Science Support for Emergency Stabilization and Rehabilitation Planning in the Northern Great Basin

Version 2024

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This document was originally developed in the aftermath of the 2012 wildfire season to provide relevant science for use in preparing post-fire Emergency Stabilization and Rehabilitation plans. The information below is arranged by topic and is relevant to both public and private sagebrush rangelands within the northern Great Basin with an emphasis on areas likely to be impacted by invasive annual grasses. Our goal with this document is to create a pathway for quickly linking relevant science with issues that are likely to be a part of ESR planning. Click on the icons at the end of paragraphs to access the literature.

Goal-setting is a necessary first step in planning post-fire restoration
Clearly articulated **goals** in ESR planning are invaluable for prioritizing ESR activities as well as monitoring and evaluating outcomes. Goals should relate to ecological outcomes, not treatment benchmarks (e.g., restoring resistance to invasive annual grasses within a 5-year time frame vs. applying pre-emergent herbicide to 5000 acres). Goal setting and restoration planning are described in Mangold et al. (2005). Goals should include easily measured benchmarks, as well as realistic timeframes for planning and evaluation of outcomes. Thoughtful timeline for monitoring restoration outcomes will allow practitioners to distinguish persistent postfire increases in invasive annual grasses from transient postfire effects, and will more accurately reflect progress towards desired ecological outcomes. Whenever possible, leave out small areas from treatments for monitoring as 'controls'; this will greatly assist with learning from the contrast of 'no treatment' with 'treatment(s)'. An example of utilizing controls to evaluate ESR success at a landscape scale is pasted below ("Final Report.Miller Homestead").

Mangold et al. 2005. Restoration guideline: Final Report.Miller Homestead.pdf

Strategically grazing post-fire landscapes with virtual fencing
On federal lands, grazing management is typically curtailed post-fire (for approximately 2 years) to allow for vegetation recovery. In cases where portions of a pasture remain unburned, those unburned areas must be fenced for grazing to occur and such fencing is often financially, logistically, or administratively infeasible. In such cases, virtual fencing technologies may be an option for grazing unburned areas while keeping livestock out burned portions of a pasture. While virtual fencing is not 100% effective in containing animals, research indicates it is

sufficiently effective to provide protection to vegetation recovering from fire (Boyd et al. 2022).

Boyd et al. 2022.
Virtual fencing effectiv

Importance of large perennial grasses in annual grass-prone environments
Within sagebrush plant communities, plant functional groups vary with respect to their influence on post-fire successional trajectories. In low to mid-elevation sagebrush plant communities, established large perennial bunchgrasses (both native and non-native) play a critical role in decreasing invasion rates of exotic annual grasses (Chambers et al. 2007, Davies 2008). Davies et al. (2009) reported that degree of post-fire invasion of cheatgrass increased when bunchgrass mortality (in the fire) was high. Decreases in other plant functional groups (e.g., shrubs) have not been shown to affect annual grass invasion.

Davies 2008. Medusahead dispe... Chambers et al. 2007. What makes. Davies et al. 2009. Interacti...

Fire-based perennial bunchgrass mortality/fire severity
Perennial bunchgrasses are a key plant functional group for maintaining plant community resistance to invasion by exotic annual grasses, but because their growing points are at or near ground level, these species can be killed by wildfire. Thus, fire effects on susceptibility of a plant community to annual grass invasion are a function of pre-fire perennial bunchgrass abundance and mortality of bunchgrasses during the fire. Mortality rates of perennial bunchgrasses during wildfire are a function of heat load, which is governed by factors including proximity to woody fuels and the amount of litter within bunchgrass crowns. Boyd et al. (2015) found that post-fire soil color (black under shrubs and brown in interspaces) and depth of burn of individual bunchgrasses could be used to accurately characterize plant community level fire-based mortality of perennial bunchgrasses; and by extension could be used to help inform spatial allocation of post-fire bunchgrass rehabilitation effort. Hulet et al. (2015) presented a framework for using pre-fire fuel composition and structure data to infer likelihood of post-fire resistance to annual grasses at the plant community scale. Anthony et al. (2024) found that post-fire invasive annual grasses increased most with high pre-fire annual grass:perennial grass ratios, and where pre-fire abundance of shrubs was > 10% (which may be linked to the effects of shrubs on fire-based perennial bunchgrass mortality). Use of emerging geospatial tools (e.g., the Rangeland Analysis Platform, https://rangelands.app/; The SageCon Landscape Planning Tool, https://oregonexplorer.info/content/sagecon-landscape-planning-tool?topic&ptopic) will help determine pre-fire fuel and biotic characteristics within large landscapes, which informs pre-fire fire resilience and can be used to spatially inform allocation of ESR resources.

Boyd et al. 2015. Predicting fire-based Hulet et al. 2015. Prefire (preemptive) Anthony et al. 2024. nSatellite-derived prefi

Not all burned areas need rehabilitation

Natural recovery refers to the post-disturbance change in plant communities in the absence of rehabilitation treatment. Previous research in good condition Wyoming big sagebrush communities has shown that natural processes can result in the recovery of some plant functional groups within relatively short time frames, but the extent of natural recovery is strongly related to the characteristics of the disturbance (Boyd and Svejcar 2011). Research has shown that burned areas with sufficient pre-burn perennial bunchgrass abundance are less likely to need post-fire rehabilitation (James and Svejcar 2010). Davies et al. (2007) reported that fire in good condition Wyoming big sagebrush increased herbaceous production. In another study, (Pyke et al. 2003) nearly 2/3 of native species on rehabilitated Great Basin rangeland were the product of natural recovery, not rehabilitation treatment. Additionally, recent research (Davies et al. 2024) indicates that *drill seeding itself represents a disturbance that is capable of increasing the abundance of invasive annual grasses* and thus should only be used where likelihood of natural recovery is low. In summary, "no treatment" may be the best decision in areas with high resistance/resilience, relatively intact pre-fire perennial bunchgrass communities, and/or low burn severity. Note that "no treatment" does not preclude prioritization of relatively intact areas (pre-fire) for Early Detection and Rapid Response monitoring (see the "Maintain" category in document linked to the "Strategic allocation of restoration resources across post-fire landscapes" section below). The SageCon Landscape Planning Tool can be used to evaluate both abiotic resistance and resilience as well as pre-fire plant community composition: https://oregonexplorer.info/content/sagecon-landscape-planning-tool?topic&ptopic. This tool also includes layers representing post-fire likelihood of annual grass invasion and an elevation and heatload index (which is another way to think about and map potential for resilience to fire and resistance to post-fire annual grass invasion; e.g., high elevation wet vs lower elevation dry sites).

Boyd and Svejcar. 2011. The ... | Davies et al. 2007. Short-term... | Pyke et 2003. Coordinated Ir | James and Svejcar. 2010. Lim... | Davies et al. 2024. Post-fire managemen

Seed mix considerations

Because of high mortality at the seedling stage (James 2011; Boyd and James 2013) in most cases it is better to seed perennial bunchgrasses at high rates in smaller areas than at low rates across larger areas (Davies et al. 2024). Seed rate per species should be only slightly lower (if at all) with increasing seed mix diversity, because drastically reducing the seed rate per species will lead to low density for the 'winners' in the seed mix and result in ultimate failure to meet restoration goals. Seed mixes should be aligned with *soil characteristics and invasive annual grass abundance* (see "Native perennial bunchgrass species vs. introduced perennial species" below) and include at least a few species and/or seed sources (particularly in all native mixes) to maximize the likelihood of initial success. General guidelines for formulating seed mixes and related restoration planning considerations can be found in Mangold et al. (2005).

James et al. 2011. Demographic process | Boyd and James. 2013. Variation in tim | Davies et al. 2024. Long-term effects of r | Mangold et al. 2005. Restoration guidelines

Planting native perennial bunchgrass species vs. introduced perennial grasses

As we all know there is a tremendous push to use native perennial bunchgrass species in post-fire rehab. However, a considerable body of evidence suggests that the probability of establishment of planted perennial bunchgrasses is much higher with aggressive non-native perennial grasses like crested wheatgrass as compared to native species. Because of the increased establishment probability, planting crested wheatgrass can be a valuable tool (vs. native species) on low to mid elevation sites that are prone to annual grass invasion/expansion in the post-fire environment, particularly in areas that are already dominated by invasive annual grasses (Davies et al 2021, 2021b; see the "Contain" category in document linked to the "Strategic allocation of restoration resources across post-fire landscapes" section below). Davies et al. (2024) found no benefit to co-seeding native and introduced perennial bunchgrasses, and suggested seeding the former only on sites where they are reasonably likely to succeed (see the "Improve" category in document linked to the "Strategic allocation of restoration resources across post-fire landscapes" section below) and the latter on sites where seeding success is unlikely with native species. The following references report and generally discuss relative success rates of native vs. introduced perennial bunchgrass seedstock.

Boyd and Davies 2012. Differe... | Boyd and Davies. 2012. Spati... | Boyd and Davies. 2010.pdf | Hull.1974. Species for seedin... | Robertson et al. 1966. Respo...

Davies et al. 2021. Living with exotic ann | Davies et al. 2021b. Seeding locally sourc | Davies et al. 2024. Post-fire managemen

Pre-emergent herbicide for annual grass control and assisting in perennial restoration

Regardless of plant materials used in restoration seed mixes, competition from invasive annual grass species can limit success of seeded perennial species. Pre-emergent herbicides can be used to create a relatively competition free environment to help bolster success of seeded or existing perennial species (Davies and Sheley 2011). The window of reduced competition varies with product applied; approximately 1 year for imazipic and approximately 3 years for indaziflam. Pre-emergent herbicides have been used successfully to restore both perennial bunchgrasses and sagebrush (Clenet et al. 2019). If pre-emergent herbicides are used as a precursor to seeding, it is critical that seeding be delayed until herbicide toxicity has been minimized (Davies et al. 2014). If pre-emergent herbicides are used as a tool to release existing perennial vegetation from competition with annual species, it is critical to have sufficient perennial vegetation on site prior to herbicide application (i.e., the herbicide will limit recruitment of both annuals and desired perennial species). This is especially important with indaziflam given the longer duration of toxicity. The SageCon Landscape Planning tool (https://oregonexplorer.info/content/sagecon-landscape-planning-tool?topic&ptopic) can be used to estimate pre-fire abundance of desired perennial species, as well as the likelihood of fire-induced transition to annual grasses.

Davies and Sheley. 2011. Promoting nati Clenet et al. 2019. Native seeds incorpo Davies et al. 2014. Can impazapic and se Davies et al. 2023. Effects of using indazi

Methods for restoring big sagebrush or other keystone shrub species

Post-fire restoration of sagebrush works in service of a number of goals including maintenance of intact native sagebrush plant communities, defending and growing "core" habitats, and habitat conservation for a wide variety of sagebrush-associated wildlife species. That said, if the immediate ESR goal involves decreasing potential for expansion and infill of invasive annual grasses, sagebrush as a functional plant group is not as important as large perennial bunchgrasses (see "Importance of large perennial grasses" above) and could actually decrease resistance if/when the area burns again (see "Fire-based perennial bunchgrass mortality/fire severity" above).

Broadcast seeding of sagebrush can be successful within mountain big sagebrush plant communities (Davies et al. 2019). Within the annual grass zone typified by Wyoming or basin big sagebrush, traditional broadcast or drill seeding of big sagebrush is often unsuccessful (Lysne and Pellant 2004; Knutson et al. 2014). Fall or spring planted sagebrush seedling transplants are an alternative that has shown promise in a number of studies (see Copeland et al. 2022 and Holfus et al. 2024). Competition with annual (Holfus et al. 2024) and perennial (McAdoo et al. 2013) herbaceous vegetation can reduce vigor of transplants and application of herbicide to reduce herbaceous competition can reverse these effects (McAdoo et al. 2013). Sagebrush transplants have been shown to increase growth and reproductive effort with post-planting grazing, which has the added benefit of reducing likelihood of subsequent wildfire/loss of sagebrush planting investment (Davies et al. 2020). Selectively planting post-fire transplants in locations formerly under sagebrush canopies (vs. interspace) can significantly increase transplanting success due to increased soil nutrients and reduced competition (Davies et al. 2018). Transplants are expensive on a per acre basis and because of that expense, managers may opt to wait a year post-fire to evaluate natural recovery and thus the need for transplants. Sagebrush seed has limited temporal viability (Wijayratne and Pyke 2009) and if natural recover does not occur the year following fire then, particularly on large fires, assisted restoration may be necessary.

Davies et al. 2019. postwildfire seeding t Lysne and Pellant.2004.Establish Knutson et al. 2014. Long-term seeding ef Copeland et al. 2022. Stomatal cond Holfus et al. 2024. Wyoming big sagebr McAdoo et al. 2013. Site, competition and

Davies et al. 2020. Response of planted Davies et al. 2018. Improving restoration Wijayratne and Pyke. 2009. Investigating se

Strategic allocation of restoration resources across post-fire landscapes

Post-fire ESR planning is made difficult by both the large scale at which fires often occur as well as the variability in biotic and abiotic factors within burn scars. Recent advances in geospatial technology provide information that can help mitigate both of these factors. The document below ("Strategic ESR.v1.1") uses geospatial information on biotic (e.g., pre-burn plant composition) and abiotic properties (e.g., resistance and resilience) to spatially partition post-fire landscapes into categories that suggest appropriate post-fire management response, in service of the goal of increasing resistance to invasive annual grasses within the burned area. Please note that this document is "draft" and is being refined based on our continuing interactions with land managers.

Strategic ESR.v1.1.pdf

Reducing potential for future fire/increasing the durability of ESR investments

ESR investments (particularly investments in sagebrush restoration) can be put at risk by future wildfire, especially if annual grasses increase post-fire and/or if perennial grasses increase post-fire (either through natural recovery or seeding). Both of these scenarios increase fine fuels, and accumulation of fine fuels is the best predictor of wildfire occurrence in sagebrush ecosystems (Smith et al. 2022). Livestock grazing can be used to reduce the likelihood of ignition (Davies et al. 2017; Orr et al. 2023), and if fires do occur, the behavior and severity of the resulting fire (Davies et al. 2009; 2015). Recently developed geospatial models (e.g., https://rangelands.app/great-basin-fire/) can be used to identify areas of the landscape where fine fuels represent a fire hazard and this technology can be combined with virtual fencing to strategically focus livestock grazing within those areas (O'Connor, in prep). Virtual fencing can also be used with grazing to create fuel breaks within fire-prone landscapes (Boyd et al. 2022).

Smith et al. 2022. WHere there's smoke,	Davies et al. 2017. Fall and spring grazin	Orr et al. 2023. Grazing intensity effec	Davies et al. 2009. Interaction of historic	Davies et al. 2015. Winter grazing can re	Boyd et al. 2022. Using virtual fencing t

Considering the merits prevention vs. restoration

Success rates of post-fire restoration of native perennial bunchgrasses in low to mid-elevation sagebrush communities are often very low. Exact numbers are hard to come by because of a lack of monitoring effort and likely an underreporting of negative results in the peer reviewed literature. Recent evidence suggests that preventing spread of exotic species is a higher probability option than restoration of invaded sites ("Are we missing the boat" reference below). Davies et al. ("Non-native competitive…" reference below) found that establishing aggressive non-native perennials around existing exotic annual grass infestations dramatically reduced spread of annual grass seed, likely indicating that strategic postfire activities may be a critically important practice for protecting adjacent intact parts of the landscape.

Are we missing the boat.pdf

Non-native ompetitive perenna.

Dealing with wind erosion in the post-fire environment

There will always be some soil erosion following a wildfire disturbance. As vegetation cover on landscape increases, the threat of wind erosion decreases. Generally, wind erosion occurs within the first nine to ten months post-fire. To restore sites that have burned and have high probability of wind erosion use range drills and avoid disking parallel to wind direction. Seed mixes with sterile cover crops (e.g., winter wheat) or grasses that form adventitious roots (e.g., western wheatgrass) might be useful to help stabilize soils and reduce soil erosion.

References:

Wind erosion following wildfire in Great Basin Ecosystems – Fact Sheet

General information on annual grass management, sage-grouse habitat, and sagebrush steppe conservation

Saving the sagebrush sea.pdf

Medusahead management in sageb

Crawford et al. 2004. Ecolog...

Miller Eddleman 2000.pdf

Davies et al. 2006. Vegetation characteri

Davies et al. 2007. Environmental and ve

The sagebrush conservation design: https://www.usgs.gov/publications/a-sagebrush-conservation-design-proactively-restore-americas-sagebrush-biome