MOJAVE DESERT GRASSLANDS:

40 YEARS OF COLLECTING HISTORICAL ECOLOGICAL EVIDENCE OF PAST AND PRESENT NATIVE PLANT COMMUNITY DIVERSITY

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HISTORICAL ECOLOGY OF ARID GRASSLANDS

• A diversity of native arid grassland components can be reconstructed among current native plant communities.

• Extensive examination of reference sites across the Mojave Desert of California and Nevada since the 1980s.

• Historical record searches.

• Herbaria collections.

Squirreltail grass (Elymus elymoides) field sketch on reference site
Grassland communities may have been a more common part of deserts, intermixing with Mojave desert scrub, Joshua tree savannas, and wetlands.

Distinct desert grassland communities are evidenced in the west Mojave Desert region, eastern Mojave Desert region, and a distinctive desert grassland type in the northern Mojave.

Desert wetlands also contain a significant grass component.
Desert needlegrass (*Stipa speciosa*)  
Calflora.org
• Desert needlegrass (*Stipa speciosa*)
Desert needlegrass bunches are an important part of West Mojave plant communities. Near the town of Mojave, CA. The Desert Tortoise Research Natural Area is in this region in Kern County, CA.
Desert needlegrass bunches greening up and flowering in April 2019 in the West Mojave during a rainy spring, with *Phacelia* and goldfields.
Indian rice grass (Stipa hymenoides)
Indian rice grass pure stand in southern Great Basin, Big Smoky Valley, Nevada, near Tonopah.
• Sandberg bluegrass (*Poa secunda*) lush bunches in Carrizo Plain, right, and below a drying tuft in the Nevada Mojave Desert. These small perennial tufts are often missed in surveys.
Sandberg bluegrass was once very common across the Mojave Desert. Carrizo Plain bunches mixing with red brome during a rainy spring.
Native perennial bunchgrass bottlebrush squirreltail (*Elymus elymoides*) is common in the West Mojave, and widespread in desert mountains.
But wait! Native Annual Grasses

Native annual grasses are still found in the West Mojave Desert and may have been more widespread before European settlement.

Illustration based on field sketches in the Mojave Desert around the towns of Mojave and California City:

Above: introduced non-native annual grasses are abundant in tortoise habitat, including red brome (*Bromus rubens*) and splitgrass (*Schismus* spp.).

Yet we found rare native annual grasses mixing in: small fescue (*Festuca microstachys*) and possibly Arizona chess (*Bromus trinii* = *B. berteroanus*). Small fescue is a definite native. Arizona chess is under a current controversy as to whether it is introduced from South America or native.
West Mojave creosote and Joshua tree flats with red brome and other invasive annual grasses. We found native annual grasses commonly here. Kern County, CA.
Small fescue (*Festuca microstachys*) in creosote flat, West Mojave Desert, Kern County, CA.
Native annual grass small fescue (Festuca microstachys) in Carrizo Plain with goldfields and tidy tips, as well as non-native red brome.
EAST MOJAVE

Blue grama
(*Bouteloua gracilis*)--perennial

Sixweeks grama
(*Bouteloua barbata*)--annual
• Big galleta grass (*Hilaria rigida*) flourishes on wildfire burns in Joshua tree savanna, Cima Dome and Round Valley, Mojave National Preserve, CA.
Bush muhly (*Muhlenberiga porteri*), a perennial decreaser with livestock grazing.
Left, Cima Dome, Mojave National Preserve: perennial bunchgrass Spike dropseed (Sporobolus contractus) growing on a burn; spike, right. In the foreground grows annual sixweeks grama (Bouteloua barbata). Below, annual needle grama (Bouteloua aristidoides).
After a rainy summer monsoon in Mojave National Preserve, the annual grasses grow abundantly: Sixweeks grama, and lovegrasses (*Eragrostis* spp.)—some of which may be introduced.

Annual lovegrass (*Eragrostis mexicana*), Annual needle grama (*Bouteloua aristidoides*), Annual sixweeks grama (*Bouteloua barbata*)
During rainy monsoonal summers, puffballs—a fungus—can be found growing, here among annual sixweeks grama and lovegrasses, Mojave National Preserve, CA.
Fluff grass (*Dasyochloa pulchella*), Mojave National Preserve, San Bernardino County, CA.

Also common in the northern Mojave Desert.
Red three-awn (*Aristida purpurea* var. *longiseta*), a cool-season perennial bunchgrass of the eastern Mojave Desert.
Diverse desert grassland with Joshua trees, Mojave yucca, and buckhorn cholla, Castle Mountains, CA-NV border. Big galleta grass mixes with purple three-awn (*Aristida purpurea*).
Blue grama (*Bouteloua gracilis*), Mojave National Preserve, CA, noteworthy in this far-western range as it is one of the dominant perennial grasses of the Great Plains region of North America.
NORTH MOJAVE

James galleta (*Hilaria jamesii*)
James galleta grass (*Hilaria jamesii*), Gold Point Mountains, Nye County, Nevada
James galleta grass becomes extensive in central Nevada Great Basin valley floors.
Desert bighorn sheep grazing on James galleta grass, Nevada.
DESERWETLANDS

Saltgrass (*Distichlis spicata*)
Alkali sacaton 
(*Sporobolus airoides*) and honey mesquite in Sandy Valley, Inyo County, CA, playa edge.
Saltgrass (*Distichlis spicata*) alkaline meadow along the Amargosa River, Oasis Valley, Nye County, Nevada. Northern Mojave Desert.
C3 AND C4 ADAPTATIONS

• Cool season C3 grasses dominate western Mojave Desert regions, transitioning to warm season grasses in eastern Mojave regions.
• Warm-season grasses are known as C4 plants, as they use the four-carbon compound PEP carboxylase in photosynthesis. PEP carboxylase is a photosynthetic enzyme that can “attract” CO2 more efficiently than C3 plants and allows the stomates of the plant to be closed more often—an adaptation to drought.

Temperature responses of photosynthesis in C3, C4, CAM plants

THREATS

• Historic and ongoing habitat degradation from livestock grazing and off-highway vehicle use
• Invasive non-native grasses and forbs
• Habitat destruction and fragmentation from renewable energy, urbanization
• Drought/climate change
Invasive introduced weeds are taking over desert grasslands because of disturbance: Cheatgrass (*Bromus tectorum*), red brome (*B. rubens*), Sahara mustard (*Brassica tournefortii*), and others.
Off-road vehicle recreation is increasing on public lands, and degrades native plant communities. Apple Valley CA.
Poorly managed public lands livestock grazing degrades and eliminates native desert grasslands. East Mojave, CA.
Ephemeral allotments for sheep in West Mojave.

Goldfields, showy gilia, notchleaf phacelia, Parry linanthus, desert dandelion.
Domestic sheep herds crossing highway 14 in Kern County near Mojave, CA.
Sheep-grazed West Mojave Desert next to the Desert Tortoise Research Natural Area, April, 2019. Trampled ground, sheep manure, grazed vegetation, and splitgrass (*Schismus* spp.) spreading due to soil disturbance. *Erodium* abundant.
Sheep and cattle grazing allotments on public lands in the West Mojave Desert degrades native desert grasslands and wildflower communities.

April 2019, Desert Tortoise Research Natural Area outside the fence on public lands: sheep grazing on ephemeral allotment on land managed by Bureau of Land Management.
Before and after in the West Mojave Desert nest to the Desert Tortoise Research Natural Area: thistle sage in an ungrazed desert habitat, compared to a sheep-grazed allotment on the Cantil Common Allotment, Kern County, CA. The plants are knocked down, trampled, and grazed by sheep (April 2019).
Above left, Desert Sunlight Solar Farm graded; below left, Sunshine Valley Solar Project drive and crush construction; above, Pahrump Valley Solar Project drive and crush/mowed in operation, tortoise-permeable fences.
Delicate Biological Soil Crusts with big galleta.

Drive and crush renewable energy construction methods can degrade Biological Soil Crusts and soil health.
Semi-trucks delivering palettes of solar project materials, driving onto desert site from a new access road. Sunshine Valley Solar Project under construction in Amargosa Valley, NV.
**Utility-scale solar energy** development threatens many desert grasslands.

Indian rice grass on lower Mormon Mesa, NV. Battle Born Solar Project was proposed to develop over 9,000 acres here with photovoltaic energy and battery storage.

Gila monster photographed on Mormon Mesa.
RECOMMENDATIONS

• Native grasses provide cover for tortoises from predators such as ravens.
• Native grasses are an indicator of less disturbed plant communities.
• Be careful using herbicides treatments for red brome, as there may be native grasses too.
• Consider mitigation measures and restoration activities of desert habitats that include native grasses—both perennial and annual.
Parallels with Greater sage-grouse: need perennial grasses and sagebrush for cover from predation.
Desert tortoise confronted with introduced annual splitgrass (*Schismus* sp.), northern Mojave Desert, Beatty, Nevada.

Contact me at lcunningham@westernwatersheds.org for more information and a PDF of this presentation.
Grassland restoration increases native plant cover, but interviews indicate only a subset of regionally available species are used.

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2022 CNPS Conference
October 22, 2022
Acknowledgements

For their contributions or input:

Volunteers and Interns:
Jess Fan Brown, Hallie Holmes, Juan Carlos Moso, Owen Taffe, Graeme Tanaka, Zach Toledo, Jane Weichert, Justin Xie, Nathan Zhu

For their generous funding support:
- UCSC Jean H. Langenheim Fellowship in Ecology and Evolution
- Golden Gate National Recreational Area
- Griswold Fellowship
- UCSC Hardman Native Plant Award
- Northern California Botanists
- UCSB Coastal Fund
- California Native Plant Society
- California Native Grassland Association
California coastal grasslands

- Unique summertime fog
- Dominated by perennials and annual forbs
- High species diversity

Ford and Hayes, 2007; Keeler-Wolf et al. 2007
Perennialization = increased dominance & abundance of perennial species

Ford and Hayes, 2007; Keeler-Wolf et al. 2007; Lesage, Howard, Holl 2018

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Restoration – A Growing Priority

Convention on Biological Diversity

California Biodiversity Initiative
A Roadmap for Protecting the State’s Natural Heritage

Aronson & Alexander, 2013
Brancalion et al., 2014
California Coastal Commission, 2018

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Variability in restoration

Grassland restoration outcomes are relatively unknown

For few projects resurveyed, outcomes are variable

Lack of funding leads to limitations during initial site assessments

Suding 2011; Adler et al. 2013; Brudvig et al. 2017
Management practices can greatly differ depending on agency

Practices may differ because project goals differ

There are limited sources of funding for restoration

Holl and Howarth 2000; Clewell and Aronson 2006
Rowe 2010; Homewood et al. 2001

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Science-Practice Gap

- Undertaking research studies without talking to those who may use results

- Lack of communication leads to results that are not easily applied to real-world problems

- Published research may be hard to access

Cabin 2010; Dickens and Suding 2013; Matzek et al. 2015; Carter et al. 2020
Research Questions

1. Does coastal grassland restoration meet project-based goals and a standard performance metric?

2. Is native cover related to project age?

3. What are the biggest barriers to achieving restoration goals?

4. How does funding and maintenance influence outcomes?
Restoration project selection

- 1000-km N-S gradient
- Identified 37 projects (of 48 possible)

Selection Criteria:

1. At least 3 years post-planting or -seeding
2. Size > 1 acre
3. Coastal grassland

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Field Surveys

• Used 0.25 m$^2$ quadrats every 5-m along 50-m transects

• 3 – 16 transects, scaled to site size (1-32 acre)

• Estimated absolute cover of all plants

• Collected 3 soil samples per transect in 2019
Document analysis

-reviewed project documents prior to vegetation surveys

Projects with documents = 63%

Baseline data, goals, strategies, and investment

Mazmanian and Sabatier 1983; Dunn 2000; Kubrin 2005; McDowell 2010

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Semi-structured interviews

[Interviewed one or more practitioner from each site]

[A single practitioner may be linked to more than one project]

[Focused on barriers to achieving goals, and implementation strategies]

Mazmanian and Sabatier 1983; Dunn 2000; Kubrin 2005; McDowell 2010

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Surveyed projects were mostly voluntary

- 41% Statutory
- 59% Voluntary

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Restoration is largely successful at reaching project goals

Standard performance metric:
25% native cover and 6 native species after 5 years

Project-based goals:
Varied directional goals, focused on native cover

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Plant cover is relatively stable with project age.

- Native cover range = 13% to 79%
- Native richness range = 5 to 60
Non-native competition strongly impacts restoration efforts
Native species richness per hectare is negatively associated nonnative plant cover
Financial cost has no direct effect on plant metrics but higher maintenance intensity improve biodiversity.
Barriers to achieving restoration goals

🌍 Invasive species management = 100%

🌍 Funding levels = 84%
   🗺️ Post-implementation monitoring = 20/27 (74%)

🌍 Sourcing appropriate and sufficient plant material* = 34%

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Regional biotic homogenization

88% of projects use species because they survive better or grow faster

Biotic homogenization = reduction of biological diversity through dominance of a few key species

<table>
<thead>
<tr>
<th>Species</th>
<th>Percentage</th>
<th>Occupancy</th>
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<tbody>
<tr>
<td><em>Stipa pulchra</em></td>
<td>69%</td>
<td>X X X X X X X X X</td>
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<tr>
<td><em>Elymus glaucus</em></td>
<td>59%</td>
<td>X X X X X X X X X</td>
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<tr>
<td><em>Bromus carinatus</em></td>
<td>50%</td>
<td>X X X X X X X X X</td>
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<tr>
<td><em>Hordeum brachyantherum</em></td>
<td>44%</td>
<td>X X X X X X X X X</td>
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<tr>
<td><em>Festuca rubra</em></td>
<td>31%</td>
<td>X X X X X X X X</td>
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<tr>
<td><em>Achillea millefolium</em></td>
<td>22%</td>
<td>X X X X X X X</td>
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<tr>
<td><em>Danthonia californica</em></td>
<td>22%</td>
<td>X X X X X X X X</td>
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<tr>
<td><em>Deschampsia caespitosa</em></td>
<td>17%</td>
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Holl, Luong, Brancalion 2022; Lesage, Howard and Holl 2018
Using more species can counter homogenization but is associated with greater costs.

A

![Histogram of Restoration species vs Project count](chart.png)

B

![Scatterplot of Restoration species vs Cost/ha ($x1,000)](chart.png)

C

![Scatterplot of Rarefied native species richness vs Restoration species](chart.png)
Summary: Grassland restoration is largely successful

- Successful at achieving project-based goals and standard metric

- Invasive species control

- Most projects indicate that they would have done more if possible

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Summary: Obstacles to increasing regional diversity

- Risk aversion in achieving project goals
- Difficulty in sourcing appropriate plant material

Lesage, Press and Holl 2020
Restoration needs more money and policy

- When possible, restoration should add native annual species and regionally rare species to species palettes.
- Change statutory requirements for mitigatory restoration projects.
- Expand research and production of less used species.
Regional Coordination

- Forming a working group or agency to coordinate restoration plant selection and share knowledge

- Explore the use of less common species with a shared-risk model

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Thank You

Happy to take any questions or feedback

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Stipa pulchra
COASTAL PRAIRIE RESTORATION
Choosing Plants for Success

CLIMATE CHANGE

STUDY BY
JUSTIN LUONG
KAREN HOLL & MICHAEL LOW

ART BY
LESLEY GOREN

CLIMATE CHANGE WILL ALTER PRECIPITATION

PERIODS OF Drought WILL AFFECT COASTAL PRAIRIE COMMUNITIES

WHAT Restoration Plantings Will Be Most Successful For Changing Habitat Conditions?

SERIOUS Drought WILL HELP SAVE WATER

PERIODS OF Drought WILL AFFECT COASTAL PRAIRIE COMMUNITIES

GRASSLAND RESTORATION IS EXPENSIVE, CAN BE UNPREDICTABLE

2665 LEAF SAMPLES COLLECTED

Drought Related Traits Were Measured From Each Leaf Sample. Plots Were Assessed for Plant Cover.

DRIED AMOUNT OF RAINFALL

Drought Treatment

Greater Abundance of Invasive Nonnative Grasses and Forbs

Greater Abundance of Native Grasses and Forbs

THE STUDY RESULTS SUGGEST THAT THE SELECTED NATIVE SPECIES ARE BETTER ADAPTED TO Drought THAN THE INVADERS IN THE PLOTS.

PLANTS WITH THESE TRAITS WERE MORE SUCCESSFUL:

Slower Growth Rate Overall

More Lobe Overall

Higher Carbon to Nitrogen Ratios in Drought Water Plots

Higher Delta Carbon-13 Drought Plots

A Species More Closely Related to Neighbors Were Less Likely to Die

AS THE CLIMATE CHANGES PERIODS OF Drought WILL INCREASE. UNDERSTANDING Functional Traits + Phylogenetic Distance CAN HELP INCREASE NATIVE COVER IN FUTURE RESTORATION PROJECTS.
California coastal grasslands

Native Perennial Bunchgrasses

Native Annual Forbs

Non-native annual grasses and forbs

Ford and Hayes, 2007; Keeler-Wolf et al. 2007
Conserving Native Coastal Prairie on Martin Griffin Preserve: Reintroduction of fire as a disturbance process

Brian Peterson
Fire Ecologist, Fire Forward

October 22, 2022
Martin Griffin Preserve
Martin Griffin Preserve
Changing Vegetation
Grassland Reduction
Goals

• Increase native grassland cover
• Increase native species diversity
• Mosaic structure
• Reintroduce fire as a disturbance process
• Stop encroachment
• Where we can, reverse encroachment
Challenges

- Coyote brush is hard to burn
- Coyote brush is hard to kill
- New Douglas fir forest is dense
- Containment line is a challenge
- Seed stock
Methods

• Burning
• Cutting
• Collect seed and plant
Coastal Prairie Project Area

- Coastal Conservancy Grant
  - Map Remnant Native Grassland
  - Hire Crews to Cut Material
  - Burn
  - Collect Seed
  - Monitor
Preserve Vegetation
Remnant Native Grassland Mapping
Priority Work Areas
Priority Work Areas

Before

After
Monitoring
Seed Collection
Next Steps

- More diversity
- Species targets
- Seed Collection and amplification
- Containment line/no containment line
Thank You!
Using Fine-Scale Grassland Mapping for Conservation and Management

CNPS Conference
October 2022

Dina Robertson, EBRPD
ebparks.org
Shelly Benson, Benson Biological Consulting
BensonBioConsulting.com
East Bay Regional Park District

- 150K acres
- ~70K acres of grasslands in the Park District
- 5 grassland landscape units (1 not shown here—"coastal grasslands")
Grasslands have a “PR problem”

- Dismissed and generalized “non-native annual grassland”
- Under-sampled
- Undescribed types
- Coarse scale mapping
- Rare grassland types
Native grasslands persist!

*Nassella pulchra* Association, Pleasanton Ride Regional Park
Some plants/stands over 100 years old
Native grasslands persist!

*Eschscholzia californica* Association, Pleasanton Ridge Regional Park
EBRPD grassland mapping

- Fill the knowledge gap
- Avoid impacts
- Inform adaptive management
- Get people excited about grasslands!
Vegetation Classification

A Manual of California Vegetation (MCV)

Vegetation Classification System:

- Broad
  - 1. Formation Class
  - 2. Formation Subclass
  - 3. Formation
  - 4. Division
  - 5. Macrogroup
  - 6. Group
  - 7. Alliance
  - 8. Association

Vegetation Classification

Coarse scale

Fine scale
Grassland PR Problem: Coarse Scale Mapping

• New countywide fine scale maps
• *Spoiler Alert*: grasslands mapped to Macrogroup
  • Limitations in remote sensing
Grassland PR Problem: Coarse Scale Mapping

- New countywide fine scale maps
- *Spoiler Alert*: grasslands mapped to macrogroup
  - Limitations in remote sensing
- Uncover grassland diversity using ground-based mapping
Grassland Map Area

- Field Mapping: Spring 2021 & 2022
- Area: 2,043 ac
Native Grassland

Map area = 2,043 ac
% Native = 13% (266 ac)

Pt. Pinole
Map area = 255 ac
% Native = 28%

Map area = 1,900 ac
% Native = 53%
### Grassland Communities

- **19 Types**
- **18 Native Types**
- **11 Sensitive Natural Communities (S1-S3)**
- **4 Undescribed**

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<thead>
<tr>
<th>Vegetation Type</th>
<th>Description</th>
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<tr>
<td><strong>Avena spp.-Bromus spp. Semi-Natural Alliance</strong></td>
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<tr>
<td>Bromus carinatus-Elymus glaucus Alliance</td>
<td>Bromus carinatus Association</td>
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<td>Elymus glaucus Association</td>
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<td>Pteridium aquilinum-Grass Association</td>
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<td>Corethrogyne filaginifolia-Eriogonum (elongatum, nudum) Alliance</td>
<td>Eriogonum nudum Provisional Association</td>
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<td>Viola pedunculata – (Eschscholzia californica – Nassella pulchra) Provisional Association</td>
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<td>Viola pedunculata-Erodium botrys Provisional Association</td>
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<tr>
<td><strong>Eschscholzia (californica)-Lupinus (nanus) Alliance</strong></td>
<td>Eschscholzia californica Association</td>
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<td>Lupinus bicolor Provisional Association</td>
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<td>Festuca idahoensis-Danthonia californica Alliance</td>
<td>Festuca idahoensis-Nassella pulchra Provisional Association</td>
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<td><strong>Leymus cinereus-Leymus triticoides Alliance</strong></td>
<td>Leymus triticoides Association</td>
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<td>Lotus scoparius-Lupinus albifrons-Eriodictyon spp. Alliance</td>
<td>Lupinus albifrons Association</td>
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<td><strong>Nassella spp.-Melica spp. Alliance</strong></td>
<td>Melica californica Association</td>
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<td>Nassella lepida Provisional Association</td>
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<td>Nassella pulchra Association</td>
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<td>Nassella pulchra-Avena spp.-Bromus spp. Association</td>
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<td></td>
<td>Nassella pulchra-Hemizonia congesta Association</td>
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<td></td>
<td>Nassella pulchra-Sisyrinchium bellum Provisional Association</td>
</tr>
<tr>
<td><strong>Native Perennial Forbs and Grasses Provisional Alliance</strong></td>
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New Types

**Viola pedunculata-(Eschscholzia californica-Nassella pulchra)** Provisional Association

Native perennial form, mesic sites (N-side tower)

**Viola pedunculata-Erodium botrys** Provisional Association

Non-native annual form, dry sites (W-side tower)
New Types

Nassella pulchra-
Sisyrinchium bellum
Provisional Association
Pleasanton Ridge Regional Park Grassland Map

- MMU: ~1/6 ac
- Area: 1,800 ac
- Non-native annual grass matrix
- High diversity of native types
- Native stands average 1 ac
Garin Regional Park Grassland Map

- Area: 220 ac
- Non-native annual grass matrix
- Map complexity = environmental complexity
What’s next?

- Application of data
- Monitoring
- More mapping!
- Research
- Outreach!

Grassland monitoring in _Fetuca idahoensis_ Association, Pleasanton Ridge Regional Park
Lupinus albifrons Association  

Nassella pulchra Association  

Viola-(Eschscholzia-Nassella) Association  

Bromus carinatus Association

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Shelly Benson: Shelly@BensonBioConsulting.com (BensonBioConsulting.com)
Native plants play a critical role in the resilience of California grasslands under a changing environment.

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Mary Cadenasso
Sarah Gaffney
Geneva Iversen-Krampitz
Carolyn Malmstrom
David Mitchell
Kevin Rice
Maggie Shepherd
& large team of helpers in the field and lab
California grassland’s native plants are critical for ecosystem resilience under changing conditions

• Wildflowers as emergency first responders
• Perennial grasses
  • Enhance water availability
  • Resilient to disturbance
  • Suppress late-season noxious weeds
Wildflowers are our emergency first-responders to drought, fire, disturbance, but may be at risk

- Dormancy
- Opportunistic - “Blink on and off”

-Diversity and quantity of seedbank is declining
  - Nutrient enrichment (Eskelinen et al 2021)
  - Warmer and drier winters (Harrison et al 2015)
  - Thatch build up, lack of disturbance
How can we enhance the forb seedbank?

- Moderate grazing enhanced forb seedbank → forbs replaced grasses during drought → no change in cover or biomass (vs. decreased in ungrazed conditions) (Hallett et al. 2017)

- Mowing
- Prescribed fire
- Is any disturbance sufficient to enhance forbs by decreasing grass competition and thatch?
Fire mortality- seeds

• Vulnerable to fire: Up to 85% of seed production from the previous growing season is in the thatch layer (Young et al. 1981)
• Seeds in the soil seed bank may be critical for post-fire resilience
Mendocino Complex Fire:
late July 2018

Prescribed fires: June 2018
In response to both prescribed and wildfires:
- Grass seedling germination decreased 7-fold.
- Forb germination decreased 33%.
Grazing decreased fuel load:
→ Less grass seed mortality
→ Higher density of forbs germinating in response to wildfires
Grazing doesn’t influence vegetation composition after fire

Fire only slightly decreases grass cover, despite large decreases in the seedbank

Fire increases perennial grasses and bulbs

Fire more than doubles forb and legume cover

Type of fire influences which species most respond:

- Forbs:
  - Prescribed fire → increased Erodium
  - Wildfire → increased cover of a diversity of forbs, including bulbs

- Legumes
  - Prescribed fire → increased clovers
  - Wildfire → increased clover, lupine, lotus
California grassland’s native plants are critical for ecosystem resilience under changing conditions

- Wildflowers as emergency first responders
- Need to offset declines in forb seedbanks by introducing disturbances (e.g. grazing increases forb seed bank to enhance drought response)
- Grazing increases forb germination post-fire (stimulates germination? enhances survival?) but does not influence which forbs respond to fire
- Type of fire influences which forbs dominate—wildfire results in more diverse forbs
  - Prescribed fires may not enhance forb diversity

- Perennial grasses
California grassland’s native plants are critical for ecosystem resilience under changing conditions

- Wildflowers as emergency first responders
- **Perennial grasses**
  - Enhance water availability
  - Resilient to disturbance
  - Suppress late-season noxious weeds
Native perennial grass restoration increases annual grass resilience to drought. Even a low cover of native perennial grasses (15-20%)

Natives have higher deep-root biomass → Increases deep-soil water holding capacity
Native perennial grass restoration increases annual grass resilience to drought
Even a low cover of native perennial grasses (15-20%)

- Natives have higher deep-root biomass
  - Increases deep-soil water holding capacity
  - Increases rooting depth of annual grasses
  - Annuals stay green 2 weeks longer into the dry season
  - 50% increased seed production
  - Could increase rate of post-drought recovery
California grassland’s native plants are critical for ecosystem resilience under changing conditions

- Wildflowers as emergency first responders
- Perennial grasses
  - Enhance water availability
  - Resilient to disturbance
  - Suppress late-season noxious weeds
Native perennial grasses resprout within 2 weeks after fire.
Native perennials withstand the drought, and quickly gain cover afterwards.
California grassland’s native plants are critical for ecosystem resilience under changing conditions

• Wildflowers as emergency first responders
• Perennial grasses
  • Enhance water availability
  • Resilient to disturbance
  • Suppress late-season noxious weeds
Native perennials can provide direct competition for late-season resources
Native restoration can suppress noxious weeds over time

- Over time, noxious weeds in annual exotics are highly influenced by annual rainfall, vs. natives suppress noxious weeds.
- Native perennials can actually increase during drought, leading to increased suppression of noxious grasses after drought.

[Graph showing the percentage cover of noxious weeds over years with different trends for exotic annuals and native perennials.]
California grassland’s native plants are critical for ecosystem resilience under changing conditions

• Wildflowers as emergency first responders
  • Perennial grasses
    • Native grass cover is resilient to drought
    • Low amount of native grass cover can increase deep soil moisture and extend overall grassland green season and seed production
    • Native grasses suppress late-season noxious weeds
    • Native grasses resprout quickly after fire
      • Post-fire window for restoration to control noxious weeds?
Resilience to increased change and variability in California’s grasslands:
1. Promoting forbs is critical for maintenance of plant cover and biomass in response to drought, fire, and other disturbances
2. Promoting native perennial grasses is the most effective long-term control over noxious new invasives, contributes to post-fire recovery, and improves soil water availability for all grassland species during drought