Desert Landscape Conservation Center

Appendix 2a.
Indicator Development Workshop Report

2017

Transboundary Madrean Watersheds Landscape Conservation Design Report

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Version 1.2
June 30, 2020

Madrean Watersheds Landscape Conservation Design

Indicators Workshop - November 17, 2017

University of Arizona

Workshop Summary

Contents

Next Steps and Actions

- Project Team - compile the information from today, including more detailed information on available data for priority indicators and share back (Note: Preferred communication method for this group is Google Docs)
- Convene smaller discussion on connectivity: Myles Traphagen, Max Li, Wim Van Leeuwen, Sally Hejl, Esther Rubin, Jennifer Varin (or other CNF), Scott Wilbor, Paul Bier
- Convene smaller discussion on biodiversity
    - Include: Larry Stevens, Scott Wilbor, Max Li, Bill Radke, Myles Traphagen, Tice Supplee
    - Invite attendance/input from AZGFD, Audubon Important Bird Areas program, FS, BLM, and other experts (Esther can share names)
- Webinar with Mexican partners
- Follow-up on Mexico engagement (James Callegary, Myles Traphagen, Carol Beardmore)
- Gather further input from participants
    - Give people the opportunity to comment further on the priority indicators
    - Madrean Coordinating Team and Desert LCC Science Working Group will also make suggestions

- Host a webinar to review the progress on indicators
- Convene another group meeting (in person or Webinar) between now and the May 2018 Madrean conference to identify the cross-cutting issues and get additional participation
- Develop topical groups on the emerging issues
    - Conduct outreach to experts on the topics that are emerging
    - Consider creating a land managers' group for the Madrean, and eventually involve the general public
- Ongoing - Create products that Madrean partners can share with their organizations to encourage cost share/support for addressing data gaps, implementation, monitoring, etc.

Overview Presentations

Madrean LCD and Indicators Process Overview

Louise Misztal, Sky Island Alliance and Matt Grabau, Desert LCC
View presentation here

Group questions and discussion on presentation

Mexico engagement

- Mexican partner involvement is necessary. No leads are based in Mexico nor are there partners here today.
- There are administrative difficulties in working with partners from Mexico - cannot direct funding to leads in Mexico; logistical and travel support challenges.
- Madrean 2018 Conference will have travel support for Mexican partners and interpretation
- LCD team is trying when possible to incorporate data from both sides of the border.
- The Desert LCC Science Working Group had a Mexico partners group – they haven't been active recently but there may be opportunities to get help from them.
- Mexico federal and state budgets have been slashed. A political subject, but we need to deal with it. CONANP and NGOs can and will help
- Next steps
    - Host a webinar with Mexican partners to get similar input as this meeting.
    - Volunteers to help with Mexico outreach and collaborative efforts - James Callegary, Myles Traphagen, Carol Beardmore

Desired conditions for LCD

- Developing a "scorecard" implies a desired condition, and the setting of targets (we need to know how to assign an "A"). Targets have not yet been set as part of this process.
- Many participants were involved in BLM's REA process – has this team looked at that process for guidance on desired conditions etc.?
    - SIA did look at Madrean REA during the indicators research phase.

Scenario Planning Overview

Alex Bryan, NE Climate Science Center
View presentation here

Group questions and discussion on presentation

- Human stressors (land conversion, etc.) should be included in the "human dimension" side. These will be part of the scenario planning.
- Unknowns and knowns
    - Within the "decision making structure" talk about known unknowns and knowable unknowns. It is important to understand the differing level of uncertainties.
    - Climate stressors are happening now – land managers are responding now. Some of our responses are the best guides for looking into the future. We do have a good deal of knowns now since we are monitoring today.
- Other scenario planning examples
    - Sonoran Joint Venture, taking the lead from CONANP, is doing scenario planning and including ecosystem services etc.

Introduction to LCD Spatial Analysis

Wim Van Leeuwen, Arizona Remote Sensing Center – University of Arizona
(Presentation will be posted soon)

Group questions and discussion on presentation

Model accuracy and data availability

- With models we need to consider the data source and if the model has been validated (e.g. desert tortoise presence)
    - This does depend on data availability for individual species. Models are based on completed field work.
    - Models can be based on exact observations. Predictive models show potential habitat based on abiotic factors but can't predict predators, disease etc.
- The data needs to be useful to those using it and making decisions based on it.
- This group can help identify (and find) missing data and prioritize data needs moving forward

Small group work on indicators by ecosystem

Participants divided into ecosystem working groups to assess and narrow draft indicators. The groups prioritized indicators, and then assessed the top set of priority indicators using the draft criteria provided (see Appendix 1). Representatives from the Desert LCC CMQ2 working group also provided a list of indicators for consideration (see Appendix 2).

1. Riparian indicators

Participants:

- Trevor Hare, Borderlands Restoration & Watershed Management Group
- Andy Casillas, USFS R3
- Bill Radke, USFWS

- Peter Else, Lower San Pedro Watershed Alliance
- Scott Wilbor, Sky Island Alliance
- Matt Grabau, USFWS/DLCC (group facilitator)
- Colleen Whitaker, Southwest Decision Resources (notes)

Prioritized Indicators

The group did an initial dot-vote on the full list of indicators to select those of most importance. The table below shows the results of this vote. Bolded indicators are those which the group thought were most important and were subsequently discussed and assessed. Each participant received 7 dots. A total of 6 participants voted.

Dots	Riparian Indicators
6	**Non-native vegetation - percent or presence**
6	**Riparian Obligate Guild Species (birds)** - *added by group from CMQ list*
5	**Depth to groundwater**
5	**Vegetation - volume, by height class**
4	Meso and hydro-riparian vegetation - percent or extent within the floodplain
3	Fluvial geomorphology
2	Sacaton grassland - extent or percentage
2	Mesquite bosque - extent or percentage
2	Riparian vegetation - linear connectivity
2	Dominant native riparian vegetation species - recruitment or presence
1	Canopy cover fragmentation index of floodplain
1	Riparian vegetation - patch size and class
1	Number of wells
1	Wildfire history or risk
1	Native fish - presence/abundance
0	Riparian vegetation - breadth/width
0	Cottonwood and willow - recruitment
0	Xeric riparian vegetation - extent within floodplain
0	Southwestern Willow Flycatcher - presence/abundance
0	Yellow-billed cuckoo - presence/abundance
0	Gray hawk - presence/abundance
0	Brown headed cowbird - presence/abundance

Assessing top set of riparian indicators

The top set from the dot-vote were assessed based on the criteria (Ecological, Practical, Social/cultural), and each participant assigned a High(H), Medium(M) or Low(L) score. Total scores are based on [H=3, M=2, L=1]

Riparian –Top Indicators	Ecological Score	Practical Score	Social/cultural Score
Non-native vegetation	**Total = 16 / Average = 2.7** (H-4, M-2, L-0)	**Total = 12 / Average = 2** (H-0, M-6, L-0)	**Total = 18 / Average = 3** (H-6, M-0, L-0)
Riparian obligate guild bird species	**Total = 16 / Average = 2.7** (H-4, M-2, L-0)	**Total = 14 /Average = 2.3** (H-2, M-4, L-0)	**Total = 18 / Average = 3** (H-6, M-0, L-0)
Depth to groundwater	**Total = 18 / Average = 6** (H-6, M-0, L-0)	**Total = 11 / Average = 1.8** (H-0, M-5, L-1)	**Total = 11 / Average = 1.8** (H-0, M-5, L-1)
Vegetation - volume by height class	**Total = 18 / Average = 3** (H-6, M-0, L-0)	**Total = 11 / Average = 1.8** (H-0, M-5, L-1)	**Total = 12 / Average = 2** (H-0, M-6, L-0)

Discussion on indicators during group assessment

Non-native vegetation

- Ecological
  - If the systems dry out we'll start to see upland invasive species beginning to encroach
  - Fire carrying capacity of Lehmann's lovegrass in those riparian systems as they dry out is a concern.
  - Riparian areas act like highways for invasive species - e.g. buffelgrass spreading up local stream sheds because of local connectivity
  - Could consider a suite of species for this: tamarisk, sahara mustard, arundo grass, others? Some are an issue already, some will emerge as issues
- Practicality
  - How to measure - presence/absence; something related to vulnerability
  - This is an early indicator of watershed degradation in terms of recruitment processes, depth to groundwater, drying processes, etc.
  - Not high confidence there has been a lot of widespread mapping of this.
  - If only considering tamarisk it would be "high" on practical, but because the whole suite of species it's unsure
- Social/cultural
  - Easy to get people involved in restoration
  - People are concerned about it.

Riparian obligate bird species

- Ecological
  - High ecological importance
  - Well-understood response to key stressors
  - Many respond quickly to management
- Practical
  - Survey data is good in AZ, not sure how good it is in other parts. It's getting better in Mexico
  - GAP analysis for specific species could be applied (note this is a modeling snapshot in time - if we wanted to detect changes due to management, SW ReGAP would not be helpful)

- Social/cultural
    - Popular with people
    - Tourism importance

Depth to groundwater

- Note that number of wells is also directly related to this. Some participants wanted to put dots on that as well. Consider including/combining.
- Ecological
    - Number of wells is directly related to this
- Practical
    - Available data shown now is ADWR and USGS. TNC can't share their data because much of it is taken on private property.
    - The data will be sparse; it is really hard to get. The only thing people report are production wells. Home wells on ranchettes aren't usually reported.
    - Leslie Canyon has a monitoring well
    - In Cienega watershed, a research group at UA (Jenn McIntosh) has done a lot of work about private landowners reporting with "fuzzy locations;" cheap to get but not very widespread
    - Lots of potential data; would take work to add. Less data that we know we can get reliably
- Social/cultural
    - Confusing; people fear their information being shared (private property right)
    - It does resonate with ranchers and farmers. Our target audience for this would be people who really use it, not the urban population that likely wouldn't relate to it.

Vegetation - volume, by height class

- Most participants subsumed all the vegetation indicators into this for their voting. Group agreed if another vegetation indicator were to be substituted for this it should be meso and hydro-riparian vegetation.
- Ecological
    - All agree high
    - More roots in the ground means more stable banks, floodplains, etc.
    - One way to interpret - cottonwood, willow and mesquite extent
- Practical
    - Would require LIDAR. Have this for select areas (closer to metropolitan areas), but less in rural areas. It is getting cheaper and more available
- Social/cultural
    - People don't understand it, but it's important to fire risk
    - People do understand big "dramatic" change over time images of vegetation

Comments from plenary group during shareback

- Vegetation volume doesn't seem the right characterization - it could be dense, but not attractive to birds. Diversity of species is most important
    - Vegetation volume is useful for SWFL
    - The group was discussing volume as specifically by height class
    - More vegetation volume relates to more roots in the ground and more stable banks
- Glad phenology came up in the other group – it should also be in riparian and stream section. It is related to recruitment

2. Streams indicators

Participants: *See Riparian group participants. This group discussed both streams and riparian indicators.*

Prioritized Indicators

The group did an initial dot-vote on the full list of indicators to select those of most importance. The table below shows the results of this vote. Bolded indicators are those which the group thought were most important and were subsequently discussed and assessed. Each participant received 7 dots. A total of 6 participants voted.

Dots	Streams Indicators
5	**Depth to groundwater**
5	**Human development within floodplain**
4	**Continuous perennial flow - total length**
4	**Flow presence and rate**
4	**Aquatic insects - presence of species indicative of high quality habitat**
3	Annual flow days - by reach
2	Groundwater wells - number, volume of water pumped, number of non-exempt wells
2	Invasive aquatic species - presence
1	Hard surface development in watershed
1	Water quality - dissolved oxygen
1	Flow modification by dams - storage capacity compared to discharge
1	Bullfrog - presence
0	Water quality - total dissolved solids
0	Continuous perennial flow - maximum length
0	Beaver - presence
0	Gila topminnow - presence
0	Desert pupfish - presence
0	Gila chub - presence
0	Water temperature
0	Sonoran mud turtle - extent, number of sites
0	Water quality - metals
0	Water quality - nitrates

Assessing top set of streams indicators

The top set from the dot-vote were assessed based on the criteria (Ecological, Practical, Social/cultural), and each participant assigned a High(H), Medium(M) or Low(L) score. Total scores are based on [H=3, M=2, L=1]

Streams –Top Indicators	Ecological Score	Practical Score	Social/cultural Score
Depth to groundwater	**Total = 18 / Average = 3** (H-6, M-0, L-0)	**Total = 11 / Average = 1.8** (H-0, M-5, L-1)	**Total = 16 / Average = 2.7** (H- 4, M-2, L-0)
Human impact on development	**Total = 18 / Average = 3** (H-6, M-0, L-0)	**Total = 18 / Average = 3** (H-6, M-0, L-0)	**Total = 18 / Average = 3** (H-6, M-0,L-0)
Continuous perennial flow	**Total = 18 / Average = 3** (H-6, M-0, L-0)	**Total =11 / Average = 1.8** (H-1, M-5, L-0)	**Total = 18 / Average = 3** (H-6, M-0, L-0)
Aquatic Insects	**Total = 18 / Average = 3** (H-6, M-0, L-0)	**Total = 9 / Average = 1.5** H-0, M-3, L-3)	**Total = 10 / Average = 1.7** (H-0, M-2, L-4)
Flow presence and rate	**Total = 16 / Average = 2.7** (H-4, M-2, L-0)	**Total = 12 / Average = 2** (H-0, M-6, L-0)	**Total = 12 / Average = 2** (H-1, M-4, L-1)

Discussion on each indicator during group assessment

Depth to groundwater

- Ecological
  - Should this be scored the same as for riparian? Now we are focusing on aquatic vs. riparian vegetation
  - We do have streams that are not groundwater dependent
  - Once surface water/groundwater connection breaks it is very vulnerable
- Social/cultural
  - More awareness of flowing rivers by public

Human development within floodplain

- Ecological
  - Infrastructure in floodplains is one of our biggest issues in the southwest - housing, roads, bridges, etc.
  - Primary effects are hydrology and habitat fragmentation
  - High importance throughout whole Madrean
- Practical
  - This is a remote sensing analysis
  - It should be easy to monitor
- Social
  - There are difference between people who want more development and those who don't, but all want info

Continuous perennial flow - total

- This is related to wet-dry mapping
- Ecological
  - All rated high
- Practical
  - Think we can probably get from Mexico

Aquatic Insects

- Practical
    - Data is not available; not easy to monitor, need trained people
    - Different bugs tell you different things
    - Only done with on the ground surveys. No remote sensing
    - Most of the entomology department at UA is urban focused - on the ground monitoring takes place in urban and suburban areas. Once out of that sphere - hauling equipment out is hard.
- Social/Cultural
    - People are familiar with, and concerned about, mosquitos
    - People don't know about aquatic insects
    - There is potential

Flow presence and rate

- What this could include: No-flow days, min, median, max, etc.
- Ecological
    - There has been a lot of work looking at the distribution with changes in recruitment of different species.
    - Change in flow is important when looking at why areas that used to have cottonwood etc. don't have it anymore, even if there is water there - it's down to the flow
    - Compared to continuous perennial flow - this is less important. The group slightly unsure what this really meant
- Practical
    - Gauge streams (USGS) - essentially nothing in Mexico
    - For the three rivers in the region it's practical; on smaller scale or in Mexico it's less practical
- Social/cultural
    - Picture of fish dead in mud
    - Link to economic value
    - People do understand extreme events (flood and no-flow); but actual flow numbers don't mean anything to people

Discussion: What is missing

- Don't seem to be including fluvial geomorphology, fluvial geology, channel cut down
    - The resolution we need is LIDAR or we can't do it.
    - Bank stability is important to streams, and riparian vegetation provides that stability. Is bank stability captured under vegetation volume?
    - Natural background disturbance
    - Fluvial geomorphology will be affected by what happens upstream - Adaptation strategies will apply here.
    - Sediment loading index ties to fluvial geomorphology and also human development
- How do we integrate the indicators here with those in other ecosystems?
    - Example: fluvial geomorphology is related to uplands (also sediment loading is related to grasslands and upland scrub).
    - Anthropogenic effects of people removing trees in riparian (also related to human development within floodplain)
- Are we really capturing the human development side of things?
    - Human development within floodplain is the indicator for this. Is it sufficient.
- The group decided not to use individual species as indicators because, although people are working on them, it's hard to get data. Including the guilds is important.

- Do we need something that captures Total Dissolved Solids?
- Do we need to call out water quality issues? Water quality was split out into so many choices here it kind of got lost in the voting. (consider how to re-include)
    - Could map out abandoned or producing mines (we don't currently have anything about this)

Comments from plenary group during shareback

- We seem to be missing the watershed scale for this
    - One of the limitations is that the indicators are within the riparian ecosystem. This group talked about fluvial geomorphology and sediment are really impacted by what is happening on upstream watershed (uplands)
    - Group discussed but don't have good answer for this yet
    - In grasslands, woodlands - we have fire regime, fragmentation etc. that are watershed issues that relate to overall watershed health
    - You really can't understand what is going on at a certain point if you don't consider the whole watershed. For example - ephemeral stream networks are much larger than perennial. Their ecological function is really important both for flow of nutrients, effects on species, etc. Strongly recommend incorporating some assessment at the watershed scale with some emphasis on ephemeral streams
    - What indicator might encompass this - stream length; proportion of ephemeral/non-ephemeral reaches and how that changes over time, total number of well, amount of water pumped from aquifer, etc.
    - When considering the indicators that have been prioritized, we must consider how impacted they are by fire and other upland impacts. Have to consider watershed condition - need the larger context to help it make sense
- For Truly ephemeral tributary drainages, geomorphology is important. Is it incised? Is stuff flying through the system or soaking in. Roads are a huge issue when it comes to this - and it's easy to map and analyze. We have human infrastructure, but not roads called out specifically
- We're missing the arroyos in all these ecosystems
- Geology hasn't been included (i.e. bedrock, alluvial, etc.). Some information on that is critical to understanding movement of water in these basins.
- We need to consider application to management decisions scale.

3. Springs Indicators

Participants:

- Jeri Ledbetter, Springs Stewardship Institute
- Larry Stevens, Springs Stewardship Institute
- James Callegary, USGS
- Jennifer Varin, Coronado National Forest
- Don Swann, National Park Service
- Louise Misztal, Sky Island Alliance (group facilitator)
- Abby Fullem, Southwest Decision Resources (notes)

Prioritized Indicators

The group first discussed and grouped the indicators provided. Then, they did an initial dot-vote of the grouped indicators to select those of most importance. A total of five participants voted with three dots

each. Bolded indicators are those which the group thought were most important. Indicators indented under bolded indicators were lumped together with the bolded indicator.

Dots	Springs Indicators
3	**Spring-dependent species** (*added by group)*
	Sonoran mud turtle - presence
	Native amphibians - presence/diversity
	Endemic species - presence
	Hydro-riparian vegetation - presence
	Aquatic invertebrates - presence of species that indicate high water quality
3	**Water Quantity** *(group changed from "Water Flow")*
	Depth to groundwater, flow, temporal variability, wetted area, persistence, soil water content,
2	**Human use of springs** (*added by group)*
	Level of human development
	Impacts from herbivory - class and status
2	**Springshed condition** *(group changed from Watershed condition)*
	% of springs in forests departed from original fire regime
	Local soils - conditions (where appropriate) *(group changed from Hydric soils)*
	Surface hydrology - alterations and patterns
	Past fires in the watershed
2	**Natural function of spring in landscape -** accessibility to wildlife (*added by group)*
1	**Water Quality**
	Water quality - dissolved oxygen
	Water quality - total dissolved solids
	Water quality - nitrates
	Water quality - metals
1	**Invasive Species**
	Bullfrogs - presence
	Risk to fire of tamarisk impacted species

Assessing top set of springs indicators

The top set from the dot-vote were assessed based on the criteria (Ecological, Practical, Social/cultural), and each participant assigned a High(H), Medium(M) or Low(L) score. Total scores are based on [H=3, M=2, L=1]

Springs – Top Indicators	Ecological score	Practical score	Social/cultural score
Spring-Dependent Species: diversity, invertebrates, amphibians, endemics, rare plants, hydro riparian	**Total = 15 / Average = 3** (H-5, M-0, L-0)	**Total = 10 / Average = 2** (H-0, M-5, L-0)	**Total = 10 / Average= 2** (H-0, M-5, L-0)
Water Quantity: flow, temporal variability, wetted area, persistence, soil water content, depth to groundwater	**Total = 15 / Average = 3** (H-5, M-, L-0)	**Total = 10 / Average = 2** (H-0, M-5, L-0)	**Total = 15 /Average = 3** (H-5, M-0, L-0)
Human Use of Springs: Accessible to wildlife, herbivory impacts, development, recreation	**Total = 15 / Average = 3** (H-5, M-0, L-0)	**Total = 12 / Average = 2.4** (H-2, M-3, L-0)	**Total = 15 / Average = 3** (H-5, M-0, L-0)
Springshed condition: grazing, fire return interval, fire risk (departure from historic fire regime), past fire extent, soil condition, climate factors, % of springs expressing water.	**Total = 15/ Average = 3** (H-5, M-0, L-0)	**Total = 15 / Average = 3** (H-5, M-0, L-0)	**Total = 10 / Average = 2** (H-0, M-5, L-0)
Water Quality: Dissolved oxygen, TDS, nitrates, metals	**Total = 14 / Average = 2.8** (H-4, M-1, L-0)	**Total = 10 / Average = 2** (H-0, M-5, L-0)	**Total = 15 / Average = 3** (H-5, M-0, L-0)

Discussion on indicators during group assessment

General

- Can't extrapolate springs data to larger area as they are unique ecosystems and we don't know all of their locations. Streams can host as many as 1700 rare species that are not yet listed. Rare species at a stream says a lot about habitat quality and health.
- Incorporated aspects of CNQ2 team's questions into previously drafted indicators.
- Perenniality and trends of springs are of major concern
- General policy: Lump when possible!
- We need to ensure that we are capturing everything we're crossing off into other indicators. The tools we're using to measure indicators need to take into account complex indicators.

Water Quality/Quantity

- Water quality effects a few amount of springs percentage-wise across landscape. Mining and grazing affect some but not all springs.
    - Easy for public to understand and trust water numbers. But there is a difference between aquifer and surface water

Spring-Dependent Species

- Dialogue on lumping Sonoran mud turtles with other species since it is an important predator in a trophic structure. Group decided to lump fish species, Sonoran mud turtles and mammals in "spring-dependent" species.

Natural function of spring

- Wildlife discussion focused on access to springs, and spring's role in landscape versus the spring integrity.

Springshed Condition

- Emphasis on "springshed" condition instead of watershed. How does water infiltrate to spring?
    - "Springshed condition" will include: grazing, fire return interval, fire risk (departure from historic fire regime), past fire extent, soil condition, climate factors

Human Use of Springs

- Added multiple human-related impacts to the "Human use of springs" indicator.
- Grazing related datasets would be useful (e.g. CNF grazing related springs)
- Typical component of assessment

Comments from plenary group during shareback

- Put a lot of different separate indicators under water quantity - With springs a specific indicator out of a cluster of indicators makes more sense

4. Grasslands indicators

Participants

- Chris Thiel (USFS)
- Peter Warren (retired TNC)
- Myles Traphagen (Wildlands Network)
- Carol Beardmore (Sonoran Joint Venture)
- Rob Ballard (USFS)
- Sallie Hejl (Saguaro NP)
- Alex Bryan (Northeast Climate Science Center)
- Tahnee Robertson, Southwest Decision Resources (group facilitator)
- Ashlee Simpson, University of Arizona (notes)

Prioritized Indicators

The group first discussed and grouped the indicators provided. The group agreed on priority indicators through discussion, rather than dote vote as was done in the other groups. Bolded indicators are those which the group thought were most important. Indicators indented under bolded indicators were lumped together with the bolded indicator.

Grasslands Indicators
Grassland fragmentation index
Grassland patches - size, distribution, and class, by watershed
Grassland extent - loss per year to agriculture or development
Pronghorn - presence and trend

Grassland bird guild – (*added by group)*
Regional breeding birds - relative abundance
Regional wintering birds - relative abundance
Ecologic condition of ground cover
Fire frequency (*added by group)*
Ratio of woody brush species to grass species
Bare ground - percent (*added by group)*
Invasive vs. native grasses - perennial grass composition and cover – (*edited by group)p*
Net primary productivity
~~Bison presence~~ *(removed by group)*
~~Biomass carbon sequestration index~~ *(removed by group – this is a research question)*

Assessing top set of grasslands indicators

The top set from the dot-vote were assessed based on the criteria (Ecological, Practical, Social/cultural), and each participant assigned a High(H), Medium(M) or Low(L) score. Total scores are based on [H=3, M=2, L=1]

Grasslands – Top Indicators	Ecological score	Practical score	Social/cultural score
Grassland Fragmentation Index (encompasses grassland patches, grassland extent)	**Total = 13 /Average = 2.6** (H-4, M-1, L-0) *Abstain - 1*	**Total = 12 / Average = 2.4** (H- 3, M-1, L-1) *Abstain - 1*	**Total = 9 / Average =2.25** (H-2, M-1, L-1) *Abstain - 2*
Pronghorn- presence & trend	**Total = 8 / Average = 2.7** (H- 2, M-1, L-0 *Abstain - 3*	**Total = 8 / Average = 2.7** (H-2, M-1, L-0) *Abstain - 3*	**Total = 10 / Average = 3.3** (H-3, M-0, L-1) *Abstain - 2*
Grassland Bird Guilds: Wintering and Breeding relative abundance	**Total = 14 / Average = 2.8** (H-4, M-1, L-0) *Abstain - 1*	**Total = 10 / Average = 2.5** (H-2, M-2, L-0) *Abstain* - 2	**Total = 6 / Average = 2.5** (H-1, M-0, L-3) *Abstain - 2*
Ecological Condition of Ground Cover (Ratio of Woody Species to Grass Species, Perennial Grass Composition and Cover, Percent Bare Ground, Net Primary Productivity)	**Total = 15 / Average = 3** (H-5, M-0, L-0) *Abstain - 1*	**Total = 12 / Average = 3** (H-4, M-0, L-0) *Abstain - 2*	**Total = 7 / Average = 2.3** (H-1, M-2, L-0) *Abstain - 3*

Discussion on indicators during group assessment

Grassland birds

- Wintering birds are often at their northern extent in the grasslands and many are under consideration for listing. This is a reason for splitting wintering and breeding birds.
- Relative abundance rather than presence would be more informative for birds.
- Birds is an indicator of ecosystem condition because of how they respond to stressors and change.

- Difficult to interpret changes with migratory birds because confounded by effects on species across their expansive migratory routes. It is best to focus on specific birds that are obligate or dependent on grasslands—guilds that are representative.
    - Grassland Bird Guilds: 2 indicators Wintering & Breeding

Ecological condition of ground cover

- "Ground Cover" as an indicator that encompasses 4 other indicators: Ratio of Woody Species to Grass, Perennial Grass Composition and Cover, Net Primary Productivity, Percent Bare Ground

Pronghorn

- Charismatic species, can indicate intact grasslands and levels of connectivity. But introduced and managed heavily by AGFD.

General Comments

- Bison is not a relevant indicator—DROPPED
- Biomass carbon sequestration index - may not be applicable to management because unlikely to actually measure and monitor. Could be inferred from other vegetation attributes.
    - Not necessarily a useful grassland health indicator.
    - Can be considered a research need to determine if there is an easy way to monitor that can be translated to management.
    - It's an ecosystem service that can be derived from attributes that are more practical to measure. DROPPED
- Departure from fire regime class- available information is limited to glean departure in grasslands. Fire frequency maps are informative and useful. No clear way to assess degree of departure from regime for most places. For these reasons, no need for fire regime departure indicator for grasslands. DROPPED from priority indicators.
- Invasive and Perennial Grass-extent CHANGED to Perennial Grass Composition and Cover- can look at changes over time that includes native and invasive
- Other faunal component: Small mammals, reptiles, etc.?

Comments from plenary group during shareback

- A grassland species guild was chosen as a focal species group for the Madrean REA - when they tried to analyze the status of grassland birds, they just looked at habitat. They didn't have any other data.
    - Thinks there is data available for this through AGFD.
- Add "native/invasive" into grassland indicators language. See TNC work here

5. Madrean Evergreen Woodland indicators

Participants

See Grasslands participants. The same group assessed indicators for both Grasslands and Evergreen Madrean Woodland

Prioritized Indicators

The group first discussed and grouped the indicators provided. The group agreed on priority indicators through discussion, rather than dote vote as was done in the other groups. Bolded indicators are those which the group thought were most important. Indicators indented under bolded indicators were lumped together with the bolded indicator.

Madrean Evergreen Woodland Indicators
Madrean Evergreen Woodland - extent
Patch size
Fragmentation index
Wildfire frequency, extent, severity
Fire regime departure class
Prescribed fire treatments
Fire risk - probabilities across the ecosystem
Fuel loading
Risk to fire of structures in the WUI
Vegetation phenology
Vegetation Condition (*added by group)*
Net primary productivity
Tree die-back
Carbon stocks
Exotic invasive plants - spatial extent
Coarse woody debris - volume
Encroachment of forest species into the grassland ecosystem
Bird Guilds – relative abundance (*added by group)*
~~Mexican spotted owl - presence/abundance~~ *(suggestion to remove)*
~~Mexican spotted owl - habitat intactness~~ (suggestion to remove)
Cavity nesters *(added by group)*

Assessing top set of Madrean Evergreen Woodland indicators

The top set from the dot-vote were assessed based on the criteria (Ecological, Practical, Social/cultural), and each participant assigned a High(H), Medium(M) or Low(L) score. Total scores are based on [H=3, M=2, L=1]

Woodland – Top Indicators	Ecological score	Practical score	Social/cultural score
Vegetation Condition: Plant Species Composition, Cover, NPP, and tree dieback	**Total = 12 / Average = 3** (H-4, M-0, L-0) Abstain - 1	**Total = 9 / Average = 2.3** (H-2, M-1, L-1) Abstain - 1	**Total = 5 / Average = 1.7** (H-0, M-2, L-1) Abstain - 2
Vegetation Phenology	**Total = 5 / Average = 1.7** (H-0, M-2, L-1) Abstain - 2	**Total = 4 / Average = 1.3** (H-0, M-1, L-2) Abstain - 2	**Total = 4 / Average = 1.3** (H-0, M-1, L-2) Abstain - 2
Madrean Evergreen Woodland Bird Guilds-relative abundance: Cavity nesters, those that focus on acorn use	**Total = 12 / Average = 3** (H-4, M-0, L-0) Abstain - 1	**Total = 10 / Average = 2.5** (H-2, M-2, L-0) Abstain - 1	**Total = 9 / Average = 2.3** (H-1, M-3, L-0) Abstain - 1
Madrean Evergreen Woodland Spatial Extent: connectivity and patch size	**Total = 10 / Average = 2.5** (H-2, M-2, L-0) Abstain - 1	**Total = 10 / Average = 2.5** (H-2, M-2, L-0) Abstain - 1	**Total = 4 / Average = 2** (H-1, M-0, L-1) Abstain - 3
Wildfire frequency, extent, severity Includes: Fuel loading, risk to fire of structures in WUI, Fire regime departure class, prescribed fire treatments	**Total = 12 / Average = 3** (H-4, M-0, L-0) Abstain - 1	**Total = 10 / Average = 2.5** (H-2, M-2, L-0) Abstain - 1	**Total = 6 / Average = 2** (H-1, M-1, L-1) Abstain - 2

Discussion on indicators during group assessment

Vegetation Phenology

- Ecological
  - Is this a relevant indicator to this ecosystem?
  - Can be an indicator that affects migratory birds, species interactions.
  - Oak and Juniper phenology linked to precipitation can tell you about climate change.
- Practical
  - MOTUS data.
  - Easily monitored and observed by citizen scientists. Can link satellite observations to field observed data for ground-truthing.
  - Highly variable on a landscape scale.

Bird Guilds

- Remove Mexican Spotted Owl indicators and change indicator to "Madrean Evergreen Woodland Bird Guilds-relative abundance"
  - Rare species are not very informative *because* they are rare.
  - Instead should use common obligates or highly dependent groups of birds as indicators.

Spatial Extent and Distribution

- Must consider connectivity across mountain ranges that involves the fragmentation of lowlands/grasslands. This connectivity is required for ecologically functional landscapes on a large scale.
- Woodlands are naturally fragmented by definition of sky island geography.

Additional comments

- Coarse woody debris- both fuels and habitat indicator. Unsure how relevant to this system.
- Exotic species-Not a big issue in this system.

- Carbon stocks- Research question but not easily translated to management.
- Net Primary Productivity & Tree die-back LUMPED "Vegetation Condition: Plant Species Composition and Cover"
- Encroachment of forest species in grassland ecosystem- DROPPED because it's an indicator for grasslands.
    - But native shrubby species can increase cover and biomass with lack of fire-reduces habitat and increases fuel loads.
- Fire indicators LUMPED to Fire frequency, extent, severity

6. Sonoran Desert Scrub indicators

Participants:

- Esther Rubin, Arizona Game and Fish Department
- Max Li, University of Arizona, SNRE
- Erin Posthumus, USA National Phenology Network
- Julia Sittig, Southwest Decision Resources (group facilitator and notes)

Prioritized Indicators

The group did an initial dot-vote on the full list of indicators to select those of most importance. The table below shows the results of this vote. Bolded indicators are those which the group thought were most important and were subsequently discussed and assessed. Each participant received 7 dots. A total of 6 participants voted.

Dots	Sonoran Desert Scrub Indicators
4	**Vegetation - ~~community structure and demography~~ Composition, cover and age structure**
3	**Abundance of birds dependent on SDS** (*added by group)*
3	**Mule Deer – density** *(added by group)*
2	**Rate of ecosystem change (land gain/loss) caused by human development**
0	Saguaro cactus - spatial extent
0	Exotic invasive plants - spatial extent
0	Ironwood tree - spatial extent
0	Desert tortoise - presence
0	Gila monster - presence
0	Cavity- nesting birds (woodpeckers, martins, owls) - presence
0	Lesser-nosed bat - presence and demography
0	Net primary productivity
0	Organ pipe cactus - spatial extent
0	Desert scrub ecosystem - spatial extent
0	Soil crusts – percent cover

Assessing top set of Sonoran Desert Scrub indicators

The top set from the dot-vote were assessed based on the criteria (Ecological, Practical, Social/cultural), and each participant assigned a High(H), Medium(M) or Low(L) score. Total scores are based on [H=3, M=2, L=1]

Sonoran Desert Scrub - Top Indicators	Ecological score	Practical score	Social/cultural score
Rate of ecosystem area change caused by human development	**Total = 6 / Average = 2** (H-0, M- 3, L-0)	**Total = 6 / Average = 2** (H-0, M- 3, L-0)	**Total = 9 / Average = 3** (H-3, M-0, L-0)
Vegetation – composition, cover, and age structure	**Total = 9 / Average = 3** (H-3, M-0, L-0)	**Total = 5 / Average = 1.7** (H-0, M-2, L-1)	**Total = 7 / Average = 2.3** (H-2, M-0, L-1)
Birds dependent on SDS ecosystem – abundance	**Total = 9 / Average = 3** (H-3, M-0, L-0)	**Total = 6 / Average = 2** (H-0, M-3, L-0)	**Total = 8 / Average = 2.7** (H-2, M-1, L-0)
Mule deer – density	**Total = 9 / Average = 3** (H-3, M-0, L-0)	**Total = 6 / Average = 2** (H-0, M-3, L-0)	**Total = 7 / Average = 2.3** (H-2, M-0, L-1)

Discussion on indicators during group assessment

Rate of ecosystem change caused by human development

- What variable is actually being measured?
- The NLCD system remotely measures the spatial extent of human development every 5 years, so the data would measure the amount of SDS land lost to human development.

Net Primary Productivity

- Can be counter-intuitive: invasives species presence can sometimes indicate a healthy ecosystem even though biodiversity is actually low.
- NPP needs to be coupled with other indicators of biodiversity.
- Important to consider practicality measures – cost of monitoring, etc.

Vegetation

- Vegetation community structure and demography – needs to be better defined.
- Overlaps with CMQ's vegetation composition and cover.
- Monitoring demography would be expensive.
- Changed "demography" to "age structure"
- May be able to get trees' cover remotely, but not others
- Saguaro is difficult to monitor for recruitment
- Age structure - don't want to just look at snapshot in time, want to get recruitment

Birds

- Added "Abundance of desert scrub dependent birds" to the list
- Would cover the importance of the cavity-nesting birds and include a suite of species in bird surveys.
    - As cavity nesting bird surveys can only be done at certain locations it may be spotty data
- Scale of data needed to determine vegetation recruitment of cavity-providing vegetation spatially
- Connections to biodiversity – Vegetation composition/cover/age structure and bird abundance.
    - Bats could be good for connectivity because they migrate through the Madrean system south to north.

Mule Deer

- Mule deer can be a good indicator of connectivity
- Mule deer chosen high by two group members because of high economic value to hunters, and familiarity to the public. A good deer population also indicates connectivity.

Soil

- Need an indicator for soil erosion. In some ways, vegetation cover and species composition can act as a proxy.
- Soil crusts occur when vegetation cover is low – they firm the soil when plants aren't there

Invasives

- Should we have invasive species as its own indicator?
- Could be a combination of satellite and ground truthing.
- Buffelgrass can be detected through remote imagery, but only with about 60% accuracy.
- Would be covered in the vegetation composition/cover variable

General Comments

- Spatial extent for all indicators may not be sufficient. Need to know whether the populations are sustainable – not enough to know that they're there, we should measure recruitment and/or density as well.
- Although some indicators could be monitored using remote sensing, it is important to do on-the-ground monitoring for some variables.
- Remove sensing technology will improve over time, so don't necessarily discount indicators
- Bare ground – change to "ratio of bare ground compared to vegetation cover?"
- Bats could be good indicators of human-caused stressors, but they are common beyond the Sonoran Desert scrub ecosystem. Also, monitoring birds would probably cover most of the concerns associated with bats (not sure). So no one voted on them,
    - Local endangered bat species will probably be de-listed, and USFWS will monitor them for the next 5 years.
- Overall seems representative of the Sonoran Desert Scrub ecosystem, but group had a concern that we haven't covered all the groups of animals
    - Do we need reptiles indicator?
    - What goes into the model for desert tortoise and gila monster?
    - Desert tortoise would also be good for connectivity because of its sensitivity to roads and other development.
- Connection to connectivity – mule deer, rate of ecosystem area change.

Comments from plenary group during shareback

- Reptiles and amphibians
    - Gila Monster data is likely very terrible
    - Most sensitive to human disturbance (Side blotched and horned toad) - disappear as soon as there is development/disturbance. But very difficult to measure and very expensive, whereas Mule Deer are much easier to consider.
    - Maybe a way to look at species diversity - reptile and amphibian species diversity would be good proxy, but don't know how to do this. Generalized herp diversity and relative abundance over time may work (like Organ Pipe Model - long term lizard datasets just published)
    - May also consider the guild that includes 10-12 species of breeding toads
    - Desert Tortoise - the data is very good, but they live very long

- Vegetation
    - Group understands the vegetation indicators they identified require a lot of resources, but think with increasing technology/data available that this may be possible.
    - USGS doing much higher resolution large scale maps of grassland vs. scrub - unsure exactly where it is (James Callegary is contact for this)
- Fire in Sonoran Desert Scrub
    - There is a lot of information out there on this (fires are traced every year, and with some type of intensity data is incorporated)
    - We have these Sonoran desert systems that burn so many times they turn into buffelgrass grassland - it's having huge effects on species (fountain grass, red brome)
- Classification system that is used for defining grasslands were "weird" - seems there could be as little as 7% grass and it's still classified as a grassland - worth looking further into this.
- Have no land/physical indicators – group did talk about measuring land crust, but that's difficult

Priority Madrean Topics – Connectivity and Biodiversity

Connectivity Discussion

Scott Wilbor (Sky Island Alliance) presented a summary of the current work on connectivity in the Madrean region. View presentation here.

Note: Only a handful of participants reported they felt capable of contributing to a discussion on selecting specific models and analyses for connectivity.

Group Discussion

- How to include expert opinion
    - Need to incorporate expert opinion – LANDSAT, REGAP, and other models can mischaracterize landscapes; we can integrate the knowledge of on-the-ground efforts.
    - Consider a hybrid approach of starting with models and refinement through expert opinions.
    - Could begin with expert opinion rather than existing models. For the Cienega process, the partners told the modelers what they saw and needed, and models were made based on the on-the-ground knowledge.
    - Expert opinion could be based on core patches.
- Considerations for models
    - Connectivity is often based on areas between known "cores", and it is likely that we are missing some of the existing cores.
    - Define what we want to connect
    - The role of escarpments in aerial movement of top predators.
    - Drainages can facilitate aerial movement. Existing models use slope to identify drainages.
    - Pronghorn and grassland birds need connectivity across grasslands, not drainages.
    - Issue of lack of models from Mexico - The only model Scott found for Mexico was for jaguars
    - Example from a California connectivity planning process: They stepped back and defined the areas and values to be connected before moving forward on models.
- Connectivity between water sources
    - The lack of connectivity between springs and surrounding watersheds have actually helped to protect biodiversity. Bullfrogs and crayfish are unable to expand their range because of the lack of water.

    - But need to consider harmful impediments such as dams.
- Climate Refugia
    - Connectivity modeling has not been done for climate refugia.
    - The persistence of any large-scale species depends on their ability seek their best-quality habitat.
    - Consider connectivity across elevation gradients – need to prevent roads and other development from cutting through corridors. Jaguar depend on high-elevation habitats that require upslope movement.
- Potential Indicators
    - Species
        - We know top predators are indicators for connectivity, are there other species (plant or animal) that are good indicators?
        - We don't know much about plants and dispersal related to connectivity.
        - A suite of focal species was used in the AZGFD connectivity model - it included herbivores, Gila monster, desert tortoise, etc.
    - Road density
    - Wildlife: Bill Radke is giving local landowners wildlife cameras. Could have volunteers monitor cameras.
    - Landscape integrity – roads, transmission lines, etc.
    - Gene flow across populations (John Wayne, Melanie Culver, and Ashwin Naidu at UA study gene flow)
    - Need indicators for Mexico – not just roads, but other impacts. INEGI may have that data for Mexico – specialists at statistical analysis/GIS

- Actions
    - Assess the compilation of corridor models – send to Coordinating Team, and identify potential indicators/approaches to indicators
    - Data gathering/sharing
        - Draft potential connectivity indicators
        - Create a centralized database/repository of connectivity data
        - Need to identify a location to store data
        - The DLCC website is not currently a federal website, so the information stored on it is freely available. A potential risk of having freely available materials/information is that they could be used by developers or other threats to connectivity.

Biodiversity Discussion

Matt Grabau (Desert LCC/USFWS) presented a summary of the current on biodiversity for the Madrean LCD process. (Presentation will be shared soon)

Group Discussion

- Define the value and focus of biodiversity – do we want the largest variety of species in general, or focus more on "high-value" species?
    - Focus on high-value species may make it easy to get support/resources from funders
    - Plants, invertebrates, and small mammals have boundaries within the Madrean pilot area that are not currently understood
    - Chuck Lowe did work on biodiversity
    - What are the rarest species?
    - What are the most high-priority species?
- Convene a separate discussion on the biodiversity

- Review work to date, and determine publications to work from
    - Brown and Lowe
    - AZGFD maintains a database of informational resources

Appendix 1: Draft Criteria for Selecting Indicators

The Desert LCC, with help from partners, has developed a list of criteria for selecting the indicators used in the Madrean Landscape Conservation Design process. The criteria have been grouped into Ecological Criteria, Practical Criteria, and Social/Cultural Criteria.

Prior to the November 2017 workshop, participants ranked the criteria according to their importance. The criteria are listed below, ordered in each group from highest to lowest rankings.

Ecological Criteria

- Provide information about changes in important ecosystem condition or processes
- Can detect changes over time that occur in response to management actions
- Represent ecological attributes and habitat condition for a suite of organisms and/or ecological attribute
- Have a well-understood response to key ecosystem stressors
- Are appropriate for at least the majority of the ecosystem area within the LCD area, and preferably across the Desert LCC geography
- Have low background spatial or temporal variability
- Will be selected for ecosystems that occupy a significant portion of the LCD area

Practical Criteria

- Can be easily and economically monitored
- Can be incorporated into spatial analysis
- Have existing/historic datasets
- Are already being measured as part of an existing and continuing monitoring program or system
- Overlap with existing conservation plans
- Availability of existing modeling frameworks that relate indicator values to LCD goals

Social/Cultural Criteria

- Can be easily understood by policymakers and conservation practitioners
- Can be used to easily develop products that resonate with public land or water managers
- Can be used to easily develop products that resonate with private land or water managers
- Can be used to easily develop products that resonate with the American public
- Link to human health and well-being, including provisioning services (e.g. water supplies)
- Link to economic values

Appendix 2: CMQ2 Team Indicators

CMQ2 Team
DRAFT: 5 Indicators per Ecosystem
Preliminary List for Use at Madrean LCD Workshop
November 17, 2017

Sonoran Desert Scrub

- Density of mule deer
- Abundance of breeding desert scrub-dependent bird species
- Plant species composition and cover (including non-native or invasive species)
- Abundance of cavity-nesting birds (excavating and occupying)
- Biological soil crust cover (%)

Madrean Woodland

- % canopy cover of oak species
- Age classes of dominant tree species (e.g., Pinus, Quercus), to represent recruitment of trees
- Distribution and abundance of Madrean woodland bird species (a select group, including owls)
- Timing of bird migrations (of select group of bird species)
- Plant species composition and cover (including non-native or invasive plants)

Grasslands

- % bare ground
- Vegetation composition and cover (including non-native or invasive plants)
- Abundance of breeding grassland-dependent bird species
- Abundance of wintering grassland-dependent bird species
- Height of native grasses

Springs

- Composition and abundance of amphibians
- Composition and abundance of invertebrates
- Flow rate (e.g., m^3/sec) of each spring, stratified by season.
- Composition and cover of vegetation (including non-native or invasive plants; *within predetermined area around spring?)*
- Composition (*and rate of visitation?*) of wildlife at springs *(including birds*).

Riparian

- Abundance of riparian obligate breeding bird species (e.g., top 5 representative species; true obligates) *(note: if not feasible to select a set of species that would be representative across entire DLCC, it may be better to monitor composition and relative abundance of all bird species)*
- Composition and abundance of amphibians (including non-native or invasive species)
- Age structure of native riparian-obligate trees (e.g., cottonwoods, sycamores, walnuts, etc.), to monitor recruitment.
- Composition and cover of vegetation (including non-native or invasive species; *within predetermined area around center of riparian?)*
- *Some water measure…… one suggestion was "groundwater levels in and near riparian areas", which would be great to know but very difficult to measure. Another was*

"inundation frequency", but not all riparian areas have any inundation (it may all be groundwater based). Perhaps let the vegetation be the indicator for amount of water? OR use "groundwater levels in the watershed"? (not sure if that can be measured in all areas, thinking of remote areas in Mexico, would they have ability to measure this?)

Streams

- Composition and relative abundance of fish species (including non-native and invasive species)
- Composition and relative abundance of invertebrate species (including non-native and invasive species)
- Water flow rates, stratified by season, and at key locations to represent entire waterway.
- Water quality: contaminants and sediments, stratified by season, and at key locations to represent entire waterway.
- Water temperature, stratified by season, and at key locations to represent entire waterway.

Appendix 3: Participants

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