An Integrated Approach for Repairing Degraded Mojave Desert Shrublands

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November 10th, 2016
Society for Ecological Restoration, Southwest Chapter
Las Vegas, Nevada
Mojave Desert is Symbolic of Major Ecological Restoration Challenges

Photos: T. Esque
Mojave Desert is Symbolic of Major Ecological Restoration Challenges

Adapted from Nussear et al. 2009

Renewable Energy Production and Transmission in Relation to Genetic Diversity Hotspots in the Mojave Desert

Vandergast et al. 2013.
Wildfire: A Novel Disturbance Transforming Mojave Desert Shrublands

- Fires are carried by non-native annual grasses
- >1 million acres burned or re-burned in 2005/2006
- ~5% of federally-designated critical habitat
Cascading Degradation of Habitat with Repeated Burning

Dry Middle Fire, NV

One-time Burned

Repeatedly Burned

Jacob’06 Fire, AZ
Partnerships and Collaborations are Essential!
A Mojave Ecoregional Approach to Ecological Restoration

“The right seed at the right site at the right time”

Provide Suitable Native Plant Materials

Prioritize Restoration Sites

Implement Appropriate Practices

Ensure Compatibility with Tortoise Health & Well-being
Prioritize Restoration Sites

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Integration with National Seed Strategy

GOAL 1
Identify seed needs, and ensure the reliable availability of genetically appropriate seed.

GOAL 2
Identify research needs and conduct research to provide genetically appropriate seed and to improve technology for native seed production and ecosystem restoration.

GOAL 3
Develop tools that enable managers to make timely, informed seeding decisions for ecological restoration.

GOAL 4
Develop strategies for internal and external communication.
Selecting Native Plant Materials: Finding “The Right Seed…”

- Priority Species List
  - Tortoise food and cover plants
  - Availability for immediate use
  - Potential for commercial collection vs. production

- Landscape Genetics

- Multiple Common Gardens
Species Observed in Tortoise Diets

>200,000 “bite-counts” for 98 tortoises in CA, AZ, UT

41% of Diet
Brome grasses
Mediterranean split grass
Red filaree
Russian thistle

Annual forbs: 28%
Perennial forbs: 6%
Perennial grasses: 4%
Annual grass: 1%
Diversity of Pollinators Also Supported

National Strategy to Promote the Health of Honey Bees and Other Pollinators
Long-lived, Shrubs Provide Majority of Cover for Tortoises

<table>
<thead>
<tr>
<th>Species</th>
<th>#Obs</th>
<th>% Use(^a)</th>
<th># Sites</th>
<th>Habit / Recovery(^b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creosotebush, <em>Larrea tridentata</em></td>
<td>1659</td>
<td>43.08</td>
<td>8</td>
<td>Shrub / -</td>
</tr>
<tr>
<td>White bursage, <em>Ambrosia dumosa</em></td>
<td>889</td>
<td>23.08</td>
<td>8</td>
<td>Shrub / -</td>
</tr>
<tr>
<td>Utah yucca, <em>Yucca schidigera</em></td>
<td>185</td>
<td>4.80</td>
<td>6</td>
<td>Shrub / -</td>
</tr>
<tr>
<td>Wolfberry, <em>Lycium andersonii</em></td>
<td>173</td>
<td>4.49</td>
<td>8</td>
<td>Shrub / -</td>
</tr>
<tr>
<td>Cheesebush, <em>Hymenolea salsola</em></td>
<td>138</td>
<td>3.58</td>
<td>5</td>
<td>Shrub / +</td>
</tr>
<tr>
<td>Nevada jointfir, <em>Ephedra nevadensis</em></td>
<td>132</td>
<td>3.43</td>
<td>6</td>
<td>Shrub / -</td>
</tr>
<tr>
<td>Desert globemallow, <em>Sphaeralcea ambigua</em></td>
<td>123</td>
<td>3.19</td>
<td>6</td>
<td>Per Forb/ +</td>
</tr>
<tr>
<td>Joshua tree, <em>Yucca brevifolia</em></td>
<td>120</td>
<td>3.12</td>
<td>4</td>
<td>Shrub / -</td>
</tr>
<tr>
<td>Desert holly, <em>Atriplex hymenolytra</em></td>
<td>53</td>
<td>1.38</td>
<td>2</td>
<td>Shrub / -</td>
</tr>
<tr>
<td>Range ratany, <em>Krameria grayi</em></td>
<td>53</td>
<td>1.38</td>
<td>5</td>
<td>Shrub / -</td>
</tr>
<tr>
<td>Jointfir, <em>Ephedra sp.</em></td>
<td>44</td>
<td>1.14</td>
<td>1</td>
<td>Shrub / -</td>
</tr>
</tbody>
</table>

\(^a\)Based on 3,800 observations across 8 monitoring sites in CA and NV

\(^b\)Based on short- and long-term recovery (Shryock et al. 2014)
Early-Colonizing Forbs Can Provide Short-Term Thermal Cover for Tortoises

Desert globemallow, *Sphaeralcea ambiguа*

Drake *et al.* 2015
Seeding Promotes Recruitment of Short-lived Perennial Forbs
Seed Costs For Native Shrubs are Prohibitive

< 5% for Bonnie Springs, NV 2005 (22 seeds/m² *H. salsola*)
5% for Coyote Springs, NV in 2005 (17 seeds/m² *A. dumosa, A. canescens*)
4% for Coyote Springs, NV in 2006 (29 seeds/m² *L. tridentata, A. dumosa, H. salsola*)

<table>
<thead>
<tr>
<th>Species</th>
<th>Relative Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand dropseed, <em>Sporobolus cryptandrus</em></td>
<td>1.0</td>
</tr>
<tr>
<td>Sideoats grama, <em>Bouteloua curtipendula</em></td>
<td>6.0</td>
</tr>
<tr>
<td>Indian ricegrass (Rimrock), <em>Achnatherum hymenoides</em></td>
<td>7.6</td>
</tr>
<tr>
<td>Palmer’s penstemon, <em>Penstemon palmeri</em></td>
<td>31.1</td>
</tr>
<tr>
<td>White evening primrose, <em>Oenothera dentata</em></td>
<td>40.3</td>
</tr>
<tr>
<td>Cheesebush, <em>Hymenoclea salsola</em></td>
<td>44.3</td>
</tr>
<tr>
<td>Desert marigold, <em>Baileya multiradiata</em></td>
<td>69.2</td>
</tr>
<tr>
<td>Indian ricegrass (Paloma), <em>A. hymenoides</em></td>
<td>80.0</td>
</tr>
<tr>
<td>Creosotebush, <em>Larrea tridentata</em></td>
<td>96.2</td>
</tr>
<tr>
<td>Nevada Ephedra, <em>Ephedra nevadensis</em></td>
<td>905.1</td>
</tr>
</tbody>
</table>

Seed Costs For Native Shrubs are Prohibitive
High Priority Species (2016-2017)

Work Done, or in Progress:
- Desert Globemallow (*Sphaeralcea ambigu*)
- Nevada Jointfir (*Ephedra nevadensis*)
- Burrobrush (*Ambrosia dumosa*)
- Desert Indianwheat (*Plantago ovata*)
- Creosote (*Larrea tridentata*)
- Indian Ricegrass (*Stipa hymenoides*)
- Big Galleta (*Pleuraphis rigida*)

High Future Priority:
- Bush Muhly (*Muhlenbergia porteri*)
- Yellow Cups (*Chylismia brevipes*)
- Lanceleaf Browneyes (*Chylismia claviformis*)
- Sixweeks Fescue (*Vulpia octoflora*)
- Needle Grama (*Bouteloua aristidoides*)
- Sixweeks Grama (*Bouteloua barbata*)
- Smooth Desert Dandelion (*Malacothrix glabrata*)
- Chia (*Salvia columbariae*)
- Cheesebush (*Ambrosia salsola*)
- Pincushion Flower (*Chaenactis salsola*)
- Anderson Wolfberry (*Lycium andersonii*)
- White Ratany (*Krameria bicolor*)
- Littleleaf Ratany (*Krameria erecta*)

Slide courtesy J. Perkins
Selecting Native Plant Materials: Finding “The Right Seed…”

- Priority Species List
- Landscape Genetics
- Multiple Common Gardens

Provide Suitable Native Plant Materials

Daniel Shryock, USGS

Ecological Applications

Article
Landscape genetic approaches to guide native plant restoration in the Mojave Desert
Daniel F. Shryock, Caroline A. Havrilla, Lesley A. DeFalco, Todd C. Esque, Nathan A. Custer, Troy E. Wood
Accepted manuscript online: 5 October 2016  Full publication history
DOI: 10.1002/eap.1447  View/save citation
Detecting Genetic Signal of Adaptation

Ephedra nevadensis
- Long-lived
- Evergreen
- Wind-pollinated
- 43 popns, 403 indiv
- 404 loci

Sphaeralcea ambigua
- Short-lived
- Drought deciduous
- Insect-pollinated
- 47 popns, 446 indiv
- 153 loci

Shryock et al. 2016 Ecological Applications
Ephedra nevadensis

Strongest predictors:

- Mean annual temperature
- Precipitation variability

Shryock *et al.* 2016 *Ecological Applications*
Sphaeralcea ambigua

Strongest predictors:

- Mean annual temperature
- Temperature variability
- Precipitation totals

Shryock et al. 2016 Ecological Applications
Spatial Interpolations of Between-Population Adaptive Divergence

Ephedra nevadensis

Sphaeralcea ambigua

Shryock et al. 2016 Ecological Applications
• Incorporates 9 environmental variables
• Effective across plant functional types
Local Provenancing

- **Local** (Home-site advantage approach)
  - Pros: Locally-adapted, native genotype
  - Cons: Low diversity / inbreeding depression

Admixture Provenancing

- **Admixture** (Genetic diversity approach)
  - Pros: Promote adaptive potential, resilience
  - Cons: Outbreeding depression/genetic swamping

Models from D. Shryock, USGS
**Predictive Provenancing**

- **Pros:** Promote resilience to climate change
- **Cons:** Uncertainty, need fitness data

- **Pros:**
  - Promote resilience to climate change

- **Cons:**
  - Uncertainty
  - Need fitness data

- **Examples:**
  - Fort Irwin NTC, Zone 3
  - Jojoba Farm, Zone 6
  - Amargosa Vy, Zone 5
  - Utah DWR, Zone 2

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**USGS Provisional Seed Transfer Zones**
Selecting Native Plant Materials: “The Right Seed...”

- Priority Species List
- Landscape Genetics
- Multiple Common Gardens

- *Larrea tridentata*
- *Sphaeralcea ambiguа*
- *Ambrosia dumosa*
Multiple Common Gardens

- Identify quantitative fitness traits
- Understand fitness risk of seed transfer

**Physiology**
$A_{\text{max}}, g_{\text{max}}, \text{leaf N, } \psi$

**Morphology**
Stem diam, canopy, leaf shape, stem water isotope

**Phenology**
Leaf formation/senescence, flowering/fruiting
Assessing Appropriate Restoration Practices:
“...the Right Place at the Right Time”

- Substrate preparation
  - Decompress, surface roughening
- Broadcast seeding
  - Timing, seed rates, encapsulation
- Container stock planting
  - Moisture amendments
- Herbicides
  - Pre- and post-emergent
- Seed encapsulation
  - Clay balls, sand wafers
Neighborhood Approach to Understanding Recruitment of Woody Species

• Many desert studies measure nurse and seedling pairs in undisturbed habitats (McAuliffe 1988, Cody 1993, Walker et al. 2015)

• Seedlings likely influenced by multispecies “neighborhoods”

Forbs, Grasses                      Shrubs

  Competitor                       Facilitator

  Opportunistic                    Conservative

(Butterfield & Briggs 2011)
Mojave Network of Long-term Monitoring Sites

- **Implementation**
  - 17 fire locations/7 fires
  - Burn-unseeded, Burn-seeded, unburned
  - Monitoring: 150 m x 2 m belts
Seedling Neighborhoods

• Seedlings counted in each 2 m x 2 m quadrat (brittlebush, cresotebush, bursage)

• Neighboring species counted and classified:
  • Cactus
  • Forb
  • Perennial grass
  • Shrubs* (Shryock et al. 2014)

• Ordination of neighborhood

Forbs, Grasses

*Group 1, 2, 3

Competitor

Facilitator

Opportunistic

Conservative
Neighborhood Influence on Recruitment

Forbs

Group 3

UBCR, $P < 0.01$, $r^2=0.62$

UBCR, $P < 0.01$, $r^2=0.19$
## Soil Seed Bank 5 Years After Seeding

<table>
<thead>
<tr>
<th></th>
<th>Unseeded Burn (#/m²)</th>
<th>Seeded Burn (#/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lsmean 95% CI</td>
<td>Lsmean 95% CI</td>
</tr>
<tr>
<td>Seeded perennial forbs</td>
<td>11 a 5--26</td>
<td>66 b 41--106</td>
</tr>
<tr>
<td>Other perennial forbs</td>
<td>23 13--41</td>
<td>18 10--34</td>
</tr>
<tr>
<td>Seeded shrub</td>
<td>22 a 11--45</td>
<td>3 b 1--10</td>
</tr>
<tr>
<td>Perennial grass</td>
<td>4 1--13</td>
<td>3 1--11</td>
</tr>
</tbody>
</table>
Implications

- Lack of shrubs that provide the regeneration niche for seedlings limits the effectiveness of broadcast seeding

- Alternative practices for reinstating nurse plants are needed (container stock, artificial structure)

- Seeding rate is important to minimize increase in granivore pressure
Establishment of long-lived shrubs

- Hand-sowing of seeds
- Diversionary seeding
- Outplanting seedlings (90,000 over 3 years)
Prioritize Restoration Sites

Provide Suitable Native Plant Materials

Ensure Compatibility with Tortoise Health & Well-being

Implement Appropriate Practices

Kristina Drake, USGS

K. Drake