among the streams of this ecosystem.

Faunal and floral composition and dynamics – both terrestrial and aquatic – are shaped by episodic flooding and associated sediment scour and deposition, and by the rise and fall of the water table. Vegetation is relatively dense, especially when compared to drier washes. The water table is usually not far below the surface such as where the bedrock can force groundwater to the surface at some localities, or where the water table can simply intersects the stream channel, or where an alluvial water table is shallow and channel is primarily groundwater fed baseflow (e.g., Calamusso 2005, Eby et al. 2003, Horton et al. 2001, Katz et al. 2009, Leenhouts et al. 2006, Lite and Stromberg 2005, Propst et al. 2008, Shafroth et al. 2000, Shafroth et al. 2010, Snyder and Williams 2000, Stromberg 1998, Stromberg 2001, Stromberg et al. 1996, Stromberg et al. 2005, Stromberg et al. 2006, Stromberg et al. 2007, USFWS 1999, Webb and Leake 2006).

This riparian and aquatic ecosystem has high spatial and temporal variation that is driven by many abiotic factors. The timing, duration, temperature range of flow pulses (from watershed runoff) - are shaped by the warm, arid climate with extreme contrast between daytime and nighttime temperatures. Spatial extent of perennial flow is controlled by the complex interplay among factors such as distribution of bedrock, channel morphology, slope, thickness of alluvium, rock type, fracturing, evapotranspiration, sills that can force alluvial groundwater flow to the surface, the distribution of buried channel gravels, and by the distribution of springs from deeper aquifers with sufficient discharge to support streamflow. The limited precipitation is concentrated at higher elevations mostly as rainfall but sometimes also as snow, and substantial precipitation and/or snowmelt events are necessary to produce surface runoff (e.g., Price et al. 2005).

The presence and magnitude of such runoff events vary greatly from season to season, year to year, and decade to decade (e.g., Price et al. 2005, Serrat-Capdevila et al. 2007). Perennial surface water flow within the Coronado NF and in surrounding watersheds appears to have declined in recent years. The cause of the decline is thought to be prolonged drought from 1995-2005. In addition, extraction of groundwater for land uses such as agriculture and development is lowering water tables and decreasing perennial surface water (CNF 2009).

Evaporation and riparian transpiration also consume water seasonally, contributing to losses of flow along individual stream reaches during the growing season, with a proportionately smaller affect during runoff flow pulses. Riparian water table dynamics follow suit: the water table rises during high-flow events and falls between such events, unless the water table is controlled primarily by an upward leakage of groundwater, forced to the surface by bedrock sills (e.g., Webb and Leake 2006). However, Large intense storms can also cause dynamic response in groundwater table, regardless of stream flow characteristics.

Average concentrations of particulate organic matter can be lower during runoff pulses, as are concentrations of suspended and re-suspended sediment through dilution. In contrast, concentrations of particulate organic matter are higher during baseflow, as are concentrations of suspended and re-suspended sediment. One important characteristic of groundwater inputs to streamflow is that groundwater temperatures tend to be stable over the longterm (Stromberg et al. 2009).

Fire

Fire in riparian areas is less common than in surrounding uplands but does occur, as often as 5-15 times in the last 22 years, and burned from less than 1 acre up to approximately 300 acres (CNF 2009). Fire is a disturbance agent and many riparian species respond by re-sprouting after fire (Luce et al. 2012, Stromberg and Rychener 2010).

E-3.1.6 Change Agent Effects on the CE

This section of the conceptual model presents a narrative description of the primary change agents and current knowledge of their effects on North American Warm Desert Riparian Woodland, Shrubland and Mesquite Bosque / Stream ecosystems. The section contains two sub-sections: (1) A list of primary change agents identified for the CE; and (2) a discussion of altered dynamics caused by these agents.

E-3.1.6.1 List of Primary Change Agents

Occurrences of this ecosystem – both their riparian areas and aquatic communities – are directly affected by concentrated grazing, cutting of woody vegetation, land development, river channelization including channel dredging and bank armoring, diversion of flows, withdrawals of groundwater, wildfire suppression, non-native terrestrial and aquatic plants and animals, unregulated recreation (both motorized and non-motorized), roadways and railways that cut through/along riparian corridors, mining, point-source and diffuse (runoff) pollution, and fragmentation by dams. Occurrences are also indirectly affected by climate change and by human activities across the surrounding watersheds that alter watershed runoff and groundwater recharge/discharge by altering ground cover and through water diversions and withdrawals; or that result in point and non-point-source pollution, including from abandoned and active mines and possibly from atmospheric deposition.

E-3.1.6.2 Altered Dynamics

Table E-10 identifies the most likely impacts associated with each of the stressors identified. Change agents, and the specific stressors they generate, cause alteration to the key ecological attributes (KEAs) for individual occurrences of this ecosystem type. Some stressors directly remove the conservation element, such as new rural or urban development. Other stressors such as roads and other infrastructure corridors (e.g. railroads, power lines, solar arrays, oil pumping platforms and the like) cause fragmentation in the distribution or connectivity of the conservation element (Debinski and Holt 2001). Irrigated agriculture, in addition to completely removing portions of a conservation element, can also cause downstream alteration to a riparian/stream ecosystem through polluted runoff and return flow and through flow alteration (e.g., Boody and DeVore 2006, Chipps et al. 2006, Pimentel et al. 2004). Water development projects can have a double effect on aquatic CEs, as they can change the amount and timing of flow, and also can fragment the network of flow (Poff et al. 2010). Aquatic invasive species often have profound effects on the amount of oxygen available, can directly compete with native species, and have been shown to completely replace the native ecosystem habitat (e.g. tamarisk) (USGS 2011).

Stressors can cause different degrees of alteration to an individual KEA, i.e., different degrees of stress; and the degree of alteration to a KEA will depend on the cumulative effects of all stressors acting on it. Responses to stress in key ecological attributes of biotic condition for riparian/stream ecosystems may include a reduction in species taxonomic and genetic diversity due to fragmentation and loss of habitat at the scale of the ecoregion (Vranckx et al. 2011). Individual species can become less abundant as their habitats become fragmented or continually disturbed such that reproduction is less successful, causing alteration to functional diversity and food web structure (Calamusso et al. 2005). As native species become stressed, other more tolerant and opportunistic species may increase in abundance, causing additional changes to functional diversity and food web structure. Shifts in species abundance and composition can also alter abiotic dynamics. For example, changes in vegetation can alter nutrient cycling or cause changes in vegetation on stream banks that affect bank and channel stability; and changes in beaver populations can change hydrology and nutrient cycling. **Figure E-28** and **Figure E-29** capture these interactions, and the use of indicators to track them.

Table E-10. Stressors and their likely impacts on the North American Warm Desert Lower Montane Riparian Woodland and Shrubland and Stream ecosystem type in the Madrean Archipelago ecoregion (with representative citations specific to impacts to aquatic resources in general, within the ecoregion, or in the western US, but not an exhaustive literature review, of which there are many for each stressor).

Stressor	Impacts
Land Use	
Concentrated grazing	Removal of native vegetation, changes to native composition and structure, possibly favoring invasion of non-native vegetation (Patten 1998, Robinett 2005b) thus altering native vegetation assemblage and overall ecological function (Faber-Langendoen et al. 2008); erosion of stream banks and channel; stream pollution (sediment, manure) (Robinett 2005b) which can be detrimental to fish habitats (Calamusso 2005).
Unregulated recreation	Elimination and fragmentation of riparian habitat; increased soil erosion; point and non-point source pollution, cutting of woody vegetation, (Debinski and Holt 2000).

Stressor	Impacts
Cutting of woody vegetation	Removal of native vegetation, possibly favoring invasion of non-native vegetation (Patten 1998, Stromberg et al. 2009), thus altering native vegetation assemblage and overall ecological function (Faber-Langendoen et al. 2008) which can impact the amount of woody debris important for fish habitat (Calamusso 2005).
Development	
Roadways/railways	Elimination and fragmentation of riparian habitat; altered longitudinal surface flow paths in alluvial aquifer; non-point source pollution (Comer and Faber-Langendoen 2013, Comer and Hak 2009).
Mining within riparian zone	Elimination and fragmentation of riparian habitat; altered alluvial/channel geomorphic dynamics; altered longitudinal groundwater flow paths in alluvial aquifer; point source pollution (Berkman and Rabeni 1987, Mol and Ouboter 2004).
Altered watershed ground cover	Alteration of runoff and recharge at both the watershed scale and immediately along the riparian/stream corridor; altered sediment inputs from watershed during runoff events; altered non-point source pollution (Anning et al. 2009, Poff et al. 2010, Webb and Leake 2006).
Land development	Elimination and fragmentation of riparian habitat; reduced alluvial recharge during rainfall/runoff; increased soil erosion; non-point source pollution (McKinney and Anning 2009).
Fragmentation by dams	Fragmentation of riparian habitat and aquatic connectivity very important to fish habitat (Calamusso 2005)
Hydrologic Alterations	
River channelization	Elimination of natural geomorphic dynamics; elimination of bank and over-bank recharge to alluvial aquifer during runoff pulses; elimination of groundwater discharge along armored reaches; channel entrenchment resulting in lowered groundwater table (Hereford 1993, Webb et al. 2007) which degrades fish habitat (Calamusso 2005).
Diversion of flows	Loss of surface flows, both baseflow and runoff, with consequent loss of natural alluvial groundwater recharge/discharge dynamics, disconnect with the floodplain which can increase sediment transport and change the aquatic habitat (Calamusso 2005, Poff et al. 2010, Shafroth et al. 2010, Theobald et al. 2010), causing loss to flora an faunal ecology (Faber-Langendoen et al. 2008, Patten 1998, Stromberg et al. 2007).
Point-source pollution along riparian zone	Direct alteration of surface water and potentially also groundwater quality which can lead to poor water quality detrimental to fish habitats (Calamusso 2005, Luce et al. 2012).
Point-source pollution, watershed	Alteration of water quality in flows arriving from upstream and tributaries which can lead to poor water quality detrimental to fish habitats (Calamusso 2005, Luce et al. 2012).

Stressor	Impacts
Non-point-source pollution	Alteration of water quality in flows arriving from upstream and tributaries as well as in surface runoff along/within the riparian zone itself (Abell et al. 2000) which can lead to poor water quality detrimental to fish habitats (Calamusso 2005).
Withdrawals of groundwater	Loss of baseflow (magnitude and spatial extent) and lowering of alluvial water table (Calamusso 2005, Poff et al. 2010, Stromberg et al. 1996). Changes in flow can cause increased channel incision and down cutting of the stream bed (Hereford 1993, Webb et al. 2007), and cause severe habitat changes (Falke et al. 2011, Robinett 2005b).
Changes to natural Wildfire regime	Change in vegetation succession dynamics, such as the encroachment and increase density of native and non-native woody species, such as tamarisk , and hot fires that change soil characteristics (Stromberg and Rychener 2010, Stromberg et al. 2009, U.S. Fish and Wildlife Service 2002).
Invasive Species	
Non-native terrestrial plants and animals	Replacement of native vegetation, altering riparian habitat suitability for terrestrial fauna; alteration of shading of channel affecting water temperature and habitat quality;, alteration of fire risk; alteration of soil and channel stability either through an increase (such as tamarisk thickets) or decrease (annuals replacing perennial graminoid species); alteration of ground-litter chemistry; alteration of evapotranspiration rates and timing (Robinett 2005b, Stromberg 1998).
Non-native aquatic plants and animals	Removal or reduction of native aquatic species due to competition, predation, alteration of water quality (Calamusso 2005, Rinne 1996, USEPA 2005).
Climate change	Alteration of precipitation and evapotranspiration rates and timing, resulting in direct alteration of runoff and recharge at both the watershed scale and immediately along the riparian/stream corridor. Impacts may also occur through changes in human consumption of surface water and groundwater in response to climate change (Price et al. 2005).

E-3.1.7 Ecological Status: Key Ecological Attributes and Indicators

This section of the conceptual model addresses key ecological attributes and their potential indicators. The ecological status is a way of describing current status via criteria, functionality, or levels of attributes and asks if they are within the normal range of variation.

E-3.1.7.1 Key Ecological Attributes

Table E-11 identifies the key ecological attributes for the CE within the Madrean Archipelago ecoregion. A **key ecological attribute** of a focal ecological resource is a characteristic of the resource's biology, ecology, or physical environment that is critical to the resource's persistence in the face of both natural and human-caused disturbance. Alteration of such a characteristic beyond some critical range of variation will lead to the degradation or loss of the resource within decades or less. The KEAs table lists the identified key ecological attributes, with a brief definition, a rationale for why it is important for the CE, and a listing of stressors or change agents that might be affecting the key attribute.

Table E-11. Key ecological attributes (KEA) and stressors of North American Warm Desert Lower Montane Riparian Woodland and Shrubland and Stream ecosystem

KEA Class: **Name**	**Definition**	**Rationale**	**Stressors**
Landscape Context: **Landscape Cover**	The extent of natural ground cover for the watershed containing the riparian/stream ecosystem occurrence, versus the extent of different kinds of modifications to the watershed surface for human use.	Surrounding watershed cover in unaltered landscapes helps determine the rates of precipitation runoff versus infiltration, evapotranspiration, soil erosion (both "sheet" and "channel" erosion), and transport of sediment, dissolved and suspended nutrients to the riparian/stream location from the watershed as a whole and from its immediate "near-stream" buffer zone. Surrounding watershed cover also shapes the connectivity between the riparian/stream corridor and the surrounding landscape for fauna that move between the two settings; and the longitudinal connectivity of the buffer zone alongside the corridor within which additional wildlife movement takes place. (Comer and Faber-Langendoen 2013, Comer and Hak 2009)	Stressors to landscape cover include watershed development and/or excessive grazing, which can alter the rates of runoff versus infiltration from precipitation, evapotranspiration, soil erosion (both "sheet" and "channel" erosion), and transport of sediment, dissolved and suspended nutrients to the riparian/stream location from the watershed as a whole and from its immediate "near-stream" buffer zone. Development and excessive grazing also can introduce pollutants and cause fragmentation (reduces connectivity) between the riparian/stream corridor and the surrounding landscape and along the buffer zone surrounding the corridor. Climate change also has the potential to cause additional change in landscape cover.
Size/Extent: **Vegetation Corridor Extent**	The longitudinal extent of uninterrupted (unfragmented) native vegetation patches along the riparian corridor.	Unfragmented riparian corridors support individual animal movement, gene flow, and natural flooding and sediment deposition and scour processes upon which aquatic and wetland species depend. More extensive and highly connected riparian corridors are ecologically more resistant and resilient, for example by providing refugia and movement routes that support recovery following disturbance or incursions by non-native species (Faber-Langendoen et al. 2012b). Within the MAR, streams were naturally patterned perennial and intermittent, making for naturally patchy corridors, so the degree of fragmentation change from historic will not be used as a measure of health.	Stressors to vegetation corridor extent include development on/in the riparian corridor itself, including: conversion to agriculture, excessive grazing, commercial/industrial/residential use; construction of transportation infrastructure; and dams/impoundments. These changes can alter the movement of water, nutrients, animals, and sediment. Lateral constrictions can lead to increased velocity of flows, contributing to increased erosion and down-cutting. Climate change also has the potential to cause additional change in vegetation corridor extent, through its impacts on hydrology (see Hydrologic Regime).

KEA Class: **Name**	**Definition**	**Rationale**	**Stressors**
Size/Extent: **Aquatic Corridor Extent**	The longitudinal extent of the stream channel network, uninterrupted by barriers or reaches with seasonal or intermittent flow.	Unfragmented aquatic corridors support up- and downstream movement and gene flow for aquatic animal species, natural downstream transport of larvae and seeds, and natural downstream transport of sediment and both dissolved and suspended nutrient matter -- all processes crucial to sustaining the aquatic food web, aquatic and riparian species populations, and succession and recovery from disturbances. More extensive and highly connected aquatic corridors are ecologically more resistant and resilient, for example by providing refugia and movement routes that support recovery following disturbance. Within the MAR, streams were naturally patterned perennial and intermittent, making for naturally patchy corridors, so the degree of fragmentation change from historic would require accurate maps showing the distribution prior to European influence. At the time of this assessment, such a map was not available.	Stressors affecting aquatic corridor extent include dams and diversions, riparian corridor development (see Vegetation Corridor Extent), surface- and groundwater use (see Hydrologic Regime), channelization (see Geomorphology), and concentrated contamination such as from mine waste (see Water Chemistry). Climate change also has the potential to cause additional change in aquatic corridor extent, through its impacts on hydrology (see Hydrologic Regime).
Biotic Condition: **Riparian Fauna**	The taxonomic and functional (e.g., guild) composition of the native faunal assemblage of the riparian corridor including birds, mammals, reptiles and amphibians, and invertebrates; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The taxonomic and functional composition of riparian faunal assemblage is important aspects of the ecological integrity of a riparian ecosystem. Numerous native species of birds, mammals, reptiles and amphibians, and invertebrates use riparian habitat for feeding, resting, breeding, and movement; and their patterns of use vary over time (seasonal, annual, longer-term). These species vary in their sensitivity to different stresses such as alterations to riparian vegetation composition, riparian corridor connectivity, soil moisture, and the availability of surface water. Alterations in the taxonomic and functional composition of the terrestrial faunal assemblage beyond their natural ranges of variation therefore strongly indicate the types and severities of stresses imposed on the riparian ecosystem.	Stressors to the taxonomic and functional composition of the riparian faunal assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, floral composition, and abiotic condition of the riparian/stream ecosystem; and incursions of non-native species that alter the food web or directly compete with or prey on the native fauna.

KEA Class: Name	Definition	Rationale	Stressors
Biotic Condition: **Riparian & Aquatic Flora**	The taxonomic composition of the native floral assemblage of the riparian corridor including woody and non-woody vegetation - terrestrial, wetland, and aquatic - and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The taxonomic composition of the riparian & aquatic floral assemblage is an important aspect of the ecological integrity of a riparian/aquatic ecosystem. Numerous native species of woody and non-woody plants occur preferentially or exclusively in riparian habitats, from floodplain terraces to stream banks and perennial pools; and occur in different successional settings following disturbance. These species vary in their sensitivity to different stresses such as alterations to riparian corridor hydrology (e.g., water table and flood dynamics), aquatic and riparian corridor connectivity (affecting availability of seed for re-colonization following disturbance), and altered water quality. Alterations in the taxonomic composition of the riparian floral assemblage beyond its natural range of variation therefore strongly indicates the types and severities of stresses imposed on the riparian ecosystem.	Stressors to the taxonomic composition of the riparian native floral assemblage experiences include the cumulative impacts of all stressors affecting the landscape context, size/extent, and abiotic condition of the riparian/stream ecosystem, including altered wildfire and excessive grazing; and incursions of non-native species that alter the habitat (e.g., alter soils) or directly compete with the native flora.
Biotic Condition: **Aquatic Fauna**	The taxonomic and functional (e.g., guild) composition of the native faunal assemblage of the stream, including fishes, reptiles and amphibians, and invertebrates; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The taxonomic and functional composition of the aquatic faunal assemblage are important aspects of the ecological integrity of a stream ecosystem. Aquatic species - as especially well studied for fishes and macroinvertebrates - vary in their roles in the aquatic food web and in their sensitivity to different stresses such as alterations to stream hydrology, habitat quality, water quality, and nutrient inputs. Alterations in the taxonomic and functional composition of the aquatic faunal assemblage beyond their natural ranges of variation therefore strongly indicate the types and severities of stresses imposed on the aquatic ecosystem.	Stressors affecting the taxonomic and functional composition of the aquatic faunal assemblage include the cumulative impacts of all stressors affecting the landscape context, size/extent, and abiotic condition of the riparian/stream ecosystem; and incursions of non-native species that alter the food web or directly compete with or prey on the native fauna.

KEA Class: Name	Definition	Rationale	Stressors
***Abiotic Condition:* Hydrologic Regime**	The pattern of surface flow in the stream channel and surface-groundwater interaction along the riparian corridor - as characterized by, for example, the frequency, magnitude, timing, and duration of extreme flow conditions and extreme water table elevations; the magnitude and timing of seasonal and annual baseflow and total discharge; and the magnitude of seasonal and annual water table mean elevation.	The surface flow regime determines which aquatic species can persist in a stream system through their requirements for or tolerances of different flow conditions at different times of the year; shapes sediment transport and geomorphology and therefore aquatic habitat distributions and quality; and determines the pattern of flood disturbance. In turn, interactions between the surface flow regime and underlying aquifer conditions shape the pattern of baseflow and the pattern of water table variation along the riparian corridor. The surface flow regime and surface-groundwater interactions thereby together strongly influences both aquatic and riparian habitat and biological diversity (e.g., Poff et al. 1997; Poff et al. 2007).	Stressors affecting the hydrologic regime include watershed development that alters runoff, infiltration (recharge), and evapotranspiration rates; surface water diversions, transfers, and use; groundwater withdrawals from basin-fill and alluvial aquifers; return flows of municipal and agricultural wastewater; dams, dam operations, and impoundment evaporation; riparian corridor development; and alterations to the riparian floral assemblage including invasions of non-native flora with high water consumption. Climate change also has the potential to cause additional change in the hydrologic regime, through its effects on precipitation form (snow vs. rain), spatial distribution, magnitude, and timing; and through its effects of evapotranspiration rates both within the riparian zone and across the surrounding watershed. Climate change may also cause changes in human water use.
***Abiotic Condition:* Geomorphology**	The geomorphology of the stream channel, banks, and floodplain, including channel bed form, cross-sectional form, sediment size distributions, and geomorphic stability/turnover.	Channel and floodplain geomorphology, shaped by watershed runoff (sediment and water) and surface flows in the stream, create the habitat template for both riparian and stream flora and fauna. Altered channel substrate and geomorphology strongly affect aquatic faunal assemblage composition and complexity and both stream-floodplain and surface-groundwater interactions along riparian corridors.	Stressors affecting the geomorphology of the stream channel, banks, and floodplain include the cumulative effects of alterations to watershed cover, riparian and aquatic corridor connectivity, riparian flora, and hydrology; the effects of bank and channel trampling from excessive use by livestock; and the effects of direct channel and floodplain modifications such as channelization and gravel mining. Climate change also has the potential to cause additional change in stream channel morphology through its impacts on watershed cover (see Landscape Cover) and hydrology (see Hydrologic Regime).

KEA Class: Name	Definition	Rationale	Stressors
Abiotic Condition: **Water Chemistry**	The chemical composition of the water moving into the riparian corridor water table and along the stream channel, including the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The chemistry of the water flowing into and through riparian and stream habitat strongly determine which plant and animal species can persist in these habitats through their requirements for or tolerances of different soil and stream water chemistries. Stream fauna, for example, vary in their requirements for or tolerances of variation in salinity, dissolved oxygen, temperature, turbidity, and the presence/absence of different dissolved and suspended matter including anthropogenic pollutants.	Stressors affecting water quality include effects of single catastrophic high or low concentration perturbation such as low oxygen, high temp, or heavy metals can be devastating to aquatic ecosystems. Additionaly,the cumulative effects of non-point source pollution from watershed development, point-source pollution (e.g., municipal, industrial, mining wastewater), atmospheric deposition, excessive use of riparian zones as pasturing areas for livestock, and altered groundwater discharge (see Hydrologic Regime). Climate change has the potential to exacerbate these impacts through changes in watershed runoff and water use.
Abiotic Condition: **Fire**	The pattern of fire occurrence (fire regime) within the riparian corridor, as characterized by its frequency, intensity, and spatial extent.	Fire is a natural agent of disturbance in riparian vegetation communities, where it helps shape community succession, triggers reproductive activity, and shapes the cycling of soil nutrients.	Stressors affecting the fire regime include ecologically incompatible fire management practices, and changes in landscape and riparian corridor vegetation due to other factors.

E-3.1.8 Relationship of KEAs to Fundamentals of Rangeland Health

The key ecological attributes and stressors listed in **Table E-11** also encompass the four fundamentals of rangeland health (USDI BLM 2006), as shown in **Table E-12**. The KEA for Landscape Cover specifically refers to watershed conditions; all other KEAs refer specifically to Ecological Processes and Habitat. Abiotic condition also has stressors that arise as a result of modifications to the watershed or modifications to water quality. These relationships are also indicated in **Table E-12**. Further information about interpretation and assessment of these fundamentals of rangeland health is found in Pellant et al. (2005).

Table E-12. Relationship of key ecological attributes (KEA) for the North American Warm Desert Lower Montane and Foothill Riparian Woodland and Shrubland and Stream ecosystem to fundamentals of rangeland health.

Key Ecological Attribute	Watersheds	Ecological Processes	Water Quality	Habitat
Landscape Cover	X		X	
Vegetation Corridor Extent		X		X
Aquatic Corridor Extent		X		X
Biotic Condition: Riparian Fauna		X		X
Biotic Condition: Riparian and Aquatic Flora		X		X
Biotic Condition: Aquatic Fauna		X		X
Abiotic Condition: Hydrologic Regime	X	X	X	X
Abiotic Condition: Geomorphology	X	X	X	X
Abiotic Condition: Water Chemistry	X	X	X	X
Abiotic Condition: Fire	X	X	X	X

E-3.1.9 Conceptual Model Diagrams

Figure E-28. Conceptual model diagram for North American Warm Desert Lower Montane Riparian Woodland & Shrubland and Aquatic Stream Ecosystem describing the structural components and functional relationships that characterize this system. Ovals represent key ecological attributes and Ecosystem Drivers. Arrows indicate functional relationships among components. Line weights indicate relative importance. The model is constrained by global climatic and atmospheric conditions, topography, parent material and potential biota.

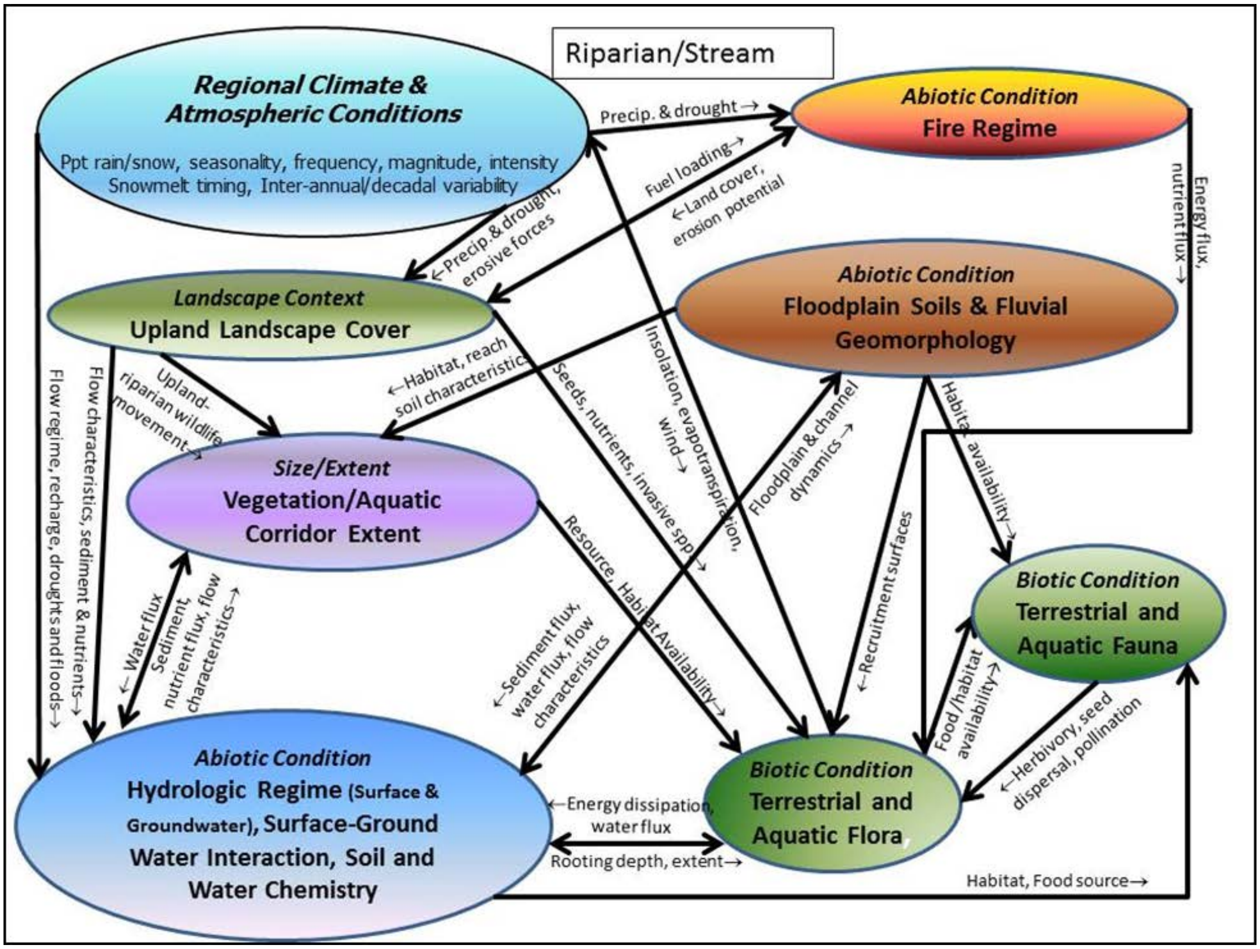
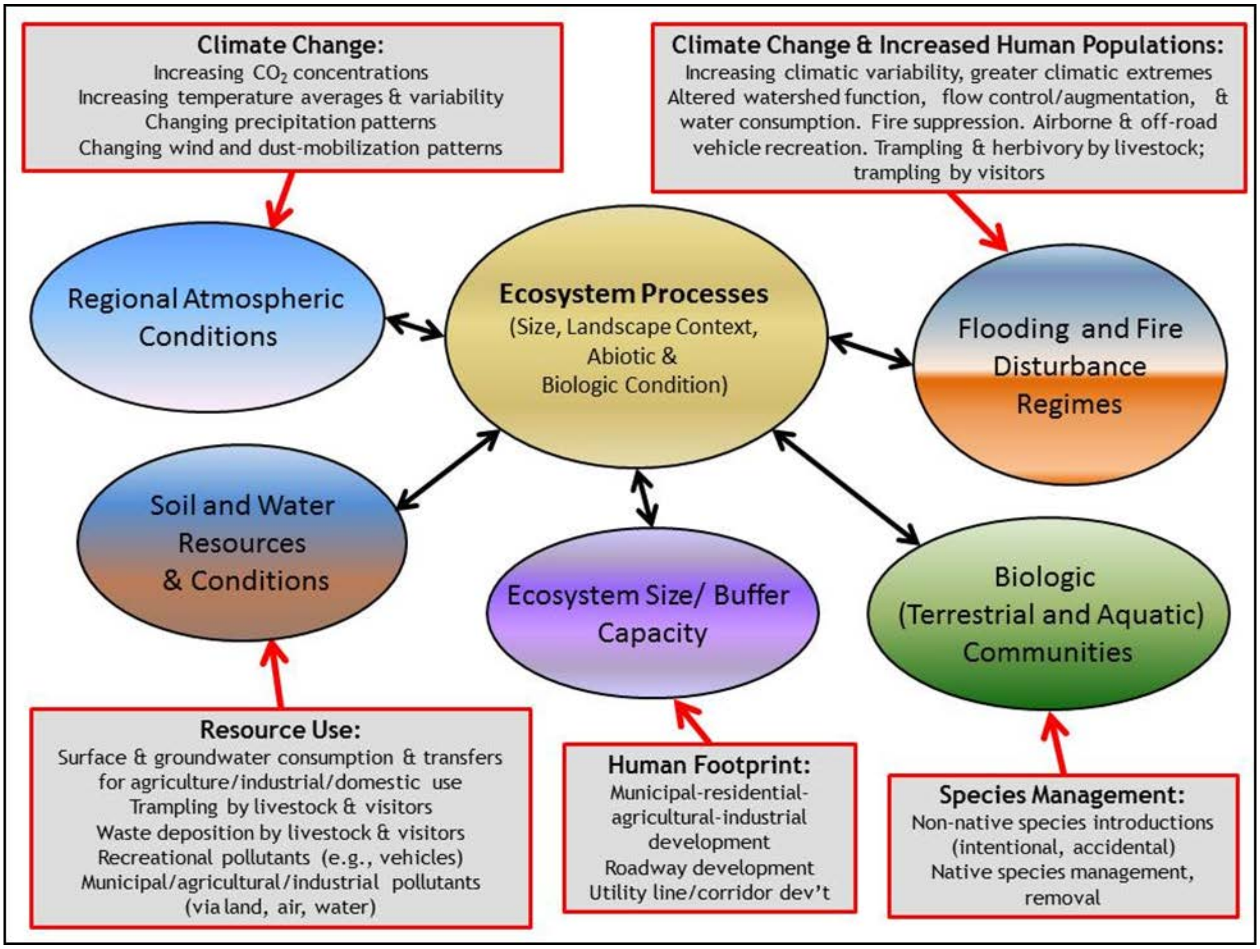


Figure E-29. Major stressors affecting riparian ecosystems' key ecological attributes.



E-3.2 Ecological Status Assessment Results and Interpretation

This section of the appendix presents and discusses the results of the ecological status assessment for the North American Warm Desert Lower Montane and Foothill Riparian Woodland and Shrubland and Stream CE. The presentation addresses each indicator separately, and then addresses the overall assessment, which integrates the results of all individual indicators. The results are presented using a common framework, in which the status of an indicator – or the combination of all indicator – is scored on a scale from 0.0 to 1.0, where 0.0 indicates a condition of complete replacement of reference ecological conditions due to the impacts of stressors, and 1.0 indicates a condition of no alteration of reference ecological conditions. The same color ramp is used for all results, yellow to dark blue, where yellow equals low scores, green moderate scores and blues high scores.

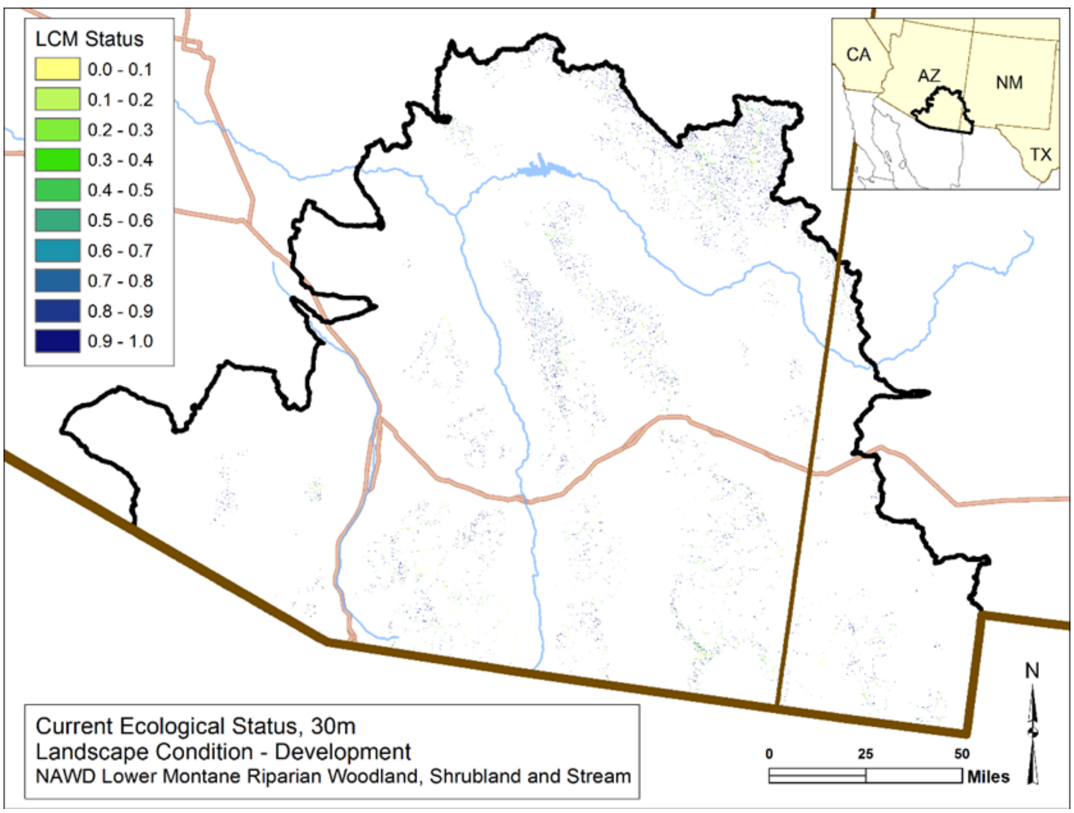
E-3.2.1 Development Indicator

Development is a stressor-based indicator of the spatial extent and intensity of human modifications to the land surface that alter land cover and watershed functions crucial to the ecological integrity of aquatic and wetland conservation elements in the MAR ecoregion. As noted earlier, the indicator takes into account the density of urban development; infrastructure such as above- and below-ground distribution corridors, communication towers, and border barriers; a wide range of transportation features; mines and landfills; dams; recreational development; agriculture; and energy development.

The scoring is on a continuous scale, from 1.0 indicating no ecologically relevant modifications to 0.0 indicating modifications that essentially eliminate all natural cover and natural watershed functions.

As also discussed earlier (see **Figure** E-1), the results across the whole ecoregion show several large areas and corridors of intense development throughout the ecoregion, representing areas of municipal and agricultural development. Development impacts are especially noticeable in the Tucson metropolitan area; in and around every residential community in the ecoregion; and along corridors associated with Interstate highways 10 and 19, US highway 70 and 191, and many other larger roads. Smaller roads lie along almost all larger riparian corridors in the ecoregion, where they result in lower scores as well. However, almost all occurrences of this CE type occur in areas well away from all forms of development. As a result, as seen in **Figure E-30**, almost all pixels in the distribution of the North American Warm Desert Lower Montane and Foothill Riparian Woodland and Shrubland and Stream CE register high scores (i.e., close to 1.0) for landscape development. (The map of the results for this indicator for this ecoregion omits the background topographic relief, because the pixels are so few and, with their high scores registering as a blue color, they are almost invisible when viewed with the background relief present.)

Figure E-30. Scores for the development indicator for North American Warm Desert Lower Montane and Foothill Riparian Woodland and Shrubland and Stream CE . Hillshade is turned off so individual pixels can be seen.

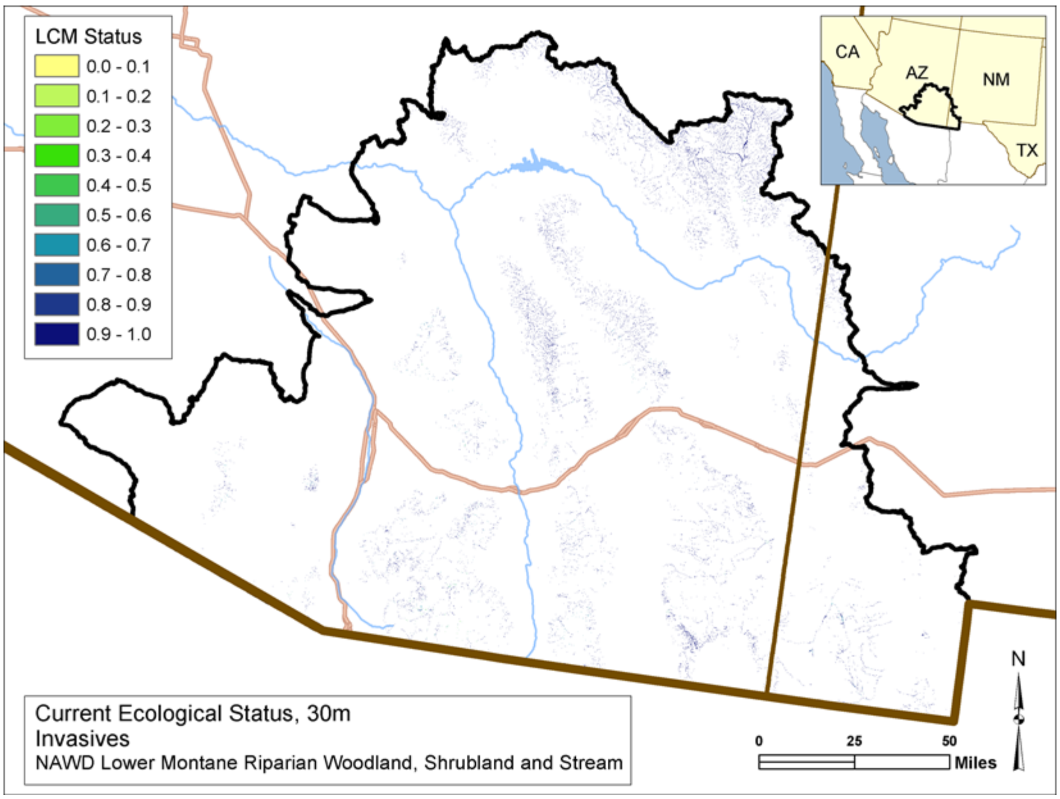


E-3.2.2 Aquatic and Terrestrial Invasive Species Indicator

The Invasives indicator is a stressor based indicator of the presence non-native invasive species including terrestrial woody and herbaceous plants such as tamarisk and cheat grass (*Bromus tectorum*) and aquatic invasive animals and aquatic plants (such as bull frogs, crayfish, non-native fish, and pondweed).

Scores for invasives mean the following: a score of 0.35 indicates a combination of aggressive aquatic animals and abundance of terrestrial plant species, 0.5 indicates the presence highly aggressive aquatic species such as bullfrogs or crayfish, and a score of 0.7 the presence less aggressive aquatic species such as non-native salamanders, or >25% cover on non-native terrestrial plant species. There are a couple of dozen pixels where aggressive non-native aquatic animals occur within this CE (**Figure E-31**). This CE has less invasive species impact than its lower elevation riparian counterpart. However, much of the distribution of this CE has not yet been surveyed for non-native invasive species.

Figure E-31. Scores for the invasive species indicator for North American Warm Desert Lower Montane and Foothill Riparian Woodland, Shrubland & Stream CE. Invasives include terrestrial plants, aquatic animals and aquatic plants, scores are for each pixel of the distribution of Hillshade is turned off so individual pixels can be seen.

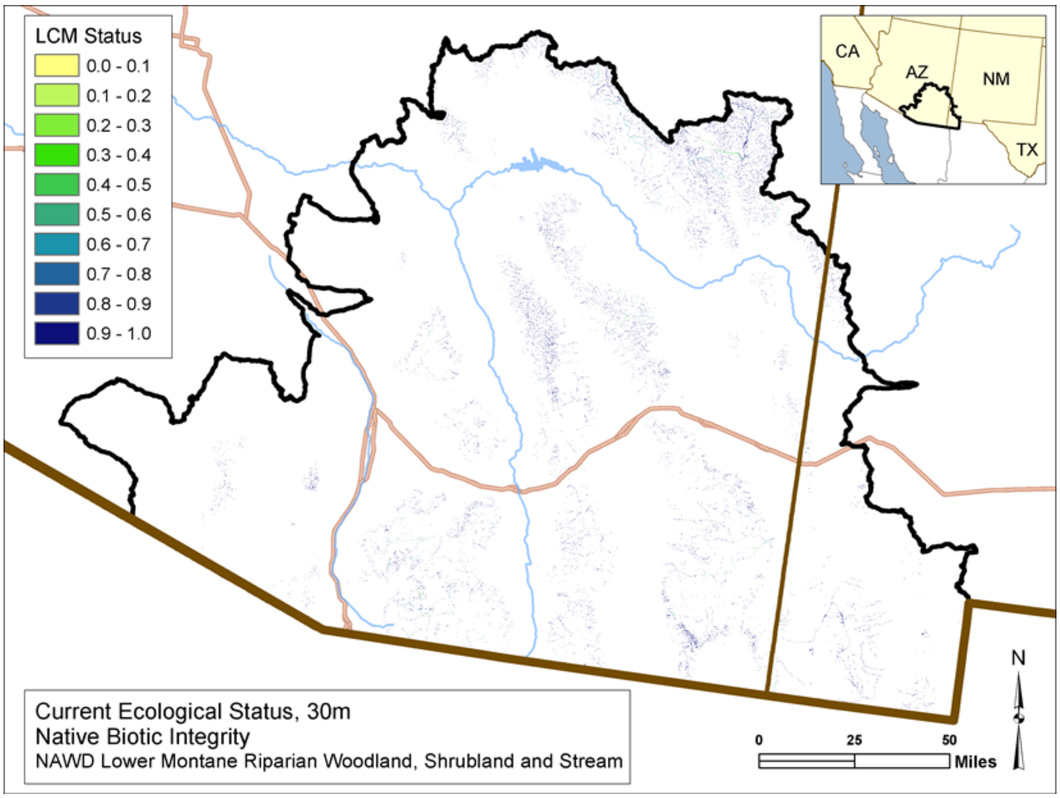


E-3.2.3 Native Biotic Integrity Indicator

This indicator is a direct measure of integrity (a combination of native fish, endangered species, and benthic macro-invertebrates) and shows how many of the expected native species are present. While this is a limited data set, the data points are well distributed throughout the major rivers and tributaries of the Arizona portion. Of the 287 sample points across all CEs, 17% scored highly, 47% scored moderately, and 36% scored poorly. Stream reaches with null data were not scored. A lack of data does not mean the stream is in good ecological heath, rather it means no one has looked. This indicator is different from all other indicators in that it is looking at a positive response rather than a negative one. The scores for native biotic integrity are relative to the high status scores such as development. Scores of 0.25 indicate no native fish were found, few endangered species were located and the stream reach had a low (poor) benthic macro-invertebrate score. Only a few pixels received such a low score as it was rare to have all three sources of native biotic integrity measured at the same sampling location. 0.5

means no native fish occur or the benthic score was moderate. Scores of 0.7 indicate 1-3 native fish are present or 1-4 endangered species have been recorded. There are reaches in the southern portion of the ecoregion that have fewer than expected native fish species (Figure E-32).

Figure E-32. Scores for the native biotic integrity indicator for North American Warm Desert Lower Montane & Foothill Riparian Woodland, Shrubland & Stream CE. Native biotic integrity is a combination of native fish, endangered species, and benthic macro-invertebrates. Scores are) for each pixel of the distribution of the CE. Zoom in to see individual pixels. Hillshade is turned off so individual pixels can be seen.



E-3.2.4 Water Use Indicator

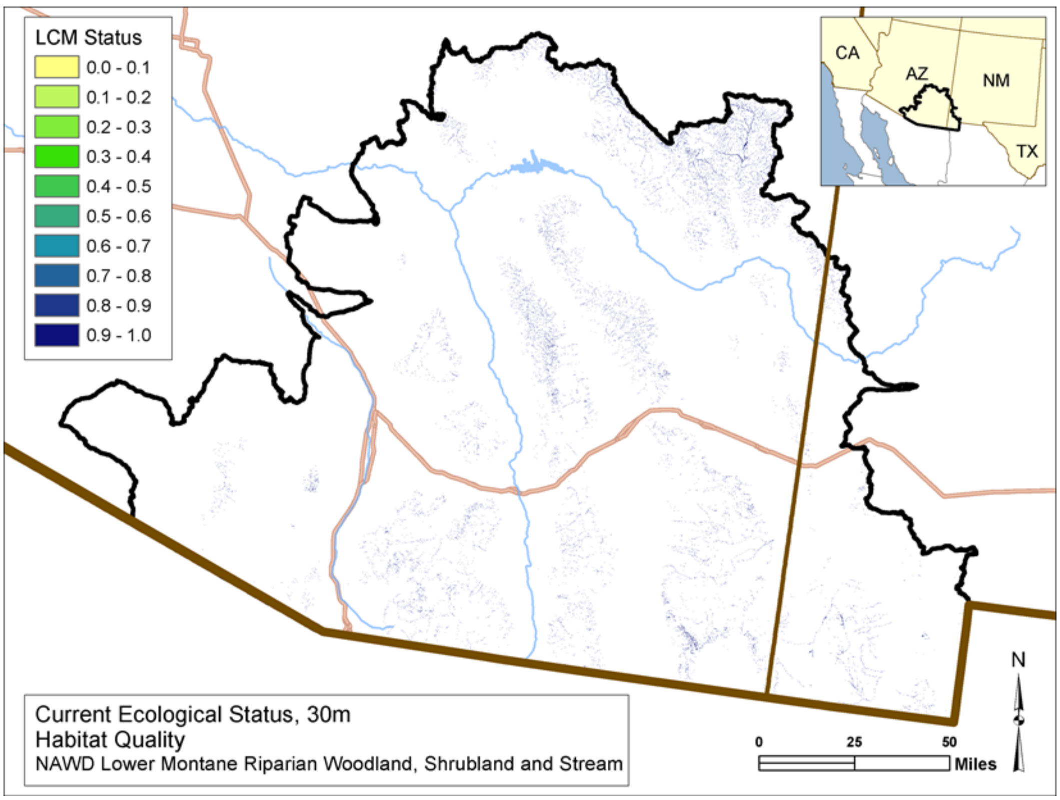
Water use was not assessed for this CE. Most of the water use impacts across the ecoregion occur across the valley floors and along alluvial bottoms, while this CE occurs at higher elevations. Any diversions or dams present within this CE are included in the Landscape Condition-Development (**Figure** E-1, **Figure E-30**), but are not common (ADWR 2009); and the CE is not significantly affected by groundwater pumping from basin fill valley-bottom alluvial aquifers, where most groundwater withdrawals take place.

E-3.2.5 Habitat Quality Indicator

Figure E-33 displays the pixel-scale scores for the Habitat Quality indicator. This indicator is a direct measure of habitat quality. Habitat quality is a combination Proper Functioning Condition scores and Aquatic Habitat scores that indicate the stability of the channel bed, banks and floodplain soils and how well they would resist erosion during rainfall and runoff events. This is an extremely limited data set, distributed across only the Arizona portion of the REA. Of the 118 sample points across all CEs, 50%

scored highly, 49% scored moderately, and 1% scored poorly. Stream reaches with null data were not scored. A lack of data does not mean the CE is in good ecological heath, rather it means no one has looked. This indicator was included to compare direct measures against indirect, stressor measures. High scores indicate Proper Functioning Condition or high Aquatic Assessment scores, where there is good vegetative cover and expected ratios of pool to riffles. Lowest scores (0.49) are places where both PFC and Aquatic habitat scored poorly. Very few pixels had data for this indicator for this CE, so this indicator was not useful in comparing the ecological status across the ecoregion.

Figure E-33. Scores for the habitat quality indicator for North American Warm Desert Lower Montane and Foothill Riparian Woodland and Shrubland and Stream CE Habitat Quality includes Proper Functioning Condition (PFC) and Aquatic Habitat Assessment (AZDEQ Channel Stability). Scores are for each pixel of the distribution of the CE. Hillshade is turned off so individual pixels may be seen.

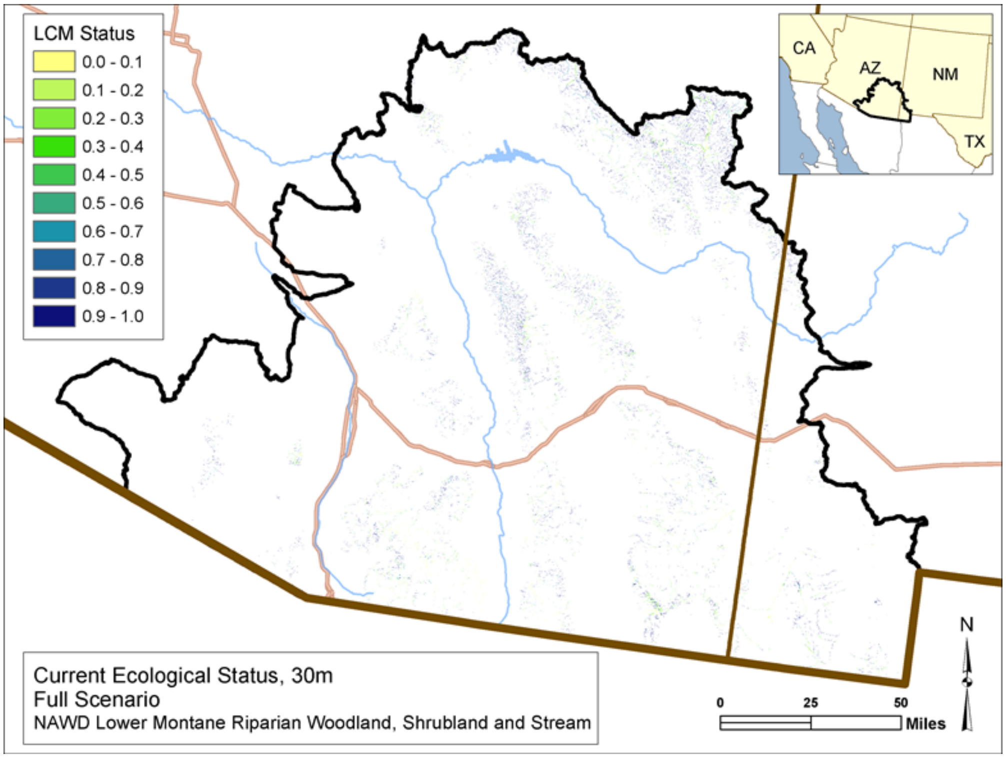


E-3.2.6 Current Ecological Status: Full Scenario

Figure E-34 shows the result of all indicators for this CE, combined together for a single score per pixel of CE distribution. The Lower Mountian and foothill riparian areas are not without roads, mining and associated dams and other water manipulation that still play a role in the degradation of these habitats, along with invasive species. These two indicators (Landscape Condition-Development) and invasive species (terrestrial plants, aquatic animals and aquatic plants), when combined, show that montane and foothill riparian area conditions vary significantly across the ecoregion. This combination illustrates that development is the strongest driving factor in the varying condition of this CE across the ecoregion.

The southern central portion of the ecoregion has mining, transportation corridors and towns (e.g. Warren, Bakerville, and Bisbee junction) that occur at similar elevations as this CE. Additional concentrations of development occur in the easternmost New Mexico portion of the ecoregion. Compared to the lower elevation riparian corridors (**Figure E-15**, the North American Warm Desert Riparian Woodland, Shrubland and Mesquite Bosque and Stream CE), the North American Warm Desert Lower Montane and Foothill Riparian Woodland, Shrubland and Stream CE is faring much better overall in the MAR, in that more watersheds are in better overall condition (**Figure E-35**). These areas are not impacted by significant groundwater withdrawal and surface water diversions, nor are they as heavily exposed to development.

Figure E-34. Overall ecological status scores for the North American Warm Desert Lower Montane and Foothill Riparian Woodland and Shrubland and Stream CE Full scenario includes all indicators combined – for each pixel (upper map) and all 5th-level HUCs (lower map) containing occurrences of the CE. Hillshade is turned off in the upper map so individual pixels may be seen.



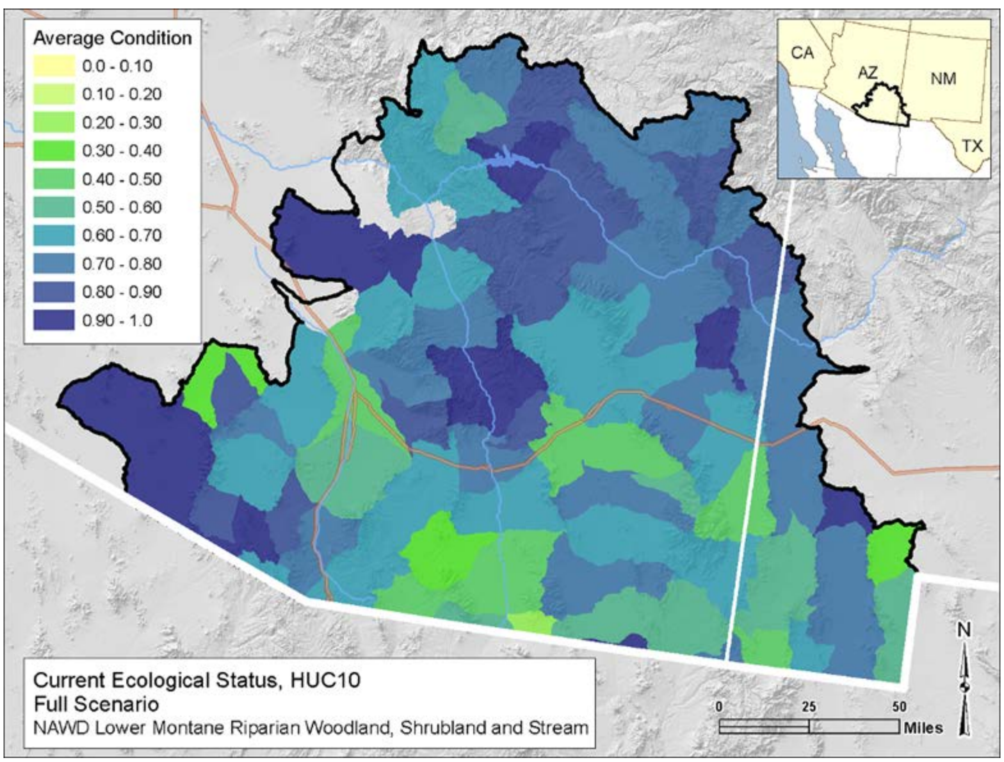
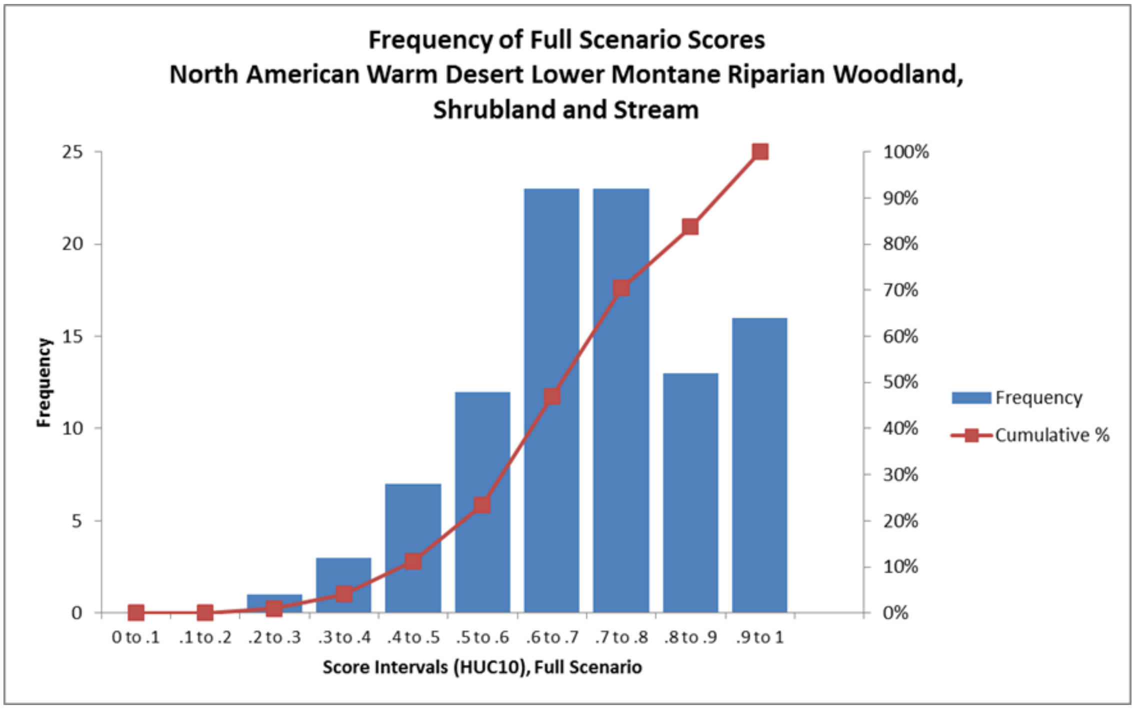


Figure E-35. Frequency distribution of the overall ecological status scores (by 5th-level HUC) with a running cumulative percent. The x-axis represents the 0.1 increment scoring intervals, while the y-axis shows the number of HUCs in each interval (left) and the cumulative percentage of the HUCs in each interval (right).



E-3.3 References for the CE

Abell, R., D. Olson, E. Dinerstein, P. Hurley, J. Diggs, W. Eichbaum, S. Walters, W. Wetterngel, T. Allnutt, C. Loucks, and P. Hedao. 2000. Freshwater Ecoregions of North America: A conservation assessment. Island Press, Washington, DC.

Anning, D.W., S.A. Thiros, L.M. Bexfield, T.S. McKinney, and J.M. Green. 2009. Southwest Principal Aquifers Regional Ground-Water Quality Assessment. U.S. Department of the Interior, U.S. Geological Survey Fact Sheet 2009-3015. http://water.usgs.gov/nawqa/studies/praq/swpa.

Berkman, H.E. and C.F. Rabeni. 1987. Effect of siltation on stream fish communities. Environmental Biologi of Fishes 18:285-294

Boody, G., and B. Devore. 2006. Redesigning agriculture. BioScience 56(10):839-845. [http://dx.doi.org/10.1641/0006-3568(2006)56[839:RA]2.0.CO;2]

Calamusso, B. 2005. Fishes of Southwestern Grasslands-Ecology, Conservation, and Management. In Finch, Deborah M., Editor, Assessment of grassland ecosystem conditions in the Southwestern United States, Volume 2: Wildlife and Fish, pp. 141-168. Rocky Mountain Forest and Range Experiment Station, General Technical Report RMRS-GTR-135-vol. 2. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO.

Chipps, S. R., D. E. Hubbard, K. B. Werlin, N. J. Haugerud, K. A. Powell, J. Thompson, and T. Johnson. 2006. Association between wetland disturbance and biological attributes in floodplain wetlands. Wetlands 26(2):497-508.

Comer, P. and D. Faber-Langendoen. 2013. Assessing Ecological Integrity of Wetlands from National to Local Scales: Exploring the Predictive Power, and Limitations, of Spatial Models. National Wetlands Newsletter Special Issue on Wetland Mapping and Assessment. Environmental Law Institute. Washington DC. Vol. 35 No. 3 May/June 2013.

Comer, P. J., and J. Hak. 2009. NatureServe landscape condition model. Internal documentation for NatureServe Vista decision support software engineering, prepared by NatureServe, Boulder, CO

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. Ecological systems of the United States: A working classification of U.S. terrestrial systems. NatureServe, Arlington, VA.

CNF [Coronado National Forest]. 2009. Ecological Sustainability Report. USDA Department of Agriculture Forest Service, Southwestern Region. February 2009, 122 pp.

Debinski, D. M., and R. D. Holt. 2000. A survey and overview of habitat fragmentation experiments. Conservation Biology 14(2):342-355.

Del Rosario, R. B., and V. H. Resh. 2000. Invertebrates in intermittent and perennial streams: Is the hyporheic zone a refuge from drying? Journal of the North American Benthological Society 19(4):680-696.

Eby, L.A., W.F. Fagan, and W.L. Minckley. 2003. Variability and dynamics of a desert stream community. Ecological Applications, 13(6): 1566-1579.

Faber-Langendoen, D., G. Kudray, C. Nordman, L. Sneddon, L. Vance, E. Byers, J. Rocchio, S. Gawler, G. Kittel, S. Menard, P. Comer, E. Muldavin, M. Schafale, T. Foti, C. Josse, and J. Christy. 2008. Ecological Performance Standards for Wetland Mitigation: An Approach Based on Ecological Integrity Assessments. NatureServe, Arlington, VA.

Faber-Langendoen, D., J. Rocchio, S. Thomas, M. Kost, C. Hedge, B. Nichols, K. Walz, G. Kittel, S. Menard, J. Drake, and E. Muldavin. 2012b. Assessment of wetland ecosystem condition across landscape regions: A multi-metric approach. Part B. Ecological Integrity Assessment protocols for rapid field methods (L2). EPA/600/R-12/021b. U.S. Environmental Protection Agency Office of Research and Development, Washington, DC.

Falke, J. A., K. D. Fausch, R. M. A. A. D. S. Durnford, L. K. Riley, and R. Oad. 2011. The role of groundwater pumping and drought in shaping ecological futures for stream fishes in a dryland river basin of the western Great Plains, USA. ECOHYDROLOGY 4:682-697.

Fisher, S. G., and L. J. Gray. 1983. Secondary production and organic matter processing by collector macroinvertebrates in a desert stream. Ecology 64:1217-1224.

Grimm, N. B., and S. G. Fisher. 1989. Stability of periphyton and macroinvertebrates to disturbance by flash floods in a desert stream. Journal of the North American Benthological Society 8:293-307.

Hereford, R. 1993. Entrenchment and widening of the upper San Pedro River, Arizona. Geological Society of America Special Paper 282. 46 pp.

Horton, J.L., T.E. Kolb, and S.C. Hart. 2001. Responses of riparian trees to interannual variation in ground water depth in a semi-arid river basin. Plant, Cell and Environment 24: 293-304.

Huryn, A. D., and J. B. Wallace. 2000. Life history and production of stream insects. Annual Review of Entomology 45:83-110.

Jackson, J. K., and S. G. Fisher. 1986. Secondary production, emergence, and export of aquatic insects of a Sonoran Desert stream. Ecology 67:629-638.

Katz, G.L., J.C. Stromberg, and M.W. Denslow. 2009. Streamside herbaceous vegetation response to hydrologic restoration on the San Pedro River, Arizona. Ecohydrology 2: 213–225. DOI: 10.1002/eco.62.

Leenhouts, J.M., J.C. Stromberg, and R.L. Scott, eds. 2006. Hydrologic requirements of and consumptive ground-water use by riparian vegetation along the San Pedro River, Arizona. U.S. Geological Survey Scientific Investigations Report 2005–5163.

Levick, L., J. Fonseca, D. Goodrich, M. Hernandez, D. Semmens, J. Stromberg, R. Leidy, M. Scianni, D. P. Guertin, M. Tluczek, and W. Kepner. 2008. The ecological and hydrological significance of ephemeral and intermittent streams in the arid and semi-arid American Southwest. EPA/600/R-08/134, ARS/233046. U.S. Environmental Protection Agency and USDA/ARS Southwest Watershed Research Center. 116 pp.

Lite, S.J. and J.C. Stromberg. 2005. Surface water and ground-water thresholds for maintaining *Populus–Salix* forests, San Pedro River, Arizona. Biological Conservation 125: 153–167. DOI:10.1016/j.biocon.2005.01.020

Luce, C., P. Morgan, K. Dwire, D. Isaak, Z. Holden, and B. Rieman. 2012. Climate change, forests, fire, water, and fish: Building resilient landscapes, streams, and managers. Fort Collins, CO.

McKinney, T.S. and D.W. Anning. 2009. Geospatial data to support analysis of water-quality conditions in basin-fill aquifers in the southwestern United States. U.S. Geological Survey Scientific Investigations Report 2008-5239. http://pubs.er.usgs.gov/sir/2008/5239.

Mol, Jan H. and Paul E. Outboter. 2004. Downstream Effects of Erosion from small-scale Gold mining on the instream habitat and fish community of a small Neotropical Rainforest Stream. Conservation Biology v18,n1:201-214

Patten, D. 1998. Riparian Ecosystems of semi-arid North America: Diversity and human impacts. Wetlands 18:498-512.

Pellant, M., P. Shaver, D.A. Pyke, and J.E. Herrick. 2005. Interpreting indicators of rangeland health, version 4. Technical Reference 1734-6. BLM/WO/ST-00/001+1734/REV05. U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center, Denver, CO. 122 pp.

Pimentel, D., B. Berger, D. Filiberto, M. Newton, B. Wolfe, E. Karabinakis, S. Clark, E. Poon, E. Abbett, and S. Nandagopal. 2004. Water resources: Agricultural and environmental issues. BioScience 54(10):909-918.

Poff, N. L., J. D. Allan, M. B. Bain, J. R. Karr, K. L. Prestegaard, B. D. Richter, R. E. Sparks, and J. C. Stromberg. 1997. The natural flow regime-a paradigm for river conservation and restoration. BioScience 47(11):769-784.

Poff, N. L., B. D. Richter, A. H. Arthington, S. E. Bunn, R. J. Naiman, E. Kendy, M. Acreman, C. Apse, B. P. Bledsoe, M. C. Freeman, J. Henriksen, R. B. Jacobson, J. G. Kennen, D. M. Merritt, J. H. O'Keeffe, J. D. Olden, K. Rogers, R. E. Tharme, and A. Warner. 2010. The ecological limits of hydrologic alteration (ELOHA): A new framework for developing regional environmental flow standards. Freshwater Biology 55:147-170.

Price, J., C.H. Galbraith, M. Dixon, J. Stromberg, T. Root, D. MacMykowski, T. Maddock, III, and K. Baird. 2005. Potential Impacts of Climate Change on Ecological Resources and Biodiversity in the San Pedro Riparian National Conservation Area, Arizona. Report to U.S. EPA from the American Bird Conservancy. http://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=468326.

Propst, D.L., K.B. Gido, and J.A. Stefferud. 2008. Natural flow regimes, nonnative fishes, and native fish persistence in arid-land river systems. Ecological Applications 18(5): 1236–1252.

Robinett, D. 2005a. Ecological Site Description: Sandy Bottom PLWR2-POFR2 F041XA113AZ. United States Department of Agriculture, Natural Resources Conservation Service.

Robinett, D. 2005b. Ecological Site Description: Sandy Bottom POFR2-SAGO F041XC317AZ. United States Department of Agriculture, Natural Resources Conservation Service.

Rinne, J.N. 1996. The effects of introduced fishes on native fishes: Arizona, Southwestern United States. In Phillips et al., ed., Protection of Aquatic Biodiversity: Proceedings of the World Fisheries Congress, Theme 3, pp. 149-159.

Serrat-Capdevila, Aleix, Juan B. Valde´s , Javier Gonza´lez Pe´rez, Kate Baird, Luis J. Mata, Thomas Maddock III. 2007. Modeling climate change impacts – and uncertainty – on the hydrology of a riparian system: The San Pedro Basin (Arizona/Sonora). Journal of Hydrology, volume 347, pp 48–66.

Shafroth, P.B., A.C. Wilcox, D.A. Lytle, J.T. Hickey, D.C. Andersen, V.B. Beauchamp, A. Hautzinger, L.E. McMullen, A. Warner. 2010. Ecosystem effects of environmental flows: modeling and experimental floods in a dryland river. Freshwater Biology 55: 68–85. DOI:10.1111/j.1365-2427.2009.02271.x 1.

Shafroth, P.B., J.C. Stromberg, and D.T. Patten. 2000. Woody riparian vegetation response to different alluvial water table regimes. Western North American Naturalist 60(1): pp. 66–76.

Snyder, K.A. and D.G. Williams. 2000. Water sources used by riparian trees varies among stream types on the San Pedro River, Arizona. Agricultural and Forest Meteorology 105: 227–240.

Stefferud, J. A., P. C. Marsh, S. E. Stefferud, and R. W. Clarkson. 2009. Chapter 10: Fishes: Historical Chagnes and an Imperiled Native Fauna.*in* J. C. Stromberg and B. Tellman, editors. Ecology and Conservation of the San Pedro River. University of Arizona Press, Tucson.

Stromberg, J.C. 1998. Dynamics of Fremont cottonwood (Populus fremontii) and saltcedar (Tamarix chinensis) populations along the San Pedro River, Arizona. Journal of Arid Environments 40: 133-155.

Stromberg, J.C. 2001. Restoration of riparian vegetation in the southwestern United States: importance of flow regimes and fluvial dynamism. Journal of Arid Environments 49: 17-34. DOI:10.1006/jare.2001.0833.

Stromberg, J., and T. Rychener. 2010. Effects of Fire on Riparian Forests Along a Free-Flowing Dryland River. Wetlands 30:75-86.

Stromberg, J.C., R. Tiller, and B. Richter. 1996. Effects of groundwater decline on riparian vegetation of semiarid regions: the San Pedro, Arizona. Ecological Applications 6(1): 113-131.

Stromberg, J. C., S. J. Lite, M. D. Dixon, and R. L. Tiller. 2009. Chapter 1-Riparian Vegetation: Pattern and Process.in J. C. Stromberg and B. Tellman, editors. Ecology and Conservation of the San Pedro River. University of Arizona Press, Tucson.

Stromberg, J.C., K.J. Bagstad, J.M. Leenhouts, S.J. Lite, and E. Makings. 2005. Effects of stream flow intermittency on riparian vegetation of a semiarid region river (San Pedro River, Arizona). River Research and Applications 21: 925–938. DOI: 10.1002/Rra.858.

Stromberg, J.C., V.B. Beauchamp, M.D. Dixon, S.J. Lite, and C. Paradzick. 2007. Importance of low-flow and high-flow characteristics to restoration of riparian vegetation along rivers in arid south-western United States. Freshwater Biology 52: 651–679. DOI:10.1111/j.1365-2427.2006.01713.x.

Stromberg, J.C., S.J. Lite, T.J. Rychener, L.R. Levick, M.D. Dixon, and J.M. Watts. 2006. Status of the riparian ecosystem in the Upper San Pedro River, Arizona: Application of an assessment model. Environmental Monitoring and Assessment 115: 145–173. DOI: 10.1007/s10661-006-6549-1.

Theobald, D. M., D. M. Merritt, and J. B. Norman, III. 2010. Assessment of threats to riparian ecosystems in the western U.S. Prepared for the Western Environmental Threats Assessment Center, Prineville, OR, by the Department of Human Dimensions of Natural Resources and the Natural Resource Ecology Lab, Colorado State University and USDI Forest Service Watershed, Fish, Wildlife, Air and Rare Plants Staff, Natural Resource Research Center, Ft. Collins, CO. 56 pp.

U.S. Environmental Protection Agency (USEPA). 2005. Use of Biological Information to Better Define Designated Aquatic Life Uses in State and Tribal Water Quality Standards: Tiered Aquatic Life Uses. EPA-822-R-05-001, DRAFT, August 10, 2005.

USDI BLM [U.S. Bureau of Land Management]. 2006. 43CFR4180.1 Fundamentals of Rangeland Health. Code of Federal Regulations and Federal Register, Accessed February 2013 http://federal.eregulations.us/cfr/section/2006/04/18/43-cfr-4180.1

U.S. Fish and Wildlife Service (USFWS). 1999. Designation of Critical Habitat for the Huachuca Water Umbel, a Plant. Department of the Interior Fish and Wildlife Service, 50 CFR Part 17 RIN 1018–AF37, Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for the Huachuca Water Umbel, a Plant, Final rule. Federal Register /Vol. 64, No. 132 /Monday, July 12, 1999 /Rules and Regulations 37441-37453.

U.S. Fish and Wildlife Service (USFWS). 2002. Southwestern Willow Flycatcher Recovery Plan. Albuquerque, New Mexico.

U.S. Geological Survey (USGS). 2011. Non-indigenous aquatic species. [http://nas.er.usgs.gov/] (accessed December 2001).

Vranckx, G., H. Jacquemyn, B. Muys, and O. Honnay. 2011. Meta-analysis of susceptibility of woody plants to loss of genetic diversity through habitat fragmentation. Conservation Biology, November 2011. Early on-line publication. [10.1111/j.1523-1739.2011.01778.x]

Webb, R.H. and S.A. Leake. 2006. Ground-water surface-water interactions and long-term change in riverine riparian vegetation in the southwestern United States. Journal of Hydrology 320: 302–323. DOI:10.1016/j.jhydrol.2005.07.022.

Webb, R.H., R.M. Turner and S.A. Leake 2007. The Ribbon of Green. University of Arizona Press. Tucson, 480 pp.

Wright, E. 2002. Ecological Site Description: Loamy Bottom R041XA006NM. United States Department of Agriculture, Natural Resources Conservation Service.

Isolated Wetland Division

Playa Lakes

E-4 North American Warm Desert Playa/Ephemeral Lake

E-4.1 Conceptual Model

E-4.1.1 Classification

The ecosystem conservation elements for the MAR REA were selected from NatureServe's classification of terrestrial ecological systems (Comer et al. 2003). Over three dozen ecological systems occur in the MAR, but only a subset were chosen for the REA. The CE concept provided in this conceptual model includes this NatureServe ecological system type:

- North American Warm Desert Playa (CES302.751)

There are other terrestrial ecological systems in the NatureServe classification that also occur in the MAR, or in adjacent ecoregions, which are similar to this CE concept but are not included in this conservation element. These are listed here to help the reader understand what is not included in this conceptual model; each of these other ecological systems has information that can be searched for and reviewed on NatureServe's on-line Explorer website.

- Chihuahuan-Sonoran Desert Bottomland and Swale Grassland (CES302.746) - Tobosa/Sacaton swale (intermittently flooded)
- North American Arid West Emergent Marsh (CES300.729)
- North American Warm Desert Cienega (CES302.747)
- North American Warm Desert Lower Montane Riparian Woodland and Shrubland (CES302.748)
- North American Warm Desert Riparian Woodland and Shrubland (CES302.753)

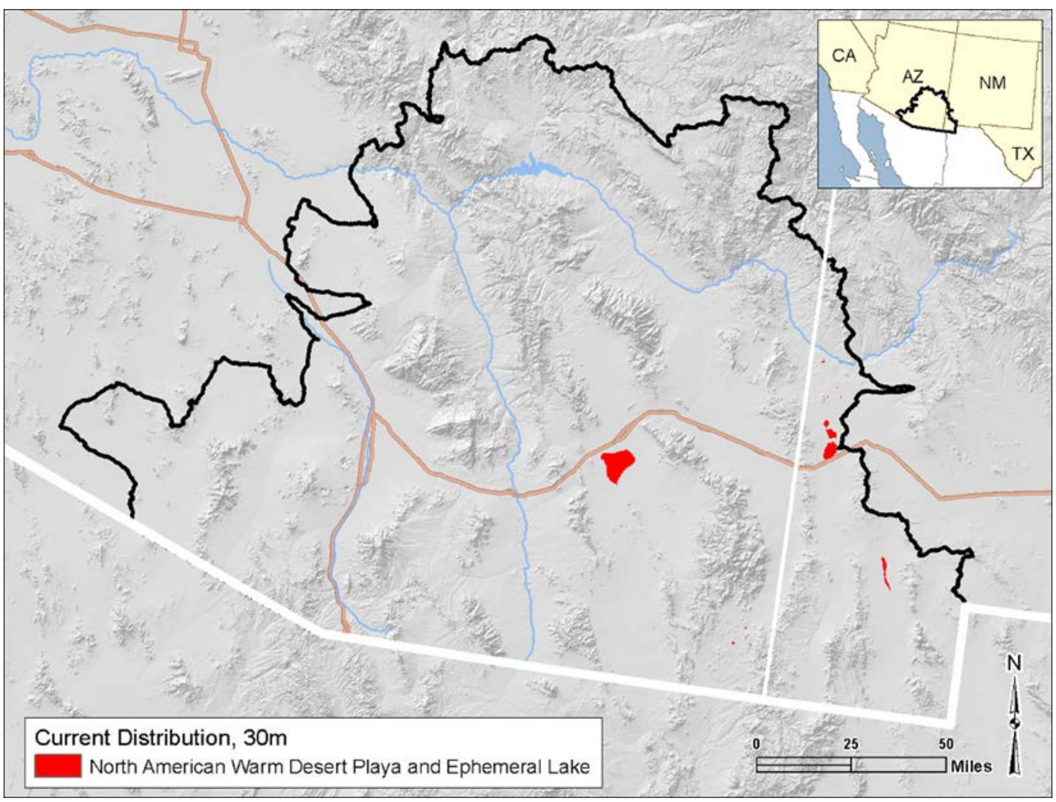
E-4.1.2 Summary

This ecological system (**Figure E-37**) consists of barren and sparsely vegetated playas (generally < 10% plant cover) in the warm deserts of North America (**Figure E-36**). They form in closed, shallow drainage pockets or basins that experience intermittent flooding from surface runoff and, in some instances, from shallow groundwater discharge (e.g., Desert Processes Working Group 1991; Haukos and Smith 1992). Flooding is followed by evaporation, leaving behind a saline evaporite residue, the chemistry of which depends on the hydrochemistry of the surrounding surface runoff catchment. The flooding also carries in sediment, typically clay, silt, and fine-grained sand, which may result in stratified deposits. The evaporites commonly contain chlorides, sulfates, nitrates, carbonates, borates, or other salts, sometimes including toxic cyanates or arsenates depending on the mineralogy of the catchment. Salt crusts are common (**Figure E-37**), with small saltgrass beds in depressions and sparse shrubs around the margins. Subsoils often include an impermeable layer of clay or carbonate-cemented soil. Playa surfaces change seasonally with addition or loss of water, and with wind activity. They can be smooth to rough, wet to dry, and hard to soft, puffy, flaky, cracked, ridged, and friable; and can have hummocky relief of 1 to 2 m. Dust generation by wind erosion of fine particles is common, but playas differ in their susceptible to wind erosion. Hard, smooth, and dry playas with a high clay/low salt content seem to be more frequent at the termini of ephemeral, intermittent, and dry desert watercourses. Soft, rough, wet playas with high salt/low clay content tend to occur in depressions whose floors intersect the water table (Desert Processes Working Group 1991).

North American Warm Desert Playas may have surrounding vegetation rings with distinct compositions that vary in response to salinity and depth to the water table. Playa plant species may include irodinebush (*Allenrolfea occidentalis*), seablite (*Suaeda* spp.), saltgrass (*Distichlis spicata*), spikerush (*Eleocharis palustris*), needlegrass (*Achnatherum spp*.), dropseedgrass (*Sporobolus spp*.), crinklemat (*Tiquilia spp*.), and saltbush (*Atriplex spp*.). Ephemeral herbaceous species may occur in high density following episodes of wetting. Adjacent vegetation is typically Sonora-Mojave Mixed Salt Desert Scrub (CES302.749), Chihuahuan Mixed Salt Desert Scrub (CES302.017), Gulf of California Coastal Mixed Salt Desert Scrub (CES302.015), Baja California del Norte Gulf Coast Ocotillo-Limberbush-Creosotebush Desert Scrub (CES302.014), or Chihuahuan Creosotebush Desert Scrub (CES302.731).

The playas in the Madrean Archipelago ecoregion, shown in **Figure E-36**, consist of Willcox (aka Wilcox) Playa in AZ; a complex of three playas near Lordsburg, NM, the middle one of which, the most frequently wetted (BLM 1993, BLM 2000a, BLM 2000b), is known as Lordsburg Playa; a small complex of playas in the Playas Valley just south of the town of Playas, NM (WWF and SIA 2007); and small occurrences in the San Bernardino Valley, AZ. All have alkaline chemistries (AHW 2013, WWF and SIA 2007) due to the geochemistry of their valleys and associated groundwater systems (e.g., ADWR 2009, Hibbs et al. 2000, Konieczki 2006).

Figure E-36. Current distribution of North American Warm Desert Playa and Ephemeral Lake CE within the MAR ecoregion.



The Willcox, Lordsburg, and Playas playas occupy low points in the former lakebeds of Pleistocene Lakes Cochise, Animas, and Playas, respectively (Allen 2005, Doty 1960, Schreiber 1978). The soils of these former lakebeds are predominantly clays, grading into stream fluvial deposits and beach deposits around the ancient lake margins (e.g., ADWR 2009, Allen 2005, Brown and Schumann 1969, Doty 1960, Hibbs et al. 2000, Schreiber 1978). Wetting occurs primarily through the accumulation of runoff from the surrounding drainage catchment, combined with on-site precipitation, with the clay soils of the ancient lakebeds preventing most downward percolation and thereby producing a perched water surface. Historically high groundwater levels (potentiometric surface elevations) in the alluvial soils of the valley bottoms may also have resulted in some groundwater contributions to playa surface wetting at these locations, perhaps arising around the margins of the ancient lakebed soils (ADWR 2009, Doty 1960, Konieczki 2006). Even where high groundwater levels did not directly contribute to historical wetting, they may have supported evapotranspiration by phreatophytes (ADWR 2009, Brown and Schumann 1969, Hibbs et al. 2000). Vegetation is extremely sparse, consisting of scattered alkali sacaton grass (*Sporobolus airoides*), other dropseedgrasses (*Sporobolus spp*.), and desert saltgrass (*Distichlis spicata*), with increasing shrub cover around the periphery consisting of saltbush (*Atriplex spp*.), mesquite (*Prosopis spp*.), and saltcedar (aka tamarisk: *Tamarix ramosissima*) (AHW 2013, Dinerstein et al. 2001, Muldavin et al. 2000, WWF and SIA 2007). Mesquite stands also occur along the ancient lake shorelines (e.g., Schreiber 1978).

The playas in the Madrean Archipelago ecoregion are ecologically distinct in three ways. Playas are very important for migratory shorebirds and waterfowl that utilize the playa during periods of inundation. In the winter tens of thousands of sandhill cranes (*Grus canadensis*) have been documented. During the winter playas provide roosting and feeding habitat for large numbers of sandhill cranes and smaller numbers of water birds such as killdeer, snipe, and white-faced ibis, particularly in wet winters. The U.S. Shorebird Conservation Plan for the Intermountain West region (Oring et al. 2005) recognizes the Willcox and Lordsburg playas as potentially important regionally. Shorebirds noted by MacCarter 1994 (cited in Dinerstein et al. 2001) and Oring et al. (2005) include breeding American avocet and snowy plover; migrating black-necked stilt, American avocet, western sandpiper, least sandpiper, long-billed dowitcher, and Wilson’s phalarope; and over-wintering snowy plover. MacCarter (1994, cited in Dinerstein et al. 2001) also reports long-billed curlew at Lordsburg Playa. In addition, playas provide auxillary habitat for grassland dependant birds. Arizona Heritage Waters program (AHW 2013) reports many grasslnad bird species such as hawks, eagles, and owls utilize Willcox Playa during the winter; and that vegetation along the periphery of the playa support northern flickers, white-necked ravens, and many songbird species. Carr (1992, cited in Dinerstein et al. 2001) also reports overwintering by McCown’s longspurs, savanna sparrows, American pipits, lark buntings, ferruginous hawks, and rough-legged hawks. Wings over Willcox (2013) provides a detailed sightings list from 2007 onward.

Second, the playas in this ecoregion support a rich and, in at least one respect, unique assemblage of macroinvertebrates. This assemblage consists of numerous insects that emerge to mature and reproduce following episodes of wetting, with different species emerging during the winter versus summer wet seasons. Collections at the University of Arizona catalog some 400 beetle genera from Willcox Playa, including over 100 collected by a single researcher in a single season of sampling (WWF and SIA 2007 and citations therein). Most notable of these insects are tiger beetles with specialized adaptations to the alkaline chemistry of the playa soils and their intermittently ponded waters. These include *Cicindela willistoni sulfontis*, *C. haemoragica*, and *C. nevadica citata* among 17 species of tiger beetle reported around Willcox Playa alone, is one of the highest diversity in North America (Dinerstein et al. 2001, Pearson et al. 2005, Rumpp 1977, WWF and SIA 2007 and citations therein). Tiger beetles could also occur at the Lordsburg or Playas playas, but no surveys are reported for these latter playa sites (WWF and SIA 2007). Dinerstein et al. (2001) also report the presence in Willcox Playa of harvester ants, *Pogonomyrmex* sp., may be an unique, undescribed species. The macroinvertebrate assemblage also includes numerous small crustaceans – particularly branchiopods – that emerge during wet episodes (WWF and SIA 2007), as is typical of playas in the Southwest (e.g., Brostoff et al. 2010 and citations therein). These crustaceans are key food resources for water birds.

Third, the playas of the Madrean Archipelago support several rare plant species. These include the Chiricahua Mountain tansyaster (*Machaeranthera riparia*) at Willcox Playa (AHW 2013, WWF and SIA 2007-Appendix B); and Griffith's saltbush (*Atriplex griffithsii*; aka *Atriplex lentiformis* var. *griffithsii* or *Atriplex torreyi* var. *griffithsii*) at Lordsburg Playa (BLM 1993, Dinerstein et al. 2001, WWF and SIA 2007).

Figure E-37. Photos of Wilcox and Lordsburg Playas. Top: Wilcox Playa, AZ in a dry (left) and wetted (right) state. Lower: Lordsburg Playa, NM in a wetted (left) and drying (right) state.

E-4.1.3 Species of Conservation or Management Concern

Below are listed some species of concern associated with this ecological system CE.

Birds: Sandhill cranes, Snowy plover, Long-billed curlew, Wilson's Snipe and burrowing owls. Many other birds use the playa edges of the playa, see text.

Invertebrates and Crustaceans: 400 beetle genera, Tiger beetles, harvester ants (*Pogonomyrmex* spp.), Ten-lined Potato Beetles, *Leptinotarsa decemlineata)*.; numerous crustaceans – particularly branchiopods, and Tadpole Shrimp (*Triops* spp.)

Plants: Chiricahua Mountain tansyaster (*Machaeranthera riparia*), Griffith's saltbush (*Atriplex griffithsii*)

Reptiles and Amphibians: Texas Horned Lizard (*Phrynosoma cornutum*), Chiricahua Leopard Frog *(Rana chiricahuensis),* Plains Leopard Frog *(Rana blairi)*.

Mammals: Javelina, mule deer

E-4.1.4 Natural Dynamics

The playas of the Madrean Archipelago ecoregion exhibit wide inter-annual variation in the seasonal numbers of birds using the playas, the density and diversity of macroinvertebrates present, the density and diversity of plankton on which the macroinvertebrates feed, and the plant species active. This variation in biological activity mostly depends on hydrologic conditions – how much water is present, at what time(s) of the year, over what area and to what depth. These conditions in turn depend primarily on rainfall magnitudes and timing, which are highly variable in this ecoregion. Other natural factors affecting playa hydrology include air temperature, humidity, and winds, which affect evapotranspiration rates; groundwater elevations, which affect the depth to water for phreatophytes and the potential for groundwater to contribute to wetting of the playa surface; and watershed vegetation cover, which affects runoff, infiltration, and evapotranspiration rates across the surrounding catchment. The natural chemistries of the water, soils, and evaporites of the playas depend on the geochemistry of the catchment and long-term patterns of precipitation and evaporation, including during the formation of Pleistocene lakes Cochise, Animas, and Playas (ADWR 2009, AHW 2013, Allen 2005, Brown and Schumann 1969, Doty 1960, Haukos and Smith 1992, Hibbs et al. 2000, Konieczki 2006, Schreiber 1978, Smith and Haukos 2002, WWF and SIA 2007).

E-4.1.5 Change Agent Effects on the CE

This section of the conceptual model presents a narrative description of the primary change agents and current knowledge of their effects on North American Warm Desert Playa ecosystems. The section contains two sub-sections: (1) A list of primary change agents identified for the CE; and (2) a discussion of altered dynamics caused by these agents.

E-4.1.5.1 List of Primary Change Agents

The locations in which this ecosystem occurs are determined by basin-scale topography and its geologic history. Within these locations, the spatial extent of the active area of each playa – the area across which wetting occurs – is affected both directly and indirectly by human activities. Activities that may directly alter playa ecological dynamics include the draining of playa waters to permit additional use of the exposed land, artificial regulation of water levels such as behind berms, diversion of runoff that would otherwise wet portions of a playa, and groundwater withdrawals that lower the water table; excessive grazing; and recreational use such as OHV activity (BLM 1993; BLM 2000a, 2000b; Dinerstein et al. 2001; WWF and SIA 2007). Willcox Playa is partially fragmented by a railroad grade that cuts across its west-northwest extension; and Lordsburg Playa is fragmented by Interstate Highway 10 and NM State Road 338, as well as by an abandoned railroad grade that cuts across its northern half. Surface diversion and groundwater withdrawal rates are high in the catchments for both the Willcox and Lordsburg playas primarily due to irrigation farming demand but secondarily due to municipal demand (ADWR 2009, Allen 2005, Konieczki 2006, Stephens and Associates 2005). Arizona Electric Power

Cooperative operates its coal-fired Apache Generating Station on the southwest edge of Willcox Playa; PNM Resources operates its natural gas-fired Lordsburg Generating Station and Tri-State Generation and Transmission Association operates its natural gas-fired Pyramid Generating Station in the immediate vicinity of Lordsburg Playa (NMENV 2013). All three facilities use groundwater for cooling (ADWR 2009, Konieczki 2006, Stephens and Associates 2005). Other activities that could indirectly alter playa ecological dynamics – because of their potential to affect playa hydrology and water chemistry – include climate change; alterations to land cover within the catchment for a playa that alter rates of water and soil runoff; and atmospheric and ground-based pollution.

E-4.1.5.2 Altered Dynamics

Table E-13 identifies the most likely impacts associated with each of the stressors listed in Section E-4.1.6.2. These impacts arise largely due to direct conversion of playa habitat to incompatible uses; alteration of playa hydrology; pollution; altered on-site soil disturbance; and altered sediment inputs from the surrounding valley. The cumulative effects of these impacts on the biological conditions in the playas may include changes in their patterns of use by bird species, changes in the seasonal composition of the invertebrate community, and losses of rare plant species. Changes in the viability of the playas as stopovers for migratory birds, in turn, will affect bird population sizes and their contributions to ecosystems elsewhere along their migration routes. (Changes elsewhere along their migration routes also necessarily affect bird utilization of the playas, in turn).

The cumulative effects of the stressors listed in **Table E-13** impacts may also include increased wind erosion of the playa soils. Such increased erosion, in turn, can promote the formation of local dust storms and larger-scale transport of dust clouds containing playa microbes and evaporites, which may affect both people and ecosystems in the surrounding region (BLM 1998, Gilbert et al. 2009). **Figure E-38** and **Figure E-39** capture these interactions, and the use of indicators to track them.

Table E-13. Stressors and their likely impacts on the North American Warm Desert Playa ecosystem type in the Madrean Archipelago ecoregion.

Stressor	Impacts
On-site surface drainage (ditches)	Reduced wetted area; increased use of land for more “dry-ground” activities such as grazing (e.g., Dinerstein et al. 2001).
On-site water level regulation	Loss of natural variation in wetted area, and in timing and duration of wetting.
Runoff inflow diversion	Loss of surface inflows, with consequent reduction in wetted area (e.g., Dinerstein et al. 2001).
Groundwater withdrawal	Increased loss of playa water due to increased infiltration through soil cracks and through more porous soils around playa margins (e.g., ADWR 2009, Dinerstein et al. 2001, Hibbs et al. 2000, Konieczki 2006, WWF and SIA 2007).
On-site development, e.g., for irrigation	Reduced wetted area; altered hydrology; introduction of agricultural chemicals; altered formation of evaporites (e.g., Dinerstein et al. 2001).
Watershed development	Altered runoff; altered sediment inputs from watershed during runoff events; altered non-point source pollution.

Stressor	Impacts
Livestock grazing	Catchment-scale removal of native vegetation in ways that alter runoff and evapotranspiration rates; on-site removal of native vegetation and/or introduction of non-native vegetation; trampling/compaction of playa soils; on-site and catchment runoff pollution by animal wastes (e.g., BLM 2000a, 2000b; Dinerstein et al. 2001; WWF and SIA 2007).
Recreation	On-site soil disturbance (e.g., BLM 1998).
Roadways/railways	Fragmentation of playa habitat; altered distribution of wetting.
Atmospheric deposition	Altered playa water and soil chemistry, such as altered pH and concentrations of S, N, and Hg.
Climate change	Altered watershed- and site-scale precipitation and evapotranspiration rates and timing, affecting magnitude, timing, and duration or wetting. Climate change may also cause changes in human consumption of surface water and groundwater.

E-4.1.6 Ecological Status: Key Ecological Attributes and Indicators

This section of the conceptual model addresses key ecological attributes and their potential indicators. The ecological status is a way of describing current status via criteria, functionality, or levels of attributes and asks if they are within the normal range of variation.

E-4.1.6.1 Key Ecological Attributes

Table E-14 identifies the key ecological attributes for the CE within the Madrean Archipelago ecoregion. A **key ecological attribute** of a focal ecological resource is a characteristic of the resource's biology, ecology, or physical environment that is critical to the resource's persistence in the face of both natural and human-caused disturbance. Alteration of such a characteristic beyond some critical range of variation will lead to the degradation or loss of the resource within decades or less. The KEAs table lists the identified key ecological attributes, with a brief definition, a rationale for why it is important for the CE, and a listing of stressors or change agents that might be affecting the key attribute.

Table E-14. Key ecological attributes (KEAs) of North American Warm Desert Playa ecosystem.

KEA Class: Name	Definition	Rationale	Stressors
Landscape Context: **Landscape Cover**	The extent of natural ground cover for the watershed containing the playa ecosystem occurrence, versus the extent of different kinds of modifications to the watershed surface for human use.	Surrounding watershed cover in unaltered landscapes helps determine the rates of precipitation runoff versus infiltration, evapotranspiration, soil erosion (both "sheet" and "channel" erosion), and transport of sediment, dissolved and suspended nutrients to the playa location from the surrounding runoff catchment. Surrounding watershed cover also shapes the connectivity between the playa and the surrounding landscape for fauna that move between the two settings (e.g., Comer and Faber-Langendoen 2013, Comer and Hak 2009, Smith and Haukos 2002).	Stressors to landscape cover include watershed development and/or excessive grazing, which can alter the rates of rainfall runoff, evapotranspiration, soil erosion (both "sheet" and "channel" erosion), and transport of sediment, dissolved and suspended nutrients to the playa. Climate change also has the potential to cause additional change in landscape cover.
Size/Extent: **Playa Area & Connectivity**	The number, average wetted area, and fully connected area of playas (watershed and ecoregional scales) and their variation over time (seasonal, annual, longer-term).	As with the size of any wetland, the amount of playa habitat available in an area directly affects the density and diversity of playa-dependent species present and their variation over seasonal, annual, and longer-term timescales (e.g., Faber-Langendoen et al. 2008). Connectivity within a playa or set of adjacent playas - how few barriers exist that may prevent movements of water and species between adjacent areas during wet episodes - in turn may affect the relative isolation of populations of some plant and animal species that require water for transport/movement between sites.	Stressors to playa area and connectivity include all factors potentially affecting the hydrology of the playas (see Hydrologic Regime), as well as direct conversion of playa habitat to other uses (e.g., for irrigated farming) and imposition of barriers to the distribution of surface water such as road/railroad grades.
Biotic Condition: **Bird Use**	The taxonomic composition and size of the bird community that assembles at the playas; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The taxonomic composition and size of the bird community using the playas are important aspects of the ecological integrity of the ecosystem. Numerous native species of birds use the playas in this ecoregion for feeding, resting, and breeding, either as home bases or as stopovers or end-points in their annual movements; and the birds community composition and size naturally vary over time (seasonal, annual, longer-term). These species vary in their sensitivity to different stresses such as alterations to wetted area and water quality that affect the availability of both physical habitat and food (e.g., AHW 2013, BLM 1993, 2000a, 2000b, Dinerstein et al. 2001, Haukos and Smith 1992, WWF and SIA 2007). Alterations in the taxonomic composition and size of the playa bird community beyond their natural ranges of variation therefore strongly indicate the types and severities of stresses imposed on the playa ecosystem.	Stressors to the taxonomic composition and size of the bird community using the playas include the cumulative impacts of all stressors affecting the landscape context, size/extent, invertebrate community composition, vegetation, and abiotic condition of the playa ecosystem; the cumulative effects of all stressors affecting the natural visitors in other parts of their annual ranges of movement; excessive hunting; disturbance during breeding; and incursions of non-native species that may compete with or prey on the native avifauna.

KEA Class: Name	Definition	Rationale	Stressors
Biotic Condition: **Invertebrates**	The taxonomic composition and biomass of the macroinvertebrate community that emerges in the playas during episodes of wetting; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The taxonomic composition and biomass of the playa macroinvertebrate community are important aspects of the ecological integrity of the ecosystem. The species native to these playas possess unique adaptations to the hydrology and chemistry of these environments. Numerous specialized native species of insects and crustaceans live and reproduce in the playas in this ecoregion, persisting as eggs or dormant life-forms during dry periods; and the composition and biomass of this community naturally vary over time (seasonal, annual, longer-term). The composition and biomass of this community vary in their sensitivity to different stresses such as alterations to the extent, duration, and timing of wet versus dry conditions; and the chemistry of the water during wet episodes (e.g., AHW 2013, BLM 1993, 2000a, 2000b, Dinerstein et al. 2001, Haukos and Smith 1992, WWF and SIA 2007). Alterations in the taxonomic composition and biomass of the playa insect and crustacean community beyond their natural ranges of variation therefore strongly indicate the types and severities of stresses imposed on the playa ecosystem.	Stressors affecting the taxonomic composition and productivity (biomass) of the playa macroinvertebrate community include the cumulative impacts of all stressors affecting the landscape context, size/extent, and abiotic condition of the playa ecosystem; and incursions of non-native species that alter the food web or directly compete with or prey on the native macroinvertebrates.
Biotic Condition: **Plants**	The taxonomic composition and coverage density of the native floral assemblage of the playas including woody and non-woody vegetation; and the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The taxonomic composition of the playa vegetation community is an important aspect of the ecological integrity of the ecosystem. The plant species native to these playas possess unique adaptations to the hydrology and soil/water chemistry of these environments. Several rare native plant species live and reproduce in the playas in this ecoregion, varying in their requirements for/tolerances of different frequencies of wetting, soil/water pH, and concentrations of nutrients and salts. The composition of this community varies in its sensitivity to different stresses such as alterations to the extent, duration, and timing of wet versus dry conditions; and the chemistry of the water during wet episodes (e.g., AHW 2013, BLM 1993, 2000a, 2000b, Dinerstein et al. 2001, Haukos and Smith 1992, WWF and SIA 2007). Alterations in the composition of the playa vegetation community beyond its natural range of variation therefore strongly indicate the types and severities of stresses imposed on the playa ecosystem.	Stressors to the taxonomic composition of the playa vegetation community include the cumulative impacts of all stressors affecting the landscape context, size/extent, and abiotic condition of the riparian/stream ecosystem, including excessive grazing and OHV activity; and incursions of non-native species that alter the habitat (e.g., alter soils) or directly compete with the native flora.

KEA Class: Name	Definition	Rationale	Stressors
Abiotic Condition: **Hydrologic Regime**	The pattern of variation in the area, timing, and duration of wetting of the playas over time (seasonal, annual, longer-term).	The pattern of variation in the area, timing, and duration of wetting of the playas over time (seasonal, annual, longer-term) is one of the two most important factors (see also Water Chemistry) shaping what native plant and animal species occur in the playas, how often they occur, when they occur by season, and for how long they remain present or absent (Haukos and Smith 1992).	Stressors affecting the hydrology of the playas include watershed development that alters runoff and evapotranspiration rates; surface water diversions; groundwater withdrawals that affect aquifer water elevations beneath the playas; impoundment and artificial regulation of playa water areas and depths; drainage of playa areas through ditching; and alterations to the playa and adjacent plant communities including invasions of non-native flora with high water consumption. Climate change also has the potential to cause additional change in the hydrologic regime, through its effects on rainfall spatial distribution, magnitude, and timing; and through its effects of evapotranspiration rates both within the playas and across the surrounding watershed. Climate change may also cause changes in human water use, leading to changes in diversions and groundwater withdrawals.
Abiotic Condition: **Soils**	The condition of the playa soils, as characterized by their particle size ranges, and by their disturbance/erosion and fracturing patterns during drying cycles.	The particle size ranges of the playa soils, and the patterns of disturbance/erosion and fracturing of these soils during drying cycles, determine the permeability of these soils and the ability of macroinvertebrate eggs and dormant life forms to persist during dry periods; and therefore directly affect playa hydrology and biological condition (Haukos and Smith 1992).	Stressors affecting the particle size ranges of the playa soils, and the patterns of disturbance/erosion and fracturing of these soils during drying cycles include: changes to the transport of sediment from the watershed out onto the playa itself caused by changes in watershed soil erosion and runoff rates and in surface drainage flow paths (see Landscape Cover; Hydrologic Regime); and human activities directly on the playa soils, such as excessive grazing and vehicular activity, that disturb playa soil structure through compaction and disaggregation.

KEA Class: Name	Definition	Rationale	Stressors
***Abiotic Condition:* Water Chemistry**	The chemical composition of the playa water during wet periods, including the pattern(s) of natural variation in this composition over time (seasonal, annual, longer-term).	The chemistry of the water that fills the playas during wet episodes strongly determines which plant and animal species can persist in this habitat, as determined by their requirements for/tolerances of different ranges of soil/water pH, and concentrations of nutrients and salts. The pattern of variation in pH and concentrations of nutrients and salts in playa waters during wet episodes over time (seasonal, annual, longer-term) is the other dominant factor (see also Hydrologic Regime) shaping what native plant and animal species occur in the playas, how often they occur, when they occur by season, and for how long they remain present or absent (Haukos and Smith 1992).	Stressors affecting playa water chemistry include effects of single catastrophic high or low concentration perturbation such as low oxygen, high temp, or heavy metals can be devastating to aquatic ecosystems. Additionaly, the cumulative effects of non-point source pollution from watershed development, point-source pollution (e.g., wastewater), atmospheric deposition, and excessive use of playa zones as pasturing areas for livestock. Climate change has the potential to exacerbate these impacts through changes in watershed runoff and water use.

E-4.1.7 Conceptual Model Diagrams

Figure E-38. Conceptual model diagram for North American Playa/Ephemeral Lake Ecosystem. This model outlines the key structural components and functional relationships that characterize this system. Ovals represent key ecological attributes and Ecosystem Drivers. Arrows indicate functional relationships among components. The model is constrained by global climatic and atmospheric conditions, topography, parent material and potential biota.

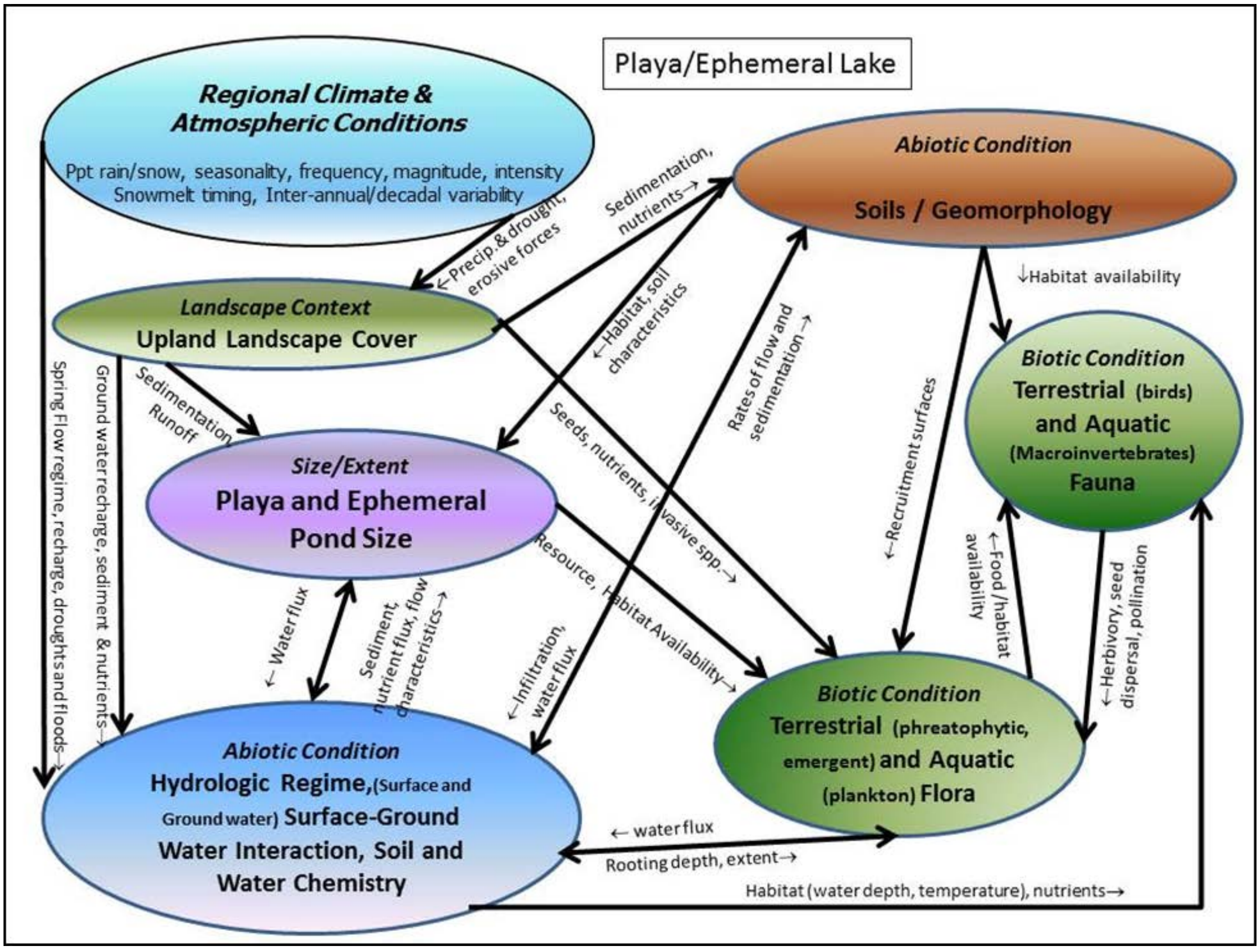
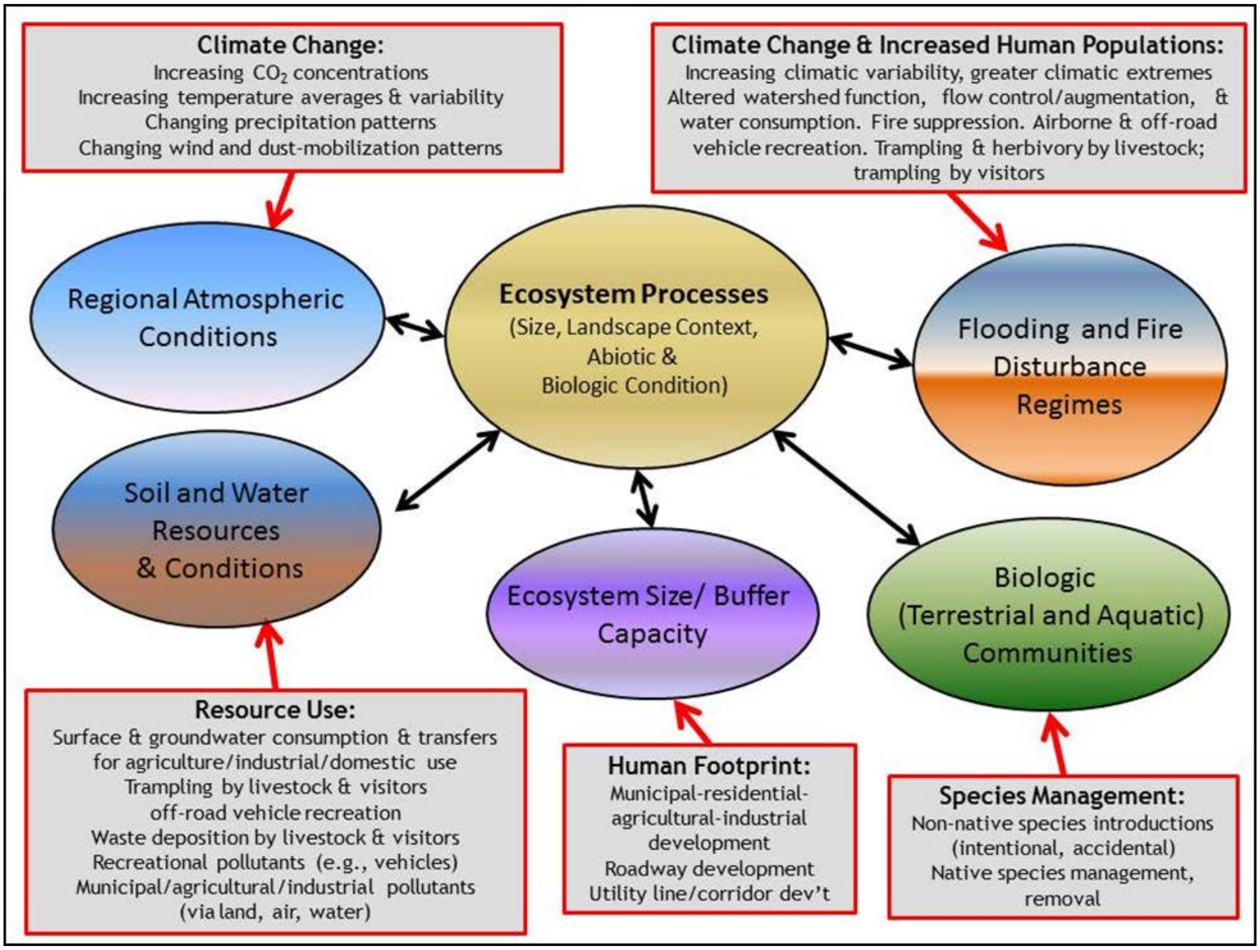


Figure E-39. Some of the greatest stressors affecting Madrean Playa Ecosystem key ecological attributes.



E-4.1.8 Relationship of KEAs to Fundamentals of Rangeland Health

The key ecological attributes and stressors listed in **Table E-14** also encompass the four fundamentals of rangeland health (USDI BLM 2006), as shown in **Table E-15**. The KEA for Landscape Cover specifically refers to watershed conditions; all other KEAs refer specifically to Ecological Processes and Habitat. Abiotic condition also has stressors that arise as a result of modifications to the watershed or modifications to water quality. These relationships are also indicated in **Table E-15**. Further information about interpretation and assessment of these fundamentals of rangeland health is found in Pellant et al. (2005).

Table E-15. Relationship of key ecological attributes (KEAs) for the North American Warm Desert Playa ecosystem to fundamentals of rangeland health.

Key Ecological Attribute	Watersheds	Ecological Processes	Water Quality	Habitat
Landscape Cover	X		X	
Playa Area & Connectivity		X		X
Bird Use		X		X
Invertebrates		X		X
Plants		X		X
Hydrologic Regime	X	X		X
Soils	X	X		X
Water Chemistry	X		X	

E-4.2 Ecological Status Assessment Results and Interpretation

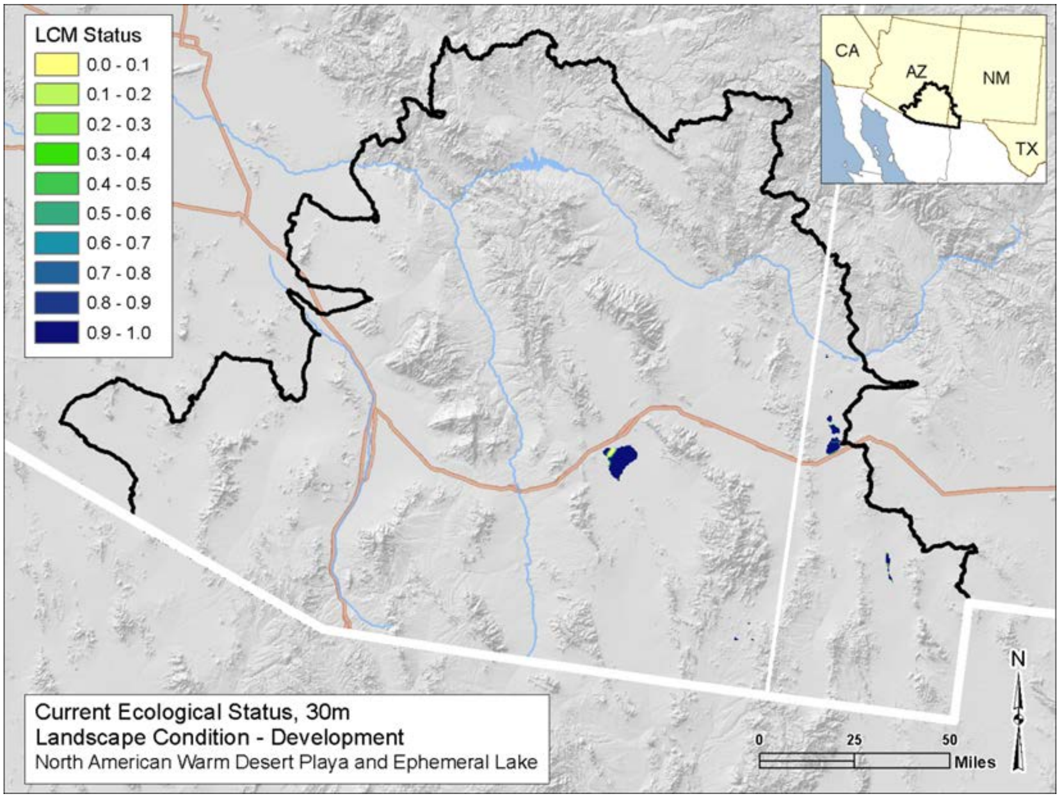
This section of the appendix presents and discusses the results of the ecological status assessment for the North American Warm Desert Playa/Ephemeral Lake CE. The presentation addresses each indicator separately, and then addresses the overall assessment, which integrates the results of all individual indicators. The results are presented using a common framework, in which the status of an indicator – or the combination of all indicator – is scored on a scale from 0.0 to 1.0, where 0.0 indicates a condition of complete replacement of reference ecological conditions due to the impacts of stressors, and 1.0 indicates a condition of no alteration of reference ecological conditions. The same color ramp is used for all results, yellow to dark blue, where yellow equals low scores, green moderate scores and blues high scores.

E-4.2.1 Development Indicator

Development is a stressor-based indicator of the spatial extent and intensity of human modifications to the land surface that alter land cover and watershed functions crucial to the ecological integrity of aquatic and wetland conservation elements in the MAR ecoregion. The indicator takes into account the density of urban development; infrastructure such as above- and below-ground distribution corridors, communication towers, and border barriers; a wide range of transportation features; mines and landfills; dams; recreational development; agriculture; and energy development. The scoring is on a continuous scale, from 1.0 indicating no ecologically relevant modifications to 0.0 indicating modifications that essentially eliminate all natural cover and natural watershed functions. **Figure** E-1 shows the results across the entire ecoregion, and the **Region-Wide Landscape Condition - Development Scenario** section describes the overall pattern of impacts represented by this indicator.

The playas of the MAR ecoregion lie adjacent to areas of development, but they are themselves relatively unaffected by on-site development (**Figure E-40**). Their intermittent wetting and unusual soils generally discourage development, with the exception of the construction of roadway and railroad grades across their open spaces, and development of their margins. As a result, the Willcox, Lordsburg, and Playas Valley playas all show areas (pixels) with significant modification by development, at the edges or cutting across the middle of larger areas with little or no development.

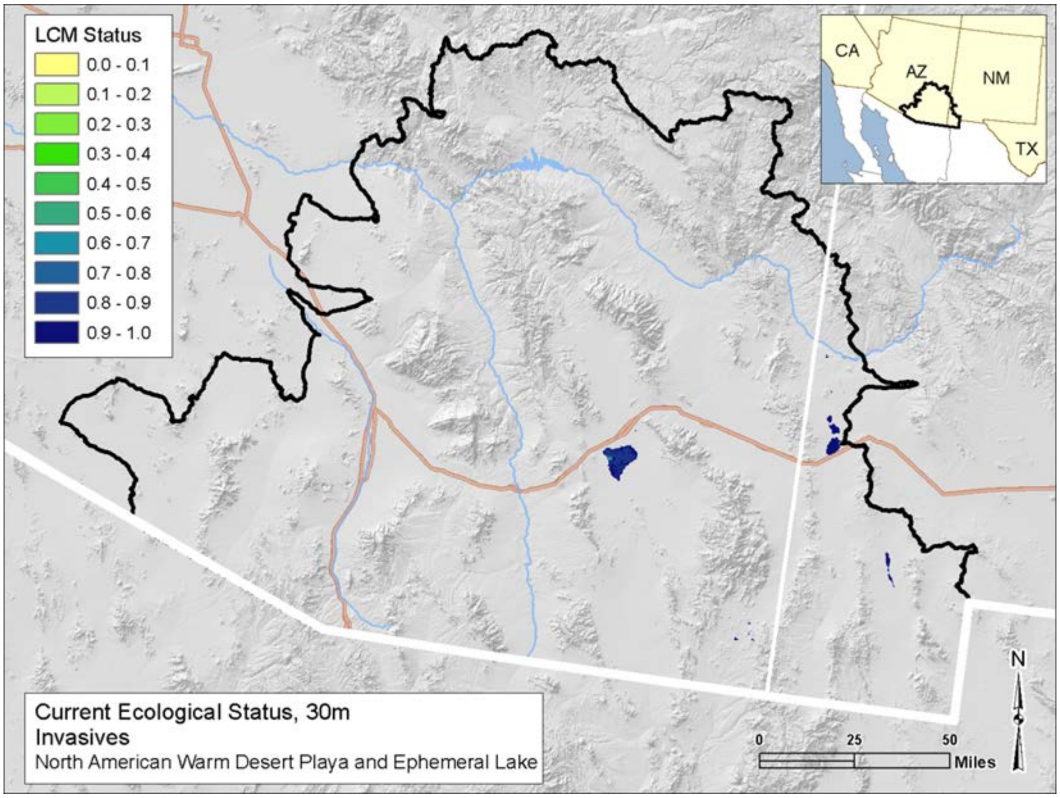
Figure E-40. Scores for the development indicator for North American Warm Desert Playa/Ephemeral Lake CE.



E-4.2.2 Aquatic and Terrestrial Invasive Species Indicator

Figure E-41 shows the Invasive Species indicator, a stressor-based indicator of the presence non-native invasive species including terrestrial woody and herbaceous plants such as tamarisk and cheat grass (*Bromus tectorum*). A few aquatic invasives have been recorded around the periphery of playas or within the HUC12 watersheds containing playa occurrences. Scores for invasives mean the following: a score of 0.35 indicates a combination of aggressive aquatic animals such as bullfrogs or crayfish and abundance of terrestrial plant species, 0.5 indicates the presence highly aggressive aquatic species and a score of 0.7 the presence less aggressive aquatic species such as non-native salamanders, or relatively high (>25%) cover on non-native terrestrial plant species. Terrestrial invasive species are quite prevalent within playas as they are both naturally disturbed (from wetting and drying from rain), as well as impacted by off-road vehicular recreational use. The Wilcox playa has significant coverage of invasive plant species on its western edge (score of 0.35), but the remainder of the playa receives a score of 0.85. The other playas show very little infestation.

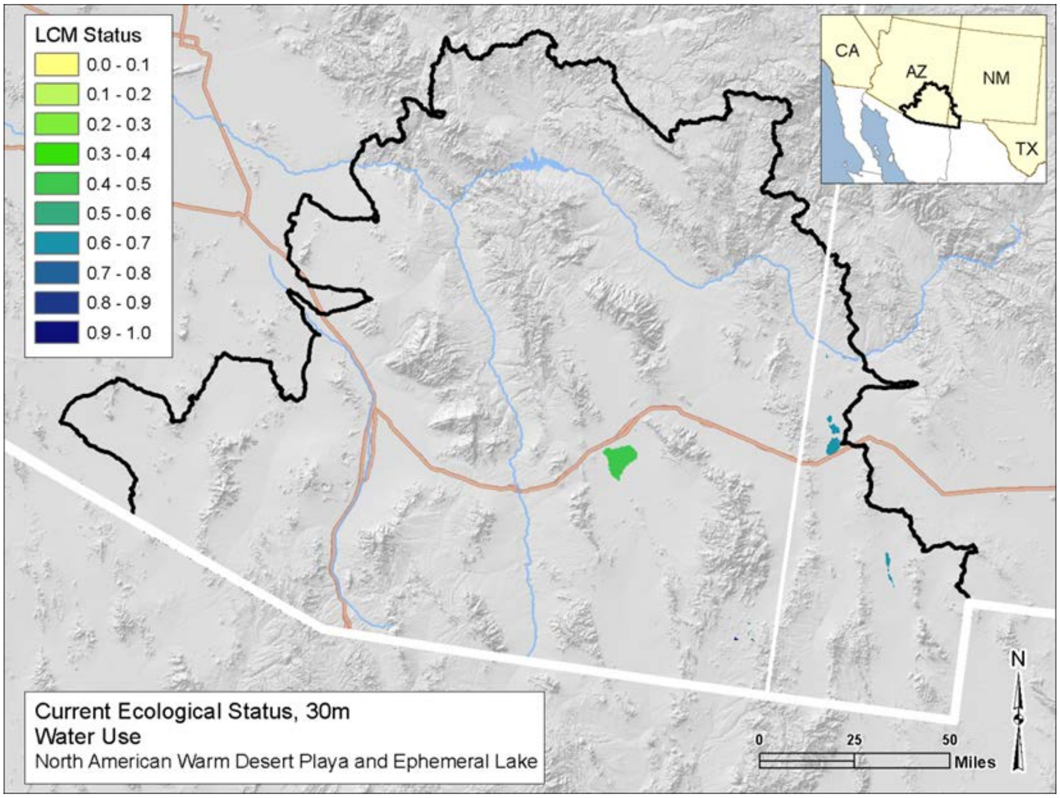
Figure E-41. Scores for the invasive species indicator for North American Warm Desert Playa & Ephemeral Lake CE. Zoom to in to see pixel color variation within playas. Invasive species include terrestrial plants, aquatic animals and aquatic plants). Scores are for each pixel of the distribution of the CE.



E-4.2.3 Water Use Indicator

Water use is a stressor-based indicator of the intensity of consumption of surface and ground water from within-ecoregion sources. As discussed above, the indicator is scored as follows: low water use, less than 0.0035 acre-feet per acre per year, status score = 1.0; medium water use, 0.01 – 0.0252 acre-feet per acre per year, status score = 0.8; medium-high water use, 0.0458 – 0.0583 acre-feet per acre per year, status score = 0.6; high water use, more than 0.0878 acre-feet per acre per year, status score = 0.5. Each pixel in the map shows the score of the Arizona groundwater basin or New Mexico County in which the pixel lies. Thus (**Figure E-42**), the results indicate a high rate of water use (high impact, low score value) in the Willcox groundwater basin, medium-high water use in Hidalgo County, affecting the Lordsburg and Playas Valley playas, and low water use in the San Bernardino groundwater basin.

Figure E-42. Scores for the water use indicator for North American Warm Desert Playa/Ephemeral Lake CE.



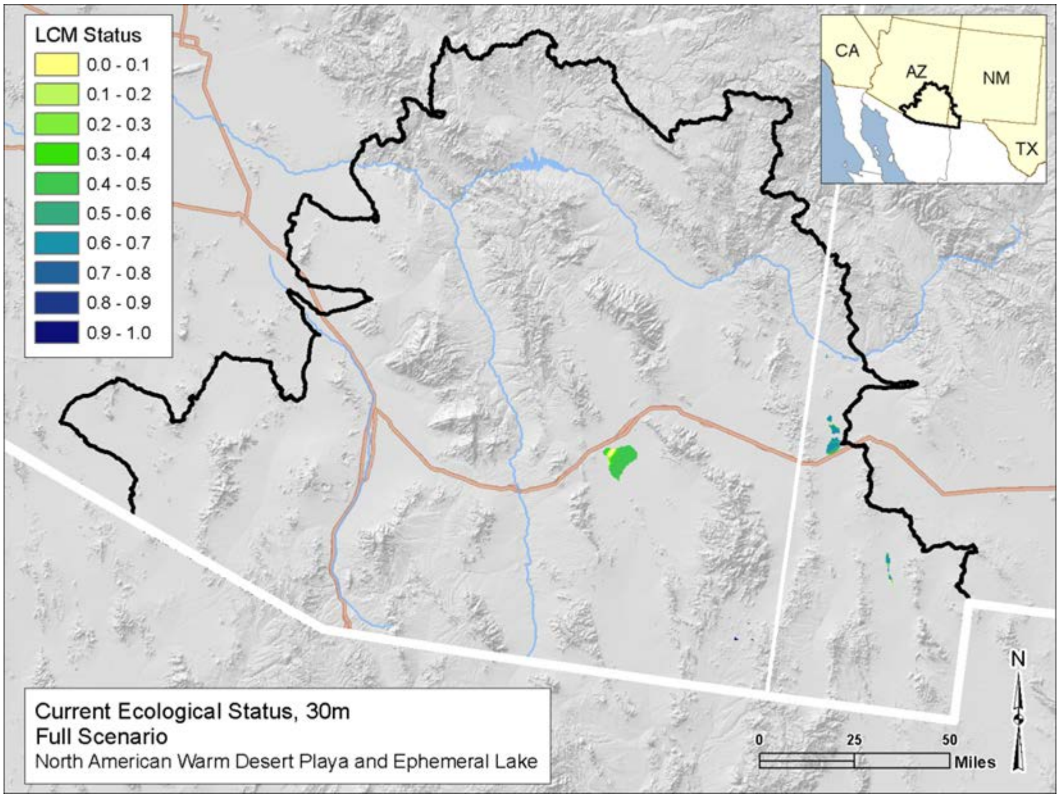
Native Biotic Integrity (presence of native fish, endangered species and benthic macro-invertebrate index) and Aquatic Habitat Quality (PFC and Channel stability) indicators were not applied to the Playa CE (**Table E-2)**.

E-4.2.4 Current Ecological Status: Full Scenario

Figure E-43 shows the overall status of the North American Warm Desert Playas and Ephemeral Lake CE. The upper panel of the figure shows the results by 30m pixel; the lower panel shows the results averaged across all CE pixels, displayed by HUC12 watershed. The overall assessment takes into account the stressor-based indicators for landscape condition (development), aquatic and terrestrial invasive species, and water use. The results are dominated by the stressor-based indicators, which together result in status scores < 0.4 for all pixels across the Willcox Playa; less than 0.6 for all pixels across the Lordsburg and Playas Valley playas; and between 0.6 and 0.9 for all pixels across the playas in the San Bernardino valley.

The HUC12 scores show the average score for the playa area on the scale of each HUC12 watershed within which one or more portions of one or more playas occur. Averaged across occurrence within each HUC12 watershed, the impacts of the stressor-based indicators result in status scores 0.4-0.5 in the area of Willcox Playa; watersheds with a wide range of overall status scores in the areas of the Lordsburg and Playas Valley playas from 0.1-0.2 up to 0.6-0.7; and watersheds with scores between 0.6-0.7 up to 0.8-0.9 in the area of the San Bernardino playas. Willcox Playa has the lowest ecological status scores due to direct impacts to the playa surface, but it is also the largests playa, so its average comes out to a higher score than one of the Lordsburg playas that lies within its own HUC12 watershed (**Figure E-44**). Overall, Willcox shows the greatest impact of stressors relative to the other playas within the MAR ecoregion.

Figure E-43. Overall ecological status scores for North American Warm Desert Playa/Ephemeral Lake CE This is for all indicators combined for each pixel (upper map) and averaged across CE occupied pixels, displayed as HUC12 watersheds (lower map) containing occurrences.



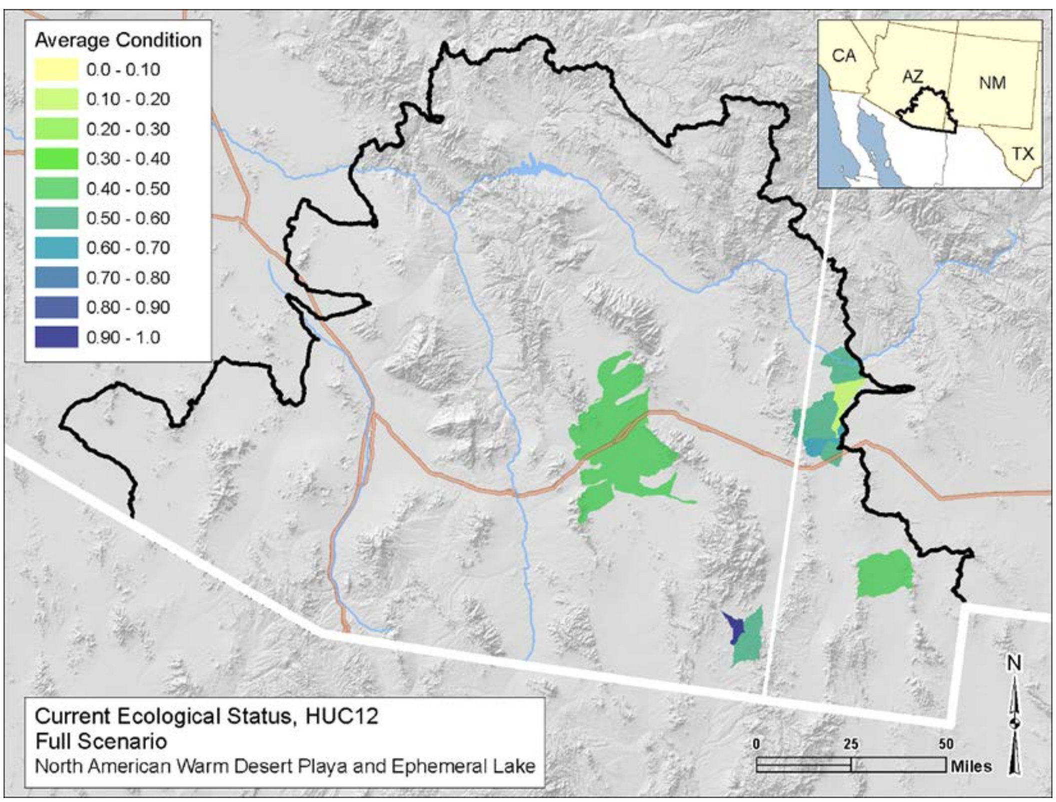
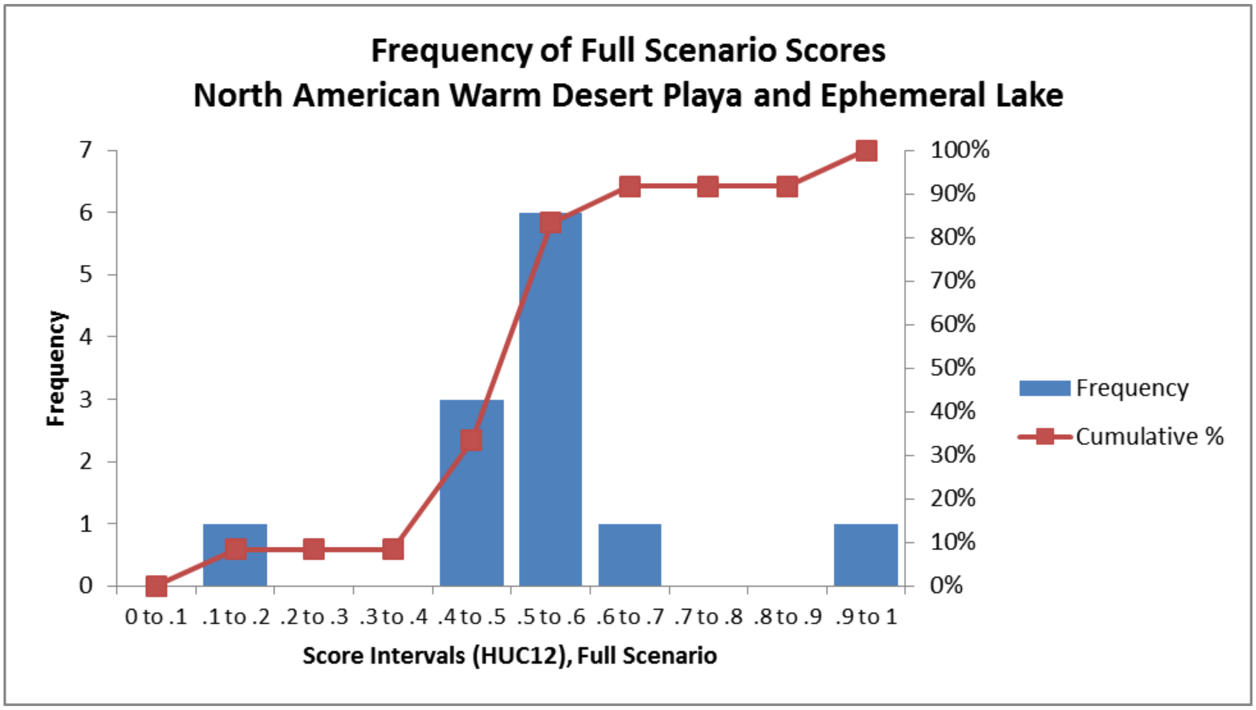


Figure E-44. Frequency distribution of the overall ecological status scores (by 6th-level HUC) with a running cumulative percent. The x-axis represents the 0.1 increment scoring intervals, while the y-axis shows the number of HUCs in each interval (left) and the cumulative percentage of the HUCs in each interval (right).



E-4.3 References for the CE

Allen, B.D. 2005. Ice Age lakes in New Mexico. In Lucas, S.G., Morgan, G.S. and Zeigler, K.E., eds., 2005, New Mexico's Ice Ages, New Mexico Museum of Natural History and Science Bulletin No. 28, pp. 107-114.

Arizona Department of Water Resources (ADWR). 2009. Arizona Water Atlas, Volume 3, Southeastern Arizona Planning Area.

Arizona Heritage Waters (AHW). 2013. Willcox Playa. Online: http://www.azheritagewaters.nau.edu/loc_wilcox_playa.html. Accessed May 2013.

Brostoff, W. N., J. G. Holmquist, J. Schmidt-Gengenbach, and P. V. Zimba. 2010. Fairy, tadpole, and clam shrimps (Branchiopoda) in seasonally inundated clay pans in the western Mojave Desert and effect on primary producers. Saline Systems 6:11. doi:10.1186/1746-1448-6-11.

Brown, S. G. Brown and H. H. Schumann. 1969. Geohydrology and Water Utilization in the Willcox Basin, Graham and Cochise Counties, Arizona. U.S. Geological Survey Water-Supply Paper 1859-F.

Bureau of Land Management (BLM). 1993. Mimbres Resource Management Plan. Las Cruces District Office, Mimbres Resource Area. Report BLM-NM-PT-93-009-4410.

Bureau of Land Management (BLM). 1998. Notice NM–030–1220–00: Emergency Closure of the Lordsburg Playa to Off-Highway Vehicles (OHV), Hidalgo County, NM. Federal Register Vol. 63, No. 122, Thursday, June 25, 1998, Notices 34661.

Bureau of Land Management (BLM). 2000a. Final Environmental Impact Statement for Riparian and Aquatic Habitat Management in the Las Cruces Field Office – New Mexico, Volume 1. Report BLM/NM/PL-00-011-1040.

Bureau of Land Management (BLM). 2000b. Final Environmental Impact Statement for Riparian and Aquatic Habitat Management in the Las Cruces Field Office – New Mexico, Volume 2: Proposed Riparian and Aquatic Habitat Management Plan. Report BLM/NM/PL-00-011-1040.

Carr, J.N. 1992. Arizona Wildlife Viewing Guide. Falcon Press.

Comer, P. and D. Faber-Langendoen. 2013. Assessing Ecological Integrity of Wetlands from National to Local Scales: Exploring the Predictive Power, and Limitations, of Spatial Models. National Wetlands Newsletter Special Issue on Wetland Mapping and Assessment. Environmental Law Institute. Washington DC. Vol. 35 No. 3 May/June 2013.

Comer, P. J., and J. Hak. 2009. NatureServe landscape condition model. Internal documentation for NatureServe Vista decision support software engineering, prepared by NatureServe, Boulder, CO

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. Ecological systems of the United States: A working classification of U.S. terrestrial systems. NatureServe, Arlington, VA.

Desert Processes Working Group. 1991. Chapter: Pattern Indicator: Playa. In: Remote Sensing Field Guide- Desert. Unpublished Report Prepared by US Army Engineer Topographic Laboratory[1] and the US Geological Survey[1]. Working Group Members: Jack N. Rinker[1], Carol S. Breed[2], John F. McCauley[2] (Emeritus), and Phyllis A. Corl[1]. Report documentation: http://www2.agc.army.mil/research/products/desert_guide/lguide1.htm. Playa Chapter: http://www2.agc.army.mil/research/products/desert_guide/lsmsheet/lsplaya.htm

Dinerstein, E., D. Olson, J. Atchley, C. Loucks, S. Contreras-Balderas, R. Abell, E. Iñigo, E. Enkerlin, C. Williams, and G. Castilleja, editors. 2001. Ecoregion-Based Conservation in the Chihuahuan Desert- A Biological Assessment. World Wildlife Fund, Comisíon National para el Conocimiento y Uso de la Biodiversidad (CONABIO), The Nature Conservancy, PRONATURA Noreste, and the Instituto Tecnologico y de Estudios Superiores de Monterrey (ITESM). October, 2000; 2nd Printing with Corrections November, 2001.

Doty, G. C. 1960. Reconnaissance of Ground Water in Playas Valley, Hidalgo County, New Mexico. New Mexico State Engineer, Technical Report 15, Santa Fe, NM.

Faber-Langendoen, D., G. Kudray, C. Nordman, L. Sneddon, L. Vance, E. Byers, J. Rocchio, S. Gawler, G. Kittel, S. Menard, P. Comer, E. Muldavin, M. Schafale, T. Foti, C. Josse, and J. Christy. 2008. Ecological Performance Standards for Wetland Mitigation: An Approach Based on Ecological Integrity Assessments. NatureServe, Arlington, VA.

Haukos, D. A. and L. M. Smith. 1992. Ecology of Playa Lakes. U.S. Department of the Interior, Fish and Wildlife Service.

Hibbs, B. J., M. M. Lee, J.W. Hawley, and J.F. Kennedy. 2000. Some notes on the hydrogeology and ground-water quality of the Animas Basin System, Southwestern New Mexico. New Mexico Geologic Society Guidebook, 51st Field Conference, Southwest Passage, pp. 227-234.

Konieczki. A. D. 2006. Investigation of the Hydrologic Monitoring Network of the Willcox and Douglas Basins of Southeastern Arizona. U.S. Department of the Interior, U.S. Geological Survey, Fact Sheet 2006–3055.

MacCarter, J.S. 1994. New Mexico Wildlife Viewing Guide. Falcon Press.

Muldavin, E., P. Durkin, M. Bradley, M. Stuever, and P. Mehlhop. 2000. Handbook of wetland vegetation communities of New Mexico: Classification and community descriptions (volume 1). Final report to the New Mexico Environment Department and the Environmental Protection Agency prepared by the New Mexico Natural Heritage Program, University of New Mexico, Albuquerque, NM.

New Mexico Department of the Environment (NMENV). 2013. Air Quality Bureau Power: Generation Projects in New Mexico. Online http://www.nmenv.state.nm.us/aqb/permit/power.html. Accessed May 2013.

Oring, L. W., L. Neel, and K. E. Oring. 2005. Intermountain West Regional Shorebird Plan, Version 1.0. Manomet Center for Conservation Sciences, Manomet, MA (2005). Revised January 29, 2013.

Pearson, D. L., C. B. Knisley, and C. J. Kazilek. 2005. A Field Guide to the Tiger Beetles of the United States and Canada: Identification, Natural History, and Distribution of the Cicindelidae: Identification, Natural History, and Distribution of the Cicindelidae. Oxford University Press.

Pellant, M., P. Shaver, D.A. Pyke, and J.E. Herrick. 2005. Interpreting indicators of rangeland health, version 4. Technical Reference 1734-6. BLM/WO/ST-00/001+1734/REV05. U.S. Department of the Interior, Bureau of Land Management, National Science and Technology Center, Denver, CO. 122 pp.

Rumpp, N. L. 1977. Tiger beetles of the genus Cicindela in the Sulphur Springs Valley, Arizona, with descriptions of three new subspecies (Cicindelidae--Coleoptera). Proceedings of the California Academy of Sciences, 41.

Schreiber, J.F., Jr. 1978. Geology of the Willcox Playa, Cochise County, Arizona. New Mexico Geologic Society Guidebook, 29th Field Conference, Land of Cochise. Contribution No. 810, Department of Geosciences, University of Arizona, Tucson.

Smith, L. M. and D. A. Haukos. 2002. Floral diversity in relation to playa wetland area and watershed disturbance. Conservation Biology 16(4): 964–974.

Stephens, Daniel B. & Associates, Inc. (2005). Southwest New Mexico Regional Water Plan. Report prepared for the Southwest New Mexico Regional Water Plan Steering Committee.

USDI BLM [U.S. Bureau of Land Management]. 2006. 43CFR4180.1 Fundamentals of Rangeland Health. Code of Federal Regulations and Federal Register, Accessed February 2013 http://federal.eregulations.us/cfr/section/2006/04/18/43-cfr-4180.1

Wings Over Willcox. 2013. Online: https://www.wingsoverwillcox.com/species.asp. Accessed May 2013.

World Wildlife Fund and Sky Island Alliance (WWF and SIA). 2007. Natural Heritage of the Peloncillo Mountain Region A Synthesis of Science.

U.S. Department of the Interior
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Data Request Method

Rapid Ecoregional Assessments (REAs)—National Operations Center, CO

Individual REA data layers and some other products are still available but are no longer being published.

If you would like to obtain more information, including data and model zip files* (containing Esri ModelBuilder files for ArcGIS 10.x and relevant Python scripts), please email **BLM_OC_REA_Data_Portal_Feedback_Team@blm.gov**.
*Note that a few models require software that BLM does not provide such as R, Maxent, and TauDEM.

Models associated with individual REAs may require data links to be updated to function properly. REA reports, technical appendices, and model overviews (for some REAs) contain detailed information to determine what products are available and what datasets are necessary to run a certain model.

Please include the report name and any specific data information that you can provide with your request.

Other BLM data can be found on the Geospatial Business Platform Hub (https://gbp-blm-egis.hub.arcgis.com).