
**Symposium Organizer:** Sarah Kulpa

**NAC20 Program Topic:** Development and use of native seed in natural areas management

**Description:** Native plant diversity is the hallmark of a healthy ecosystem. In the Great Basin, our native plant communities are threatened by the accelerated invasion of non-native species, altered fire regimes, grazing, drought, and climate change. Slowing and reversing this large-scale conversion will require coordinated efforts between researchers and land managers. Selecting the right native seed for the restoration of these native plant communities is crucial for success. This session will highlight the science and restoration efforts utilizing native seeds and plant materials in the sagebrush ecosystems of the Great Basin.

Registration

**Presentation Title:** Strong patterns of intraspecific variation and local adaptation in plants of the Great Basin, USA, revealed through a review of 75 years of experiments on 121 taxa

**Presenter:** Owen Baughman

**Co-authors:** Alison Agneray, Matt Forister, Francis Kilkenny, Erin Espeland, Rob Fiegener, Matt Horning, RC Johnson, Tom Kaye, Jeff Ott, Brad St. Clair, Beth Leger

**Abstract:** Variation in natural selection across heterogeneous landscapes often produces 1) among-population differences in phenotypic traits, 2) trait-by-environment associations, and 3) higher fitness of local populations. Using a broad literature review of common garden studies published between 1941and 2017, we documented the commonness of these three signatures in plants native to North America's Great Basin, an area of extensive restoration and revegetation efforts, and asked which traits and environmental variables were involved. We also asked, independent of geographic distance, whether populations from more similar environments had more similar traits. From 327 experiments testing 121 taxa in 170 studies, we found 95.1% of 305 experiments reported among-population differences, and 81.4% of 161 experiments reported trait-by-environment associations. Locals showed greater survival in 67% of 24 reciprocal experiments that reported survival, and higher fitness in 90% of10 reciprocal experiments that reported reproductive output. A meta-analysis on a subset of studies found that variation in eight commonly-measured traits was associated with mean annual precipitation and mean annual temperature at the source location, with notably strong relationships for flowering phenology, leaf size, and survival, among others. Although the Great Basin is sometimes perceived as a region of homogeneous ecosystems, our results demonstrate widespread habitat-related population differentiation and local adaptation. Locally-sourced plants likely harbor adaptations at rates and magnitudes that are immediately relevant to restoration success, and our results suggest that certain key traits and environmental variables should be prioritized in future assessments of plants in this region.

**Presentation Title:** Getting the right seed: Seed collection collaboration in the Great Basin

**Presenter:** Fred Edwards

**Co-authors:** Jess Kindred, Sarah Kulpa, Dirk Netz, Russ Wilhelm, Eric Roussel

**Abstract:** Wildland seed collections are the starting point for native seed research, development, and restoration. In Nevada, the Nevada Native Seed Partnership (NNSP) is strategically leveraging Seeds of Success collections of target native grasses and forbs across key seed zones, one of the many actions being implemented as part of the Nevada Seed Strategy. Finding common ground among NNSP members is key to our success; target species selected are beneficial to greater sage-grouse and pollinators and have some cultivation research completed to show how they will perform in an agricultural setting. Our ultimate goal is to increase the availability of genetically, appropriate native seed to improve the health, diversity, and success of restoration efforts and plant communities in the Great Basin. Here, we discuss the steps taken and lessons learned from our coordinated seed collection efforts in Nevada.

**Presentation Title:** Restoration from seed in the Great Basin: What are we doing well, and is there room for improvement?

**Presenter:** Elizabeth Leger

**Co-authors:** Sarah Barga, Alison Agneray, Owen Baughman, Robert Burton, Mark Williams

**Abstract:** Restoring dryland ecosystems can be extremely challenging, due in part to environmental constraints that naturally limit recruitment. When highly competitive invasive annuals and modified disturbance regimes are added to the mix, restoration from seed in dryland systems can be very daunting. Despite these challenges, seeding in the Great Basin continues to be one of the world's biggest ongoing restoration efforts, and millions of pounds of seeds are applied to wildlands, especially post-fire, in an attempt to prevent the transition of these ecosystems to invasive annual plants. Some of our practices are at the forefront of restoration best practices, such as clearly identifying seed sources, detecting weed contamination, measuring seed viability, and conducting large-scale agricultural increases for the largest seeding projects. Still, other methods deviate from recommended practices (e.g. current seed sources emphasize only a few functional groups, species, and gene pools). Great Basin case studies and large-scale reviews indicate that there is room for improvement in restoration outcomes, and research suggests that changing seed sourcing could be a way to increase restoration success. In addition to presenting these case studies and reviews, I will highlight an ongoing collaborative effort to implement restoration best practices, in Winnemucca, NV. This collaboration has resulted in the large-scale agricultural increase of locally-collected, source identified, weed-free seeds for use in post-fire restoration projects. While environmental constraints and weed pressure are difficult to control, starting restoration with seeds most likely to survive in semi-arid, invaded sites may be a way to increase overall success in this wild but imperiled region.

**Presentation Title:** Using the right seed: Improving native plant restoration in the Great Basin

**Presenter:** Sarah Kulpa

**Co-authors:** Elizabeth Leger, Owen Baughman, Robert Burton, Fred Edwards

**Abstract:** The Great Basin is home to some of the US's largest expanses of wild landscapes, supporting a wide range of plant and animal diversity. However, our native plant communities are threatened by the accelerated invasion of non-native annual grasses, altered fire regimes, drought, and climate change. Slowing and reversing this large-scale conversion will require coordinated efforts between researchers and land managers, working together to identify the most promising seed sources for restoring disturbed and invaded sites. Working with Seeds of Success teams, we collected seeds of native grass species sourced from within an area of Northern Nevada that experiences frequent fire and increased these seeds through a commercial seed producer. These locally-collected and seed-zone matched sources were sown in post-fire locations similar to the original collection locations, in experiments designed to test the long-term performance of locally sourced and increased seeds compared to the partially native seed mixes made from the best available standard cultivars and releases. We will present the experimental design and preliminary data from these seedings, highlighting the successful partnerships working to determine the best ways to restore and preserve our most impacted native plant communities.

**Presentation Title:** No really, what is local? A methodological approach to measuring patterns of local adaptation, evaluating alternative

**Presenter:** Francis Kilkenny

**Co-authors:** Sarah Barga, Alison Agneray, Owen Baughman, Robert Burton, Mark Williams

**Abstract:** As the need for ecological restoration increases, more seed will be required to meet global demands. The geographic source and evolutionary history of seeds used in restoration is important to the long-term success of restoration projects, especially in changing climates, but there is a vigorous international debate over the degree to which local adaptation should be considered in seed-sourcing decisions. While heated opinions exist across the spectrum, few studies have measured patterns of local adaptation with the scale and precision necessary to resolve these debates. This lack is due, in part, to the fact that common garden studies-the only way to directly measure local adaptation-tend to be costly and thus limited in scope. Due to the cost of developing high quality common garden datasets, several shortcut methods have been proposed to develop seed transfer guidelines, including the use of her barium records and climate data to construct species-specific ecological niche models, and the use of outlier DNA markers to detect potential climate-adapted alleles. While these methods hold promise, their accuracy must be verified with high quality common garden data. Currently, too few integrative studies exist to have a generalized understanding of the effectiveness of these methods. In this talk, I will discuss how to develop common garden datasets that measure patterns of local adaptation at the scale and precision necessary to resolve seed-sourcing debates, and to provide the needed data to verify or discard shortcut methods for seed transfer guideline development, while remaining cost and time efficient. Examples will be used from a methodological approach that is being implemented in the Intermountain West and Great Basin of the United States to develop seed transfer guidelines for important restoration species. This approach uses smart common garden design and close integration with DNA sequencing studies to build high quality datasets, which allow for the evaluation of novel methods of seed transfer guideline development and the support of seed-sourcing decisions in an era of global change.

**Presentation Title:** Forb common garden research to inform seed transfer guidance for restoration

**Presenter:** Sarah Barga

**Co-authors:** Francis Kilkenny, Fred Edwards

**Abstract:** As landscape-scale disturbances increase across public lands, understanding how to restore plant communities is of critical importance. Part of incorporating native plants into restoration is understanding the level of flexibility they display when moved away from their location of origin. Some species may be more flexible to novel conditions than others, and many arid-land species display population-level variation in their performance. Common gardens are a tool for examining variation in performance across the range of a species, and the best way to develop seed transfer guidance for restoration. While past common garden work conducted by the Great Basin Native Plant Project (USFS? Rocky Mountain Research Station and BLM? Plant Conservation and Restoration Program) has focused on dominant perennial grasses, their current work focuses on native forbs. We selected three species of forbs common across the Great Basin and known to be of interest for restoration due to their value as forage and cover resources for wildlife. To allow for population genetics work to occur alongside the common garden study, both seeds and plant tissue were collected for some species. In this talk, I will focus on the technical aspects of carrying out a large-scale common garden project, ranging from locating potential sites and site selection to garden installation and trait measurement. I will also present preliminary results for the first year of plant performance. A project of this scale also requires many partners to coordinate resource acquisition, land use, and garden monitoring. The end product will be a spatially-explicit restoration tool for land managers that will inform the appropriate selection of seed for particular restoration projects, as well as multiple research publications. This work is a step toward the larger goal of creating a streamlined approach to seed transfer development for forbs, with the plan of adding three species this year and three more species over the next couple of years.

**Presentation Title:** Surviving in the invaded desert: A climate-and trait-based approach to restoration in the Great Basin

**Presenter:** Alison Agneray

**Co-authors:** Thomas L. Parchman and Elizabeth A. Leger.

**Abstract:** In the Great Basin, there have been enormous efforts from both land managers and scientists to select genetically and environmentally appropriate seed materials for restoration projects. While most of these efforts focus on matching the climates of both seed source and planting site, plants coming from similar abiotic conditions can vary in phenotypic traits. Matching environments is not always sufficient for guaranteeing success, particularly in the most disturbed sites. Here, we asked if we could find excellent seed sources for restoration by describing plant traits that are adaptive in invaded environments. Focusing on three species of grasses, two shrubs, and two forbs common to the region, we collected seeds of each from 16 locations with similar abiotic conditions. We then planted them in four common gardens in highly invaded systems. Using these seven species from the same sites allowed us to ask whether environmental pressures were selecting for favorable traits across multiple species and functional groups at the same locations, which has not been previously studied. We also measured seed and seedling characteristics for each species and population, including seed size, emergence timing, and root length, among others. We asked:1) whether seed sources differed in survival across gardens; 2) whether any collection locations were highly successful for all species; 3) which potentially adaptive traits were predictive of survival. Populations differed in survival across the gardens in six of the seven species and differed in nearly every seed and seedling trait. The strength of these effects varied among our seven species. For example, *Elymus elymoides* showed the most variation in survival, and *Poa secunda* showed the least. No single source location was superior for all species, but several sites had either above or below average survival for many species. Generally, traits associated with root investment and phenology best predicted survival. In grasses, the populations with earlier emergence and greater root mass ratio were more likely to have increased survival in competitive environments. In the shrubs and forbs, slightly different traits were favored, likely due to their dissimilar growth forms and life-history strategies. These results provide a trait-based approach for selecting seed sources for restoration projects and demonstrated that some locations might contain populations of above-average performance for multiple species. Choosing native plants sources with the most adaptive traits, along with matching climates, will likely be more successful at restoring the most invaded communities.

**Presentation Title:** Improving our chances: when and where can precision techniques and technology reduce variability in restoration outcomes

**Presenters:** Jay Kerby and Owen Baughman

**Co-authors:** Stella Copeland, Owen Baughman, Chad Boyd, Kirk Davies, Tony Svejcar

**Abstract:** Dryland ecosystems represent a significant portion of global land area, support billions of people, and suffer high rates of land degradation. Successfully restoring native vegetation to degraded drylands is a global priority and major challenge, and there is a need for more efficient and successful strategies. We introduce the concept of 'precision restoration' as any approach which addresses individual ecological barriers to restoration success with specific tools or actions that target the barrier. Using the Great Basin, USA as a case study, we present a novel dryland restoration strategy that involves: 1) identifying specific and critical barriers to restoration success at a particular site, 2) understanding the spatial and temporal variation of each barrier, and 3) applying the best available restoration strategies, precision or otherwise, based on the specific barriers identified in the first two steps. We summarize common known and emerging critical barriers to the success of seed-based restoration across the Great Basin, discuss methods for defining the spatial and temporal variability of barriers, and give examples of decision processes that utilize our proposed restoration strategy. The proper application of this strategy will rely upon assembling information generated by both research and management. By shifting the initial focus of restoration planning away from tool selection and toward defining barriers to success and their spatiotemporal variability, the eventual choice of tools and techniques to use, and where to use them, will improve restoration outcomes and efficiency.

**Presentation Title:** Vegetation succession following post-fire seeding with conventional and native seed mixes in the Great Basin

**Presenter:** Jeff Ott

**Co-authors:** Francis F. Kilkenny, Daniel D. Summers, Tyler T. Thompson

**Abstract:** Long-term effects of post-fire seeding with conventional and native seed mixes were examined by following vegetation succession at two sites in Tintic Valley, Utah, where a seeding experiment had been installed following wildfire in 1999. Vegetation of seeded treatments and unseeded controls was monitored during post-fire years 1-3 and 16-18. All of the tested seed mixes became established and influenced successional trajectories during this timeframe. Conventional seed mixes with introduced species most effectively suppressed exotic annuals but did not follow a successional trajectory toward reference conditions from prior to the fire, while native seed mixes generally became more similar to reference vegetation over time. These results underscore the importance of identifying desired long-term outcomes of post-fire seeding and formulating seed mixes accordingly.

**Presentation Title:** The Sagebrush in Prisons Project: Restoring lands and lives

**Presenter:** Shannon Swim

**Co-Authors:** Stacy Moore, Tom Kaye

**Abstract:** The purpose of the 'Sagebrush in Prisons Project' is to improve habitat for greater sage-grouse by engaging state and federal prison systems in the production of sagebrush for habitat restoration. Greater sage-grouse was considered for listing by the U.S. Fish and Wildlife Service but was not warranted due to extraordinary conservation efforts by many federal, state, and local entities. However, conservation efforts must continue to maintain the integrity of these populations. Loss of sagebrush habitat is the primary driver of the decline of this species in the western United States. Production of sagebrush within state and federal prison systems represents a unique opportunity to provide urgently needed plant materials as well as providing information to incarcerated men and women concerning sagebrush conservation. Institute for Applied Ecology (IAE), a nonprofit organization based in Oregon, runs the 'Sagebrush in Prisons Project,' and works closely with Bureau of Land Management (BLM) and correctional center partners across the country to employ the National Seed Strategy and produce genetically appropriate native plant material for restoration projects. IAE is currently working with nine prisons in five different states. Locally, the program works with three prisons in the state of Nevada; Northern Nevada Correctional Center, Warm Springs Correctional Center and Lovelock Correctional Center, and a Federal Correctional Institution in Herlong, California to propagate hundreds of thousands of sagebrush plugs for restoration projects on BLM lands. IAE staff oversees plant production at the prison facilities, from seed germination through growth and delivery. Since the project’s inception in2014, over 1.5 million genetically appropriate native plant plugs have been produced for habitat restoration, while also allowing this underserved population the chance to be a part of something positive and changing their perspective on the importance of the sagebrush ecosystem.

**Presentation Title:** The sagebrush field of dreams project

**Presenter:** Valda Lockie

**Co-author:** Amanda Gearhart

**Abstract:** Wildfire is a major threat to sage-grouse, a sagebrush-obligate that was considered for listing by the U.S. Fish and Wildlife Service. In 2012, a 315,000-acre wildfire burned approximately one-third of the BLM Eagle Lake Field Office, much in sage-grouse 'Priority Habitat' in northeastern California and northwestern Nevada. Within the burned perimeter, approximately 5,000 acres were drill seeded and20,000 acres were aerial broadcast seeded with sagebrush (*Artemisia tridentata*), bitterbrush (*Purshia tridentata*), and various native perennial grasses. In addition, several areas were hand planted with bare-root and containerized sagebrush and bitterbrush seedlings. Subsequent monitoring revealed thatre-seeding efforts were largely unsuccessful, including the hand planted areas which had less than a 3%survival rate. Many factors contributed to low survival rate including drought and non-local seed sources. Due to this seeding failure, in 2015, local sagebrush seed was collected and sent to Northern Nevada Correctional Center for propagation. In the fall of 2016, 2,000 sagebrush seedlings were planted on BLM land in partnership with the USGS with a goal to create sagebrush islands to improve sage-grouse habitat. In 2017, this process was repeated with more than 50,000 seedlings distributed among five study sites, three sites on BLM Eagle Lake Field Office lands in California and two sites on the BLM Sierra Front Field Office lands in Nevada. Line point intercept and shrub density monitoring began in the fall of 2018 and is planned to continue through the 2020 field season. Preliminary monitoring results suggest that hand planting local sagebrush seedlings may increase mean annual survival rates.