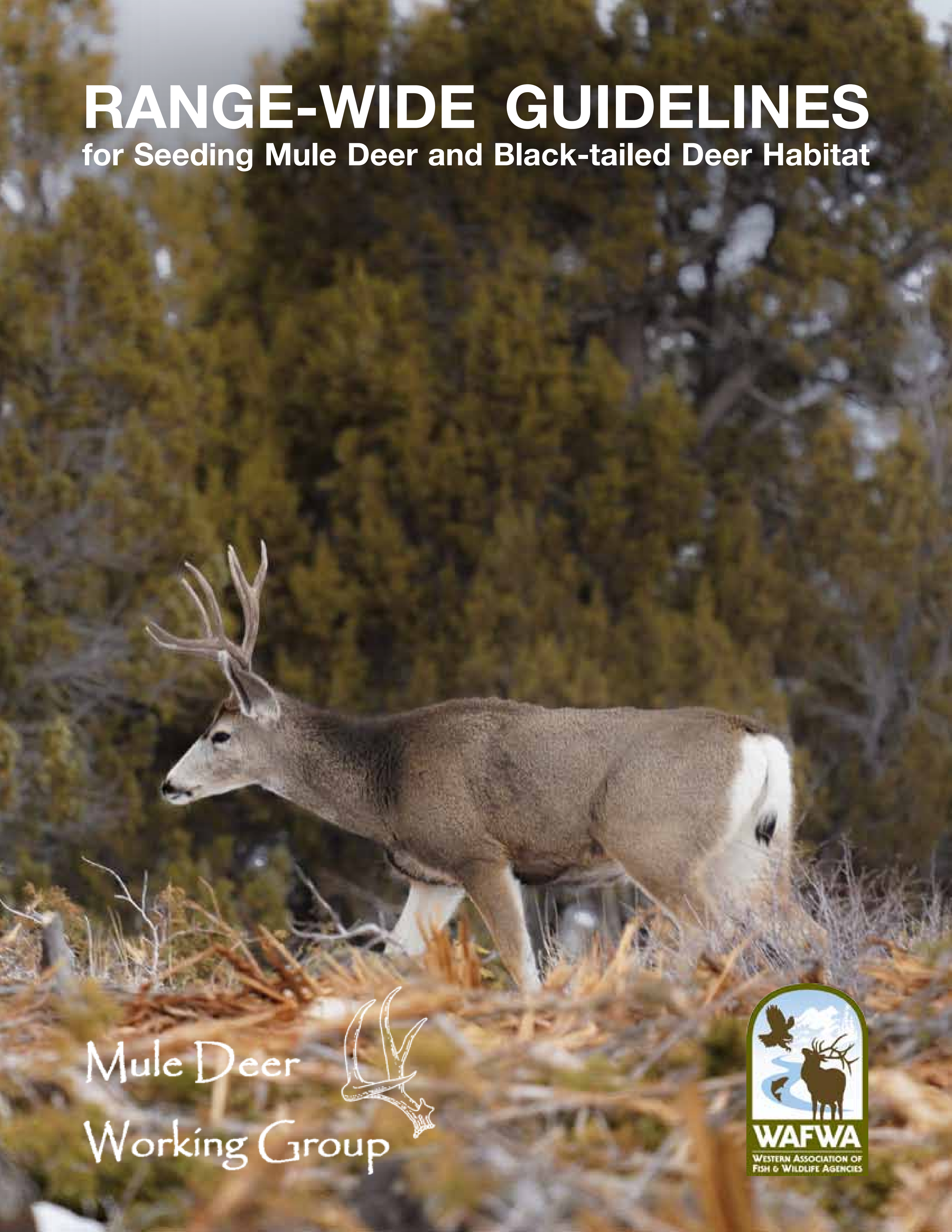
RANGE-WIDE GUIDELINES
for Seeding Mule Deer and Black-tailed Deer Habitat



Mule Deer Working Group

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Introduction

High-quality, abundant habitat is the foundation of healthy, growing mule deer and black-tailed deer (*Odocoileus hemionus*) populations. It ensures that individuals within populations have adequate food, water and shelter so they can survive and reproduce. Maintaining the right balance of productive deer habitats is one of the greatest challenges facing managers today. Human development, invasive species, changing climatic conditions, and the increasing frequency and intensity of wildfires are just some of the disturbances that are impacting the quantity and quality of mule deer and black-tailed habitat throughout their range. The need for restoration and conservation of mule deer habitat is an immense task (Remington et al. 2021). Lack of disturbance on some landscapes may also negatively impact mule deer habitats, and result in conditions where populations may not be allowed to grow. Managing landscapes to include early successional stages is generally beneficial to mule deer. Some disturbances such as prescribed fire or mechanical removal of shrubs and trees are done purposely to improve habitats by returning them to earlier successional stages (Wakeling & Bender 2003, Schroeder & Kauffman 2021). Other disturbances such as prolonged drought and expansive wildfire cannot be planned for. In either case, proactive or reactive, some type of restoration action, including reseeding, is often required following disturbance to ensure mule deer habitats maintain the right balance of food and shelter to help mule deer thrive. Following a megafire in Idaho, Germino et al. (2018) found that sagebrush established in 50% of plots where it was aerially seeded, a > 12-fold greater establishment frequency than in unseeded areas. This finding is important because aerial seeding is relatively low cost compared to other seeding or planting methods.

Figure 1. Mule deer bucks utilizing an area seeded after a wildfire. (Photo by Clint Wirick/US Fish and Wildlife Service).

These guidelines cover a variety of topics that experienced restoration practitioners have found to be important in determining the success of restoration efforts. These include: policy and position statements regarding seeding on federal

lands; ecological sites and seeding site selection; species selection, seed quality, and seeding rates; seedbed preparation and seeding techniques; post seeding maintenance and monitoring; and the importance of restoration partnerships in achieving success. Additional information on these and other restoration related topics can be found in a myriad of places, many of which are contained in the reference section of these guidelines.

Successful restoration and reseeding efforts can be complex, especially when multiple entities and jurisdictions are involved. Think of these guidelines as a quick reference to be used early in the restoration planning process to identify the important elements that need to be addressed to ensure successful restoration outcomes. Conversely, these guidelines are not meant to be a one-stop shop that provides all the answers to successful habitat restoration actions. Becoming familiar with and adhering to the information presented in these guidelines can aid biologists, land managers and restoration practitioners in providing high quality habitats for mule deer and black-tailed deer and assist them in successfully navigating the challenges of restoration and reseeding actions.

Adaptive management (Williams et al. 2009) is a systematic approach for improving resource management by learning from management outcomes. Adaptive management is framed within the context of structured decision making, with an emphasis on uncertainty about resource responses to management actions and the value of reducing that uncertainty to improve management. To improve long-term success, an adaptive management approach can be used with the overall goal of restoring desirable plant communities. The stepwise process for adaptive management involves:

1. Assessment of the overall problem,
2. Establishing management goals and objectives,
3. Implementation of control strategies and measures,
4. Monitoring the effectiveness of management actions,
5. Evaluating actual outcomes in relation to expected results, and
6. Adjusting practices as necessary.

Steps of this process should be repeated in sequence as part of a continuous learning cycle that improves management planning and strategy by learning from the outcomes of previous management actions. In general, an adaptive management strategy is considered to be successful if:

1. Stakeholders are actively involved and remain committed to the process,
2. Monitoring and assessment are used to adjust and improve management decisions, and
3. Management goals and/or objectives for the resource are being achieved.

Project Planning and Basic Considerations

There are a few basic principles to consider when planning a habitat improvement project for mule deer or for any wildlife species (Plummer et al. 1968, Stevens 2004a). Identifying and understanding the current vegetation and ecology of the site is important in predicting what response the site will have to disturbance. This not only includes biotic factors such as the current assemblage of plant species, but also abiotic factors such as topography, soils and precipitation. Past land use practices also greatly affect site potential. By considering the principles outlined in this document the probability of success is greatly increased.

Are changes to the community necessary and attainable?

Project planning and implementation requires information on the habitat needs and any habitat limiting factors for the selected wildlife species for the particular landscape in the project area. If an area provides optimum habitat for a key wildlife species, then wildlife habitat improvement should not be used as a justification for a rehabilitation and restoration project. Revegetation normally involves changes in community composition, plant cover and density, and reduction in competition from undesirable species. If the results are to be sustainable, sites targeted for revegetation must have the ecological potential to support the proposed changes and to initiate natural successional processes following treatment. This includes terrain, soil, and precipitation (Stevens 2004a). Tools that are available to help determine if the ecological change is possible include Ecological Site Descriptions and Resistance and Resilience concepts (USDA Natural Resources Conservation Service 2021; Chambers et al. 2014a and 2014b). These are discussed later in the document.

Seedbed Preparation and Control of Competition

For newly seeded plants to emerge and establish, existing vegetation must be reduced or removed. Adequate site preparation is the single most important factor that can be controlled to give a planting the highest chance of success. Competition among plant species must be understood and managed on the site, including the possible increase of undesirable or invasive weed species. Reducing competition can be done with herbicides, mechanically, through targeted grazing, or with fire. Once competition is controlled, seeding in a well-prepared seedbed with the best techniques for the various seeds will give seeded species a much higher probability of surviving and establishing in the community (Stevens 2004a). This principle is further discussed in the Seedbed Preparation and Seeding Techniques section.

Figure 2. Mule deer buck in a tree removal project. (Photo by Clint Wirick/US Fish and Wildlife Service).

Seeding Considerations

When planning a seeding project there are a number of factors to consider when deciding what to seed. Understanding the objective of your project is a big factor in what species are selected. Different agencies may have different policies regarding what may be planted on the lands they administer (see Existing Seed Policies and Position Statements section). The selected species need to be adapted to the site location in order for them to establish and persist. Even the source of the selected species should be considered as not all varieties of the same species are adapted to all locations. Other considerations include: seeding rates, selecting species that are compatible together, seed availability, understanding seed quality, and timing of seeding (Stevens 2004a).

Post-Treatment

Properly managing seedings after treatment is also important to maintain the investment in the project (Stevens 2004a). Considerations include: grazing and wildlife management, weed management, and future treatment such as prescribed burning and other human activities. Monitoring is also an often overlooked post-treatment consideration. Monitoring is critical to understand if the project is meeting the desired objectives in both the short and long term.

Partnerships

Finding rangeland ecologists, wildlife biologists, soil scientists, or others with working knowledge of local ecosystems is very beneficial. Working together with others that have years of experience will also be extremely valuable in planning a successful habitat improvement project.

Ecological Site Descriptions as Guidance for Site Potential

Applied ecologists, and all managers of wildlands, make decisions based on guidelines, theory, research results, and experience of others and themselves. Management is a challenging task, and its difficulty is compounded by the complexity of natural systems, varying goals, skill, resources, and technology to accomplish objectives. Success can be increased by relying on information about a site's potential that is developed and organized to be as specific as possible.

Site potential is something every applied ecologist needs to understand. There are important variables of climate, soil and physiography that determine the potential of any site. Ecological sites are an effective tool to conceptualize and relate site potential to restoration work.

Ecological sites provide a consistent framework for classifying and describing rangeland and forestland soils and vegetation; thereby delineating land units that share similar capabilities to respond to management activities or disturbance (USDA Natural Resources Conservation Service 2021). Ecological site classification is an approximation of the environment to the best of our understanding. An ecological site is one step in a nested, hierarchical land classification system, and is made up of a group of soil components that have the same potential to produce a certain kind and amount of vegetation. Ecological sites are documented and described in Ecological Site Descriptions (ESDs). ESDs are reports that provide detailed information about a particular kind of land - a distinctive Ecological Site. ESDs provide land managers the information needed for evaluating the land as to suitability for various land-uses, capability to respond to different management activities or disturbance processes, and ability to sustain productivity long term (USDA Natural Resources Conservation Service 2021).

Abiotic factors (see sidebar) are the components that define the potential of an ecological site. A certain assemblage of factors has a predictable outcome of a unique ecological site. When various disturbances or management occur, a given ecological sites will yield a variety of plant communities as shown in the state and transition model (see Interpreting Ecological Site Descriptions below).

Abiotic Factors

- **CLIMATE**
  - Moisture
    - Precipitation
      - Extremes and variability
      - Timing and amount
      - Type (rain or snow)
    - Flooding and ponding
      - Frequency and duration
    - Water table depth
  - Temperature
    - Extremes and variability
    - Freezes
      - Frequency and duration
    - Heat for plant growth
    - Season length
  - Wind
    - Speed
    - Frequency and duration
- **SOIL**
  - Water holding capacity
    - Texture
    - Rock fragment %
      - Surface
      - Subsurface
    - Organic matter
    - Depth and thickness
  - Parent material
  - Chemistry (salinity, carbonates, pH, etc.)
  - Structure
- **PHYSIOGRAPHY**
  - Geography (latitudinal and longitudinal gradients)
  - Elevation
  - Slope
  - Aspect
  - Landscape position

Considering the multitude of abiotic factors that affect the site's potential, and the many ways that we measure, stratify and organize their continuous values, we shouldn't be surprised to find an extensive list of ecological sites on western rangelands. For example, over 550 ecological sites have been identified in Utah, more than 1,000 have been identified in Nevada.

ESDs are commonly used as a 'standard of measure' for rangelands. Whenever we are trying to interpret data to determine if rangelands are healthy or unhealthy, in good or poor condition, or changing, ESDs represent a 'yardstick' that rangelands can be measured against.

ESDs are developed during soil survey activities conducted by the Natural Resources Conservation Service (NRCS). Data are combined and analyzed from several sources in order to approximate the historic plant communities as well as other contemporary plant communities that occur on the site. Data collected by government agencies, universities, and historical resources are all considered in developing the species composition and ecological dynamics sections of the ESD. As additional and improved information is obtained, it is incorporated into ESDs during ongoing updates.

Because ESDs are a collection of current knowledge about an ecological site, they are an excellent place for a resource manager to learn about the ecology of their specific work location. ESDs are more specific than using other singular metrics such as precipitation, elevation, or current vegetation to make assumptions about site potential.

Ecological site identification

To be useful for management, an applied ecologist needs to be able to identify the correct ecological site for the potential project area. There are primarily 3 ways to accomplish this: by referring to the soil survey, using an ecological site key, or through knowledge of the ecological site naming conventions in your area. The Natural Resources Conservation Service is a good technical source for ESDs (http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/ecoscience/desc). Another valuable resource is the Jornada Rangeland Research Program website which offers valuable information in understanding ESDs (jornada.nmsu.edu/esd).

Soil Survey

Soil surveys should be utilized to gain information whenever possible. The NRCS soil surveys for North America can be found at websoilsurvey.sc.egov.usda.gov. By locating your area of interest on the map, a myriad of soil information and management interpretations, including ecological site, becomes easily available. Because soil survey maps for wildlands can be broadly generalized, a soil scientist should be consulted, if possible, on the accuracy of designated soil map units for the local area of interest. A field check should also be made to ensure the soil and ecological site are mapped correctly.

Figure 3. Different soil types have different ecological potentials, which are described by Ecological Site Descriptions and State and Transition Models. (Photo by Jamin Johanson, USDA Natural Resource Conservation Service).

Ecological Site Keys

Ecological site keys are being developed for all areas in the West. They are typically designed as a dichotomous key, in the same pattern as most plant taxonomic keys. Because ecological sites may contain several different plant communities, the questions in the key focus primarily on the abiotic factors, so using a shovel to make simple observations of the soil is usually necessary. The best resource to obtain ecological site keys for your area is from the NRCS State Rangeland Management Specialist. Keys may also be available on the Ecological Dynamics Interpretive Tool (EDIT) found at Jornada Rangeland Research Programs (https://edit.jornada.nmsu.edu/).

Ecological site naming conventions

Ecological sites from a region are typically named with a uniform naming convention. Once you find out as much as you can about the abiotic factors (climate of the area, simple soil observations, etc.), you will be able to predict what the name of the ecological site should be and then check the listing of ecological sites in the Ecological Dynamics Interpretive Tool (EDIT, https://edit.jornada.nmsu.edu/) to see if there is a match.

Ideally, more than one technique to identify the ecological site should be used as a double check. Once the choice has been made, the ESD should be obtained from EDIT to verify agreement in the range of characteristics between the ESD and potential project area.

Interpreting Ecological Site Descriptions

Besides the range of characteristics in the abiotic factors, an ecological site description contains a description of the ecological dynamics of the site. This includes a list of plant species and their annual production values expected in a typical year in the historic (pre-European) plant community.

A state and transition model (S&TM) is also included as part of the site description. It consists of a box and arrow diagram showing ecological states (big boxes), plant communities (little boxes), transitions and pathways (arrows). The S&TM diagram communicates the various plant communities that can occur on the site and the typical disturbances (i.e., fire, drought, improper grazing or browsing, erosion, insect or disease, vegetation manipulation, etc.) that occur on the site. The outcomes of these disturbances are shown in the resulting states and plant communities by their arrangement in the S&TM diagram.

One way to think of an S&TM is as a roadmap of alternatives for a manager. Once you locate the current condition on the map (which plant community the site is currently in), then the pathways leading from that plant community represent risks and/or opportunities for change.

The absence of a box or an arrow on the S&TM is often more meaningful than the presence of one. If a manager chooses to try and change from one state to another where no arrow indicates that it has ever been documented or observed, this type of action should be considered research or experimentation, and the risks of those types of undertakings should be considered accordingly.

Each S&TM includes a diagram and several paragraphs of explanatory text in the ESD, with an explanation for each box and arrow in the diagram. In the example state and transition model in Figure 3, several important interpretations can be made, such as:

- Once invasive plants become even a minor part of the plant community, there typically is no way back to a completely native and invasive plant free community once eradication of the invasive weed species is no longer feasible.

- Historically, there was a cycle of fire as a primary disturbance that resulted in a grassland plant community, with time (succession) following this disturbance back to a shrub dominated community.
- From a relatively healthy native plant dominated system (state 2), uncharacteristically frequent fire can lead to cheatgrass (*Bromus tectorum*) dominance (state 5), long term absence of fire can lead to juniper invasion and dominance (state 3), and poor grazing management can lead to broom snakeweed (*Gutierrezia sarothrae*) dominance (state 4).
- When in a degraded state (state 3, 4, or 5), there is only one way out. That is to do a seeding with introduced grasses.
- There may be an opportunity to restore the site to dominance by natives from state 6 through long term proper grazing management or other habitat treatments.

Resistance and Resilience

There are many biotic and abiotic challenges confronted when considering undertaking restoration or rehabilitation on rangelands. The use of resistance and resilience theories is an approach that is being used to link biophysical indicators with species specific population and habitat requisites. This approach attempts to identify and account for complex factors that shape and form rangelands in both time and space. The use of resistance and resilience aids in prioritizing sites where restoration or rehabilitation may be needed and has a higher chance to succeed. It also aids in identifying the potential ecological risks associated with site work. Currently, this approach is primarily being applied to reduce impacts of persistent threats from invasive annual grasses and altered fire regimes on sagebrush ecosystems and Greater sage-grouse (*Centrocercus urophasianus*), particularly in the western portion of the species range (Chambers et al. 2016).

Resistance is the ability of an ecosystem to maintain characteristic processes despite various stressors or disturbances. Resistance to invasives are the biotic and abiotic factors and ecological processes in an ecosystem that limit the population growth of an invading species (Chambers et al. 2014).

Resilience is the capacity of an ecosystem to regain characteristic processes over time following stress or disturbance. Resilient ecosystems have the capacity to regain their fundamental structure, processes, and functioning when altered by stressors like drought, and disturbances like inappropriate livestock grazing and altered fire regimes (Allen et al. 2005, Chambers et al. 2014b, Holling 1973).

Ecological thresholds are crossed when an ecosystem does not return to the original state via natural processes following disturbance, and requires active management to restore (Chambers et al. 2014). Resistant ecosystems have the capacity to retain their fundamental structure, processes, and functioning when exposed to stresses, disturbances, or invasive species (Folke et al. 2004, Chambers et al. 2014b).

Understanding the resistance and resilience theories can aid managers in the decision-making process. Areas for priority treatment can be identified and active and/or passive restoration or revegetation activities can be designed and implemented.

Online tools are becoming available to help determine and utilize this concept (Sage Grouse Initiative 2020).

Field guides for selecting appropriate treatments, such as the guides developed by Miller et al. (2014, 2015) in the Great Basin, demonstrate excellent decision making processes to consider when planning a project and assessing a site. These field guides provide a score sheet for rapid assessment to rate resilience and resistance to invasive annuals in the Great Basin ecoregion. These assessments help determine physical factors such as soil temperature and available moisture along with current and pre-fire vegetation that will determine how a site will respond to disturbance. Understanding this potential response can help plan a more successful treatment and whether a site needs to be seeded.

Using the S&TM example in Figure 3, we can learn from the ESD that the Upland Gravelly Loam (Wyoming big sagebrush) ecological site occurring in the Great Salt Lake Area (Major Land Resource Area 28A) has an aridic xeric soil moisture regime and a mesic (warm) soil temperature regime. Using the table on page 17 of the Restoration Handbook for Sagebrush Steppe Ecosystems with Emphasis on Greater Sage-Grouse Habitat— Part 1. Concepts for Understanding and Applying Restoration (Pyke et al. 2015), that combination of moisture and temperature regimes results in a moderate resilience and moderately low resistance.

These interpretations from the example S&TM shown here can guide management decisions on this specific ecological site.

The example S&TM presented here (Figure 3) was chosen intentionally because of the disconsolate outlook and painful reality it conveys. Recognize that it is only an example, and S&TMs representing sites with improved abiotic characteristics will appropriately present better options for habitat improvement through restoration actions. The ideas on this S&TM are derived from actual observations, and are not based on expert opinion alone. For instance, for a successful native seeding to be included in this S&TM, an example would have to be observed on this ecological site. As additional and improved information is obtained, it is incorporated into ESDs during ongoing updates.

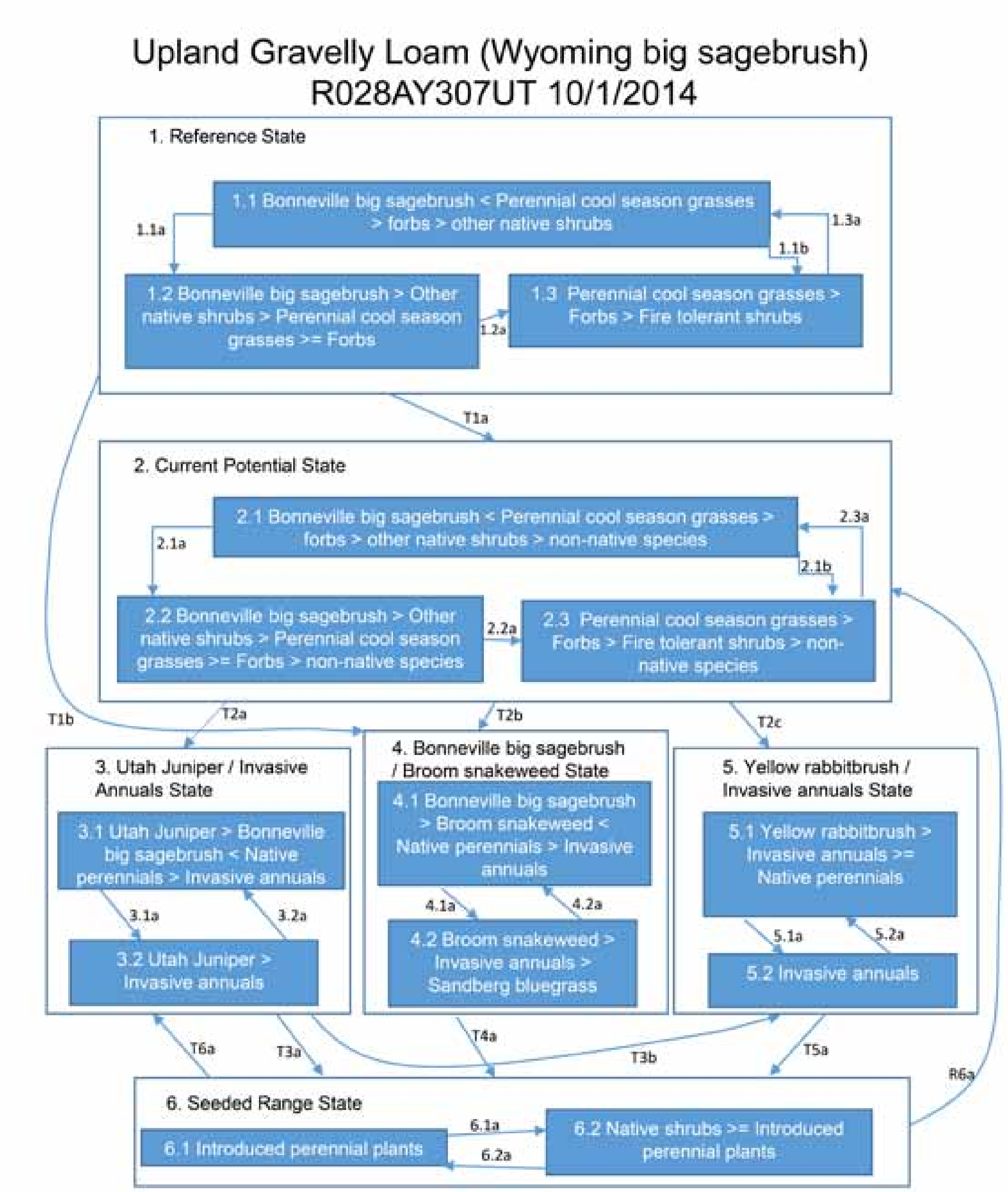

Figure 4. Example of a state and transition model from the Great Salt Lake Area. Transitions: T1a: Introduction if invasive species (primarily cheatgrass); T1b, T2b: Improper grazing; T2a: Long term absence of fire; T2c, T4b, T3b: Frequent fires; T3a, T4, T5a: Rangeland seeding, primarily introduced grasses; R6a: Long term proper grazing management. Plant community pathways: 1.1a, 1.2a: Fire, drought; 1.3a, 1.1b: Time without disturbance (succession); 2.1a, 2.2a: Fire, drought; 2.3a, 2.1b: Time without disturbance (succession); 3.1a: Drought, improper grazing, succession; 3.2a: Juniper thinning, proper grazing; 4.1a: Fire, drought; 4.2a: Time without disturbance, proper grazing; 5.1a: Fire, drought; 5.2a: Proper grazing, attempted seeding; 6.1a: Time without disturbance (succession); 6.2a: Fire, drought (USDA Natural Resources Conservation Service et al. 2021).

Species and Ecotype Selection

Seeding and planting involves introducing seeds to a site that can alter existing plant communities and influence successional processes. Most seeding projects are conducted only once, and the resultant plant community is dependent upon the initial success of the planting (Monsen et al. 2004). The decisions of what species and those that are not selected have a lasting impact on the site and its ability to provide important deer habitat. As such, the following general guidelines should be considered prior to selecting which species to include in a reseeding project to ensure the greatest probability of success.

Since rangeland communities are so diverse in nature, the choice of species to include in a reseeding to benefit mule deer depends on numerous factors that include, but are not limited to: 1) elevation, 2) length of growing season, 3) soil types, 4) erosion potential, 5) topographical exposure, 6) temperatures, 7) plant species currently present on site, 8) expected precipitation, 9) fire resistance, 10) the expected objective of the seeding, and 11) availability of seed. Most of these factors can help determine site potential and are considered in Ecological Site Descriptions which summarize what is possible on a site. The selected species that are seeded are important long term choices that can permanently alter the state of the site and what will grow there in the future.

Seeded species and varieties must be adapted to the site to establish and persist. Having a diversity of species will enhance seeding success, provide increased resistance to insects and parasites, extend the grazing or browsing period, provide wildlife habitat diversity, and generally increase production and soil protection. Species mixtures (see next section) also provide insurance against a variety of environmental hazards, and enhance forage production and forage quality for wildlife and livestock.

The presence of remnant native species can be used to identify the major plant associations that have existed on a given area providing a good key to potential species that could be included in a reseeding effort. However, many sites being considered for reseeding have likely been severely altered, so intact native species associations may be limited or absent altogether (Monsen and Stevens 2004a). Nearby undisturbed sites can also act as reference areas to determine which plant species should exist on the area being planned for reseeding. ESDs often include historical species lists of plants that likely occupied that particular ecological site.

Native plants - Species are endemic or indigenous to a specific place, region, or ecosystem. Only plants found in the U.S. prior to European settlement are considered native (USDI Bureau of Land Management 2020a). It has generally been thought that native species have been more difficult to establish in large plantings compared to selected introductions (Monsen and Stevens 2004a). Some factors influencing the use of natives include: 1) lack of seed of local origin, 2) variability in seed germination, 3) physical difficulty in processing and seeding some native species, 4) unreliable emergence and establishment, 5) susceptibility to winter injury, 6) limited ability to compete with invasive plant species during establishment, 7) low seed yields, and 8) comparatively high seed costs (Kilcher and Looman 1983). In recent years however, the use of native species has increased on reseeding projects due to selections being more readily available with research, advances in seed collection, and increased efforts and improved planting techniques. Many native species are now available commercially and prices have become much more reasonable for many (Ott et al. 2019), although some are more expensive than introduced

selections that can fill a similar niche in a reseeded plant community. Plant materials development efforts have resulted in many released varieties or cultivars of native species. Cultivated varieties of native species planted in ecological restoration are often selected for agronomic traits (vigor, rapid establishment, or enhanced forage production) and may outcompete nearby wild populations, potentially affecting community structure (Poelman et al. 2019).

Figure 5. Mixture of native forb seeds. (Photo by Daniel D. Summers, Utah Division of Wildlife Resources [UDWR]).

Non-native plants - These are species that are introduced with the help of humans to a place, region, or ecosystem where not previously found (USDI Bureau of Land Management 2020a). Although introduced species have been used historically in reseeding projects, one should be cautious when considering their use. Some introduced species are known for their ability to compete with undesirable invasive weed species, higher tolerance to grazing and drought, and lower cost compared with many native species, but they can also dominate a landscape after a short period of time. The use of some introduced species in reseeding projects has been documented to result in plant communities becoming dominated by perennial grasses and being nearly devoid of forbs and browse (Walker 1999, Davies et al. 2011). Resource managers should also be aware that the ability to use introduced species in reseeding efforts is often determined by policy statements, planning documents, and agency guidelines (see section on agency policies and position statements).

Species Adaptability – Nearly all native species consist of assemblages of different populations that have evolved under different environmental factors. Some ecotypes will grow over a wide range of sites while others will only grow within a narrow niche such as within a specific soil type or precipitation zone. When selecting which species to include in a mix, especially native species, it is advisable to plant species on sites similar to those where they originated (Monsen and Stevens 2004a). This is especially true for sagebrush. Sagebrush seeds are tiny, about 10 to 20 times smaller than common rangeland grass seeds. With only a speck of resources to draw upon, sagebrush seeds must germinate at exactly the right time or else they will dry out before their roots are established (Meyer and Monsen 1992). The optimal timing for germination varies with latitude, elevation, aspect, and soils, so sagebrush plants are adapted to site conditions at a fine scale. Local ecotypes have been shown to have greater survival in sagebrush (Wang et al. 1997, Germino et al. 2019). Selecting seed sources with seed-transfer guidelines and ecoregional classifications can be useful in selecting materials that are adapted to the site (Germino et al. 2019). The scale of seed-transfer guidelines needs to be considered. Zones at too fine of a scale may not be practical and coarser seed transfer zones may need to be used for seed planning and acquisition (Davidson and Germino 2020).

Dormancy – Seeds of many species may exhibit erratic germination following planting with no guarantee that germination will occur within the first year or more. Dormancy can provide an advantage to aid in establishment of a given species (Meyer et al. 1990) and can prevent seeds from germinating under conditions that will result in low survivability such as during periods of drought (Kildisheva et al. 2018). Some species require a stratification period (process of breaking dormancy) before germination can occur such as cold temperatures during the winter period following seeding. Dormancy can result in the creation of a seedbank from which new seedlings may occur over a period of years (Monsen and Stevens 2004a). Selecting locally adapted species, ecotypes, or varieties that have been developed for high germination rates, and planting during the appropriate season may offset some of the erratic nature of germination in some species.

Drought Tolerance – Generally speaking, the more precipitation a site receives, the higher probability that a reseeding will be a success. Sites that receive in excess of 11 inches (28 cm) of precipitation annually are usually good candidates for a successful seeding in most years (Monsen and Stevens 2004a, Valentine 1989). It is not advisable to use species or ecotypes on sites that are more arid than the site where they originate. If drought problems are anticipated, planting techniques should be used that will conserve soil moisture and assure protection of species less tolerant to drier conditions. Pitting, trenching, and furrow planting can create micro water catchments to maximize moisture. Planting in the right season will also help maximize moisture retention. Firm seedbeds also help retain moisture. Rolling or packing after planting can help create firm seedbeds (Monsen and Stevens 2004a). The drought tolerance of many introduced species, particularly perennial grasses, is one of the main reasons some promote their inclusion in reseedings (Hughes et al. 1962), especially in arid and semi-arid environments.

Establishment – Seedling establishment can be highly variable and dependent upon many factors including amount and timing of precipitation, season of planting, seedbed preparation and planting technique, competition with invasive plant species, the amount and type of residual vegetation on the seeding area, and management of the seeded area following seeding. Other considerations that could positively impact seeding establishment are planting a cover crop until the desired species can establish and persist, applying herbicides to control invasive plant species prior to planting or for the first few years following seeding, and resting the seeded area from grazing or other surface disturbing activities for several growing seasons until seedling establishment has occurred. It should also be mentioned that it takes multiple years for full establishment of seeded species to occur. While most herbaceous species will germinate and establish within the first few years following seeding, browse species and some forbs can lie in the seedbank for many years before full establishment is realized.

Figure 6. Depression created by an imprinter to create firm seedbed and capture water. (Photo by Daniel D. Summers/UDWR).

Persistence – Species that are able to persist under varied and often adverse climatic conditions, competition, and management impacts should be a high priority for inclusion in any seeding effort. However, in order for a diverse and healthy plant community to persist following a seeding, balance should always be sought when selecting the specific species, seeding rate, and number of species to include. For instance, planting a few introduced perennial grasses at high rates will almost always result in the plant community becoming dominated by seeded grasses where forbs and shrubs are likely limited. If the presence of forbs and/or shrubs are a desired goal of the seeding project, a more diverse mix of grasses, forbs and shrubs should be included. Grasses should be applied at lower rates to better enable the establishment of forbs and shrubs to ensure seeding goals are met (Johnston and Chapman 2014).

Cold Tolerance – Cold tolerance and resilience to frost generally are desired features of most plant species used in seedings in the northern portion of mule deer range. Cold tolerance is particularly important as seedlings typically emerge in early spring and need to be able to survive periods of below freezing temperatures and frost. Species known to be intolerant to cold should be planted later in the spring when possible (Monsen and Stevens 2004a).

Palatability – Forage palatability is more than just taste, it has been described as the relationship between a food's flavor and nutrient and toxin content (Burritt 2011). Longhurst et al. (1969) stated that deer forage plants have to be digestible in order to be palatable. For instance, forages that contain substances such as phenolic compounds that may inhibit digestibility would be lower on the palatability scale. Deer need forages that are high in protein content and are drawn to succulent vegetation including seedlings and young shoots characteristic of early growth stages following reseedings. This can result in animals becoming concentrated in seeded areas where newly developing plants can be permanently damaged by excessive

grazing. It is important that, whenever possible, seeded areas should be of sufficient size to dissipate grazing and lessen animal use (Monsen and Stevens 2004a) on forage sources that are highly palatable.

Broad Genetic Base – It is important to include seed sources from a broad genetic spectrum, especially when seeding native species, to ensure the greatest chance of seeding success. The use of local ecotypes, which are adapted to the site can increase success (Germino et al. 2019). In recent years plant selection and breeding has resulted in the development of many cultivars or varieties developed for one or more desirable traits, but this may narrow the genetic base and eliminate other adaptive traits important for successful establishment and persistence in a rangeland setting where all of the environmental variables cannot be controlled. Cultivar vigor and the persistence of cultivars in the landscape underscores the need for consideration of genetically appropriate plant materials in restoration programs (Poelman et al. 2019).

Species Compatibility – The success or failure of a seeding often depends upon which species are chosen to be seeded together and the rate at which they are seeded. The goals of the project should be fully understood before determining which species to include in the mix to ensure the desired plant community can be reached. According to Bentley (1967), the universal use of introduced perennial grasses for many range, watershed, and wildland seedings has created some serious problems including the decrease or elimination of desirable native species in seeded areas. Native broadleaf forbs and shrubs can be incompatible with introduced perennial grasses due to the highly competitive nature of introduced species which reduces the desirability of planting them together if quality wildlife habitat is a goal. Many important shrub and forb communities have been converted to communities dominated by introduced grasses, and as such, where shrubs and other natives are desired, the use of introduced species should be carefully regulated (Walker, 1999, Monsen and Stevens 2004a, Miller et al. 2015, Waldron et al. 2005).

See species reference guide in Appendix 1.

Planting Mixtures

When designing a restoration seeding with mule deer habitat in mind, diversity is an important consideration. Determining how and when the site will be utilized by mule deer is important. Other land uses and pressures that will occur on the site should also be considered. Multiple uses may be necessary for a particular site such as wildlife habitat, weed control, watershed and ground cover, forage production for livestock and/or wildlife, and aesthetics (Monsen and Stevens 2004a).

Natural communities in rangelands consist of a diverse mix of species. Restoring a functioning and diverse vegetation community tends to lead to higher productivity, resistance to invasion, and resilience following disturbances. Designing seed mixes that promote community diversity will help attain these benefits (Barr et al. 2016). Many of the areas in need of restoration have been altered due to past land management practices. This has led to the reduction or loss of some native species on sites (Monsen and Stevens 2004a). Planting a diverse seed mix can restore a proper ecologically functioning system. Barr et al. (2016) found that increased seed mix diversity leads to greater restoration success.

Seeding of mixtures can also help ensure establishment of at least some of the desired species on a given site. Many species establish at different rates due to year-to-year differences in climatic conditions. One species may be favored by the climate in a particular year over another. Over time and with varying conditions, the establishment of the stand will likely continue to improve (Monsen and Stevens 2004a).

Figure 7. Seed mixture for use in deer habitat restoration project. (Photo by Daniel D. Summers/UDWR).

It is important to consider which species will benefit mule deer and black-tailed deer when planning a seed mix for habitat enhancement. Seed mixes should include species that fulfill seasonal forage quality requirements (Stevens 2004b). Mule deer require high quality forage, which are typical in early successional stages of vegetation communities (Wakeling and Bender 2003). Early successional vegetation communities typically contain quality succulent forages. As communities move to later seral or climax states, high quality forage is replaced by less succulent woody vegetation (Schroeder and Kauffman 2021). As such, habitat improvement projects and seed mixes should focus on providing high quality forbs, browse, and grasses.

Treatments designed to increase desired forage components are beneficial to mule deer (Schroeder and Kauffman 2021). In order to meet seasonal forage requirements for mule deer, the season of use for a particular site should be identified to help determine which species are seeded. For summer ranges, mixtures of grasses and forbs are of particular importance. Forbs can be lacking on ranges that have a history of over-grazing, mismanagement, or other management actions. Some communities have been converted to grass communities with little diversity (Stevens 2004b). Forbs provide excellent forage. Legumes particularly can be beneficial in forage quality and by supplying nitrogen that can be used by other plants and have been promoted in range seedings for many years. Introduced species such as

alfalfa (*Medicago sativa*) are common and available in large quantities for low prices. Native forbs are more difficult to acquire and are generally much more expensive, however availability and cost are improving (Ott et al. 2019). Efforts are being made to develop forbs and other native species regionally, by groups such as the Great Basin Native Plant Project (Great Basin Native Plant Project 2020), the Colorado Plateau Native Plant Project (NatureServe 2020), and the Mojave Desert Native Plant Program (USDI Bureau of Land Management 2020b).

When evaluating seed prices, it is also helpful to understand that seeds are generally sold as a price per pound. However seed size is different for each species, which means that smaller seeded species have more seeds per pound. In some cases it may appears as if a particular species is more expensive than another but in reality it may be less expensive on per seed basis. Seeding rates therefore differ for different species and a lower seeding rate can be used for seeds with a higher amount of seeds per pound.

Figure 8. Seed increase planting of thickleaf penstemon (Penstemon pachyphylus) to increase the availability of native forbs. (Photo by Daniel D. Summers/UDWR).

Figure 9. Comparison of different seed sizes. Above L to R, Western yarrow (Achillea millefolium), Palmer penstemon (Pesnstemon palmeri), Big Sagebrush (Artemisia tridentata), Antelope bitterbrush (Purshia tridentata), below L to R, Bluebunch wheatgrass (Pseudoroegneria spicata), Indian ricegrass (Achnatherum hymenoides), sand dropseed (Sporobolus cryptandrus). (Photo by Daniel D. Summers/UDWR).

For spring and fall ranges it is important to create balanced communities that are not dominated by a single class of vegetation (e.g., grasses or browse). Considering treatments that can increase diversity in communities that are not well balanced can create more useful and beneficial ranges. Browse heavy ranges can be treated mechanically to thin shrubs with chains, harrows, or disks followed by seeding with a mixture of desirable species (Summers and Roundy 2018). Other treatment options include spot spraying or strip spraying with herbicides to thin shrubs. Grass dominated communities may be treated by targeted grazing or properly implemented interseeding to increase forbs and shrubs. Desirable shrubs can be established using interseeding or transplanting (Stevens 2004b). Prescribed fire is another tool to be considered, however fire may eliminate important browse species that do not readily resprout (Schroeder and Kauffman 2021). It is important to understanding which browse species are fire tolerant.

Figure 10. Contrast of mechanical treatment edge with diverse early seral community on the left and late seral big sagebrush community on the right. (Photo by Daniel D. Summers/UDWR).

On winter ranges, seed mixes that emphasize browse species that extend above snow are of critical importance. Wallmo (1978) advocated that more browse is better than less browse when working with deer habitat. Most winter range treatments should be done with the goal of increasing useable browse for deer (Watkins et al. 2007). Evergreen shrubs generally provide more winter forage than deciduous shrubs. Some of these include: big sagebrush (*Artemisia tridentata*), black sagebrush (*Artemisia nova*), cliffrose (*Purshia* sp.), winterfat (*Krascheninnikovia lanata*), curlleaf mountain mahogany (*Cercocarpus ledifolius*), ephedra (*Ephedra* sp.), rubber rabbitbrush (*Ericameria nauseosa*), and forage kochia (*Bassia prostrata*) Immigrant and Snowstorm varieties (Stevens 2004b). In the absence of snow, other semi-evergreen forbs and

shrubs as well as grasses and forbs that green up in late winter and early spring can also be beneficial. From a nutritional point of view, it is a good range management practice to manage fall and winter ranges for a balance among grasses, forbs, and shrubs (Welch 2004).

Figure 11. Big sagebrush is an evergreen shrub that is available for browsing during winter. (Photo courtesy of Utah Watershed Restoration Initiative).

Seeding of mixtures can be beneficial for multiple uses beyond deer habitat. Seeding multiple species can increase the period when succulent forage is available and extend the season of use for wildlife and livestock. Mixed plantings can provide greater seasonal production and improved forage quality (Gomm, 1964, Van Epps and McKell 1977, Gade and Provenza 1986, Monsen and Stevens 2004a, Schroeder and Kauffman 2021).

Diversity of species with different growth habits can provide better ground cover for watershed protection. Shrubs and trees can entrap snow and delay snowmelt (Monsen and Stevens 2004a). Having vegetation diversity on the landscape also provides for the needs of many other wildlife species in addition to mule deer. In southeast Alaska, increasing the stand dynamics and diversity of mixed hardwood-conifer forests resulted in improved habitat and food resources for black-tailed deer (Deal et al. 2017).

Mixtures and diversity on the landscape can also improve the control of invasive plant species. Perennial grasses that compete with invasive plant species are desirable and are the biggest driver in resisting invasion from exotic annuals (Monsen and Stevens 2004a; Davies et al. 2011). Species that have different periods of active growth can help compete with invasive plant species by using resources that invasive plant species would otherwise acquire. Species with early season growth characteristics can be effective in competing with invasive annuals such as cheatgrass, which is abundant across much of the mule deer habitat in the western United States (Herron et al. 2013). Big sagebrush communities with higher cover and density of deeper-rooted perennial grasses are considered to be more resistant to dominance and invasion by cheatgrass and other exotic annuals (D'Antonio & Vitousek, 1992, Chambers et al. 2007, Davies and Svejcar 2008, Davies et al. 2010, Davies et al. 2011, Chambers et al. 2014a, Chambers et al. 2017a).

Although establishing diverse communities through the planting of mixtures is usually the preferred condition, there are certain situations where one species or just a few species should be planted. Vegetation communities that are lacking certain functional groups such as forbs or shrubs may only need to be seeded by one or a few species. Loss of shrubs such as sagebrush on important winter ranges due to fire may need to be seeded exclusively with sagebrush to return this key species to the winter range. Other ranges that have been heavily utilized by wildlife or livestock may be missing important forb diversity. Native forb seed is especially expensive, therefore, seeding forb islands to increase forb abundance across the landscape has been used (Hulvey et al. 2017, Landeen et al. 2021).

Single species plantings may be appropriate in situations where specific sites require certain species due to soil conditions or resource needs (Monsen Stevens 2004a). Soil or climatic conditions may limit the species that are adapted to that specific site (Blaisdell and Holmgren 1984) and may determine what can be expected to establish and persist. Ease of planting may also favor fewer species. Some species require different planting techniques or timing. Conducting multiple different planting techniques some of which may require different timing can become expensive and may not be feasible. This may require that a simpler set of species are used (Monsen and Stevens 2004a). Single species plantings may be necessary at times due to incompatibility of certain species establishing simultaneously. Shrubs may be sensitive to competition with other species and may need to be planted alone or with limited numbers of other species (Jordon 1983, Monsen and Stevens 2004a).

Figure 12. Winter range seeding of big sagebrush and forage kochia in a grass dominated community in central Utah to increase the availability of winter forage. (Photo by Daniel D. Summers/UDWR)

Seed Quality and Rates

Seed quality and seeding rates are important considerations when designing a seeding project to improve mule deer habitat. Seed quality is one of the factors that determine the amount of seed needed to be sown. Some of the measurable attributes of seed quality are **purity, seed viability**, and **quantity of weeds or other crops** found in a particular lot of seed. Federal and state seed laws require that seed for sale be labeled with such information to allow buyers to make an informed decision (U.S. Department of Agriculture 2017). Seed quality is measured by a set of laboratory tests.

Purity is the percentage by weight of pure seed, inert matter, other crops, and weeds in a test sample (Oregon State University 2017). Seed lots containing any noxious weeds are prohibited from being sold or sown. Restricted weeds are only allowed in certain quantities. It is helpful to consult local weed laws to know noxious and restricted weeds for a given area. Many plants that are generally considered weeds have not been declared noxious weeds by governing bodies and are therefore allowed to be in seed lots. When possible, it is helpful to have access to the seed test results on individual lots from an independent third-party lab or from the vendor.

Purity often varies from species to species depending on how seed for that species is collected, harvested, and cleaned. Species such as antelope bitterbrush (*Purshia tridentata)* can be cleaned to a very high purity near 100%, while other species such as big sagebrush require much more processing and are typically sold at only 20-30% purity.

Seed viability can be determined through a couple of different tests. Germination testing is a physiological viability test, which determines the percentage of live seeds that produce normal seedlings under favorable germination conditions. Tetrazolium (TZ) tests are quick biochemical viability tests, which determine the number of live seeds based on dehydrogenase activity in seeds. It indicates the percentage of live and dead seeds in any sample regardless of its dormancy level (Oregon State University 2017). Germination testing can take a few days or up to multiple months, while TZ testing can be completed within a couple of days.

Pure Live Seed (PLS) is determined by multiplying percent viability by percent purity. PLS is a very useful way of assessing the quality of a seed lot. Buying seed on a PLS price basis can protect the buyer from paying for seed that has lost viability. Seed lots with low purity but high germination can still result in successful seedings. However, if the condition of the lot is such that inert matter is preventing seed from flowing through the seeder the lot may need to be reconditioned or a carrier may need to be added (Monsen and Stevens 2004a).

Labeling is an important aspect in assuring the seed quality. Seed labeling is information on the seed kind or variety. Kind relates to the species being offered for sale. A variety is a formalized, specific genetic subset of a kind, developed for certain beneficial attributes. The term cultivar is the equivalent of a variety for labeling purposes. The certified seed program is a third-party process for tracking seed genetic identity and genetic purity from plant breeders to seed producers and collectors and then on to the end user. Certification means the seed meets the high standards for genetic purity, pure seed and viability percentages, and contains very limited amounts of weed seed or other crop seed. Seed certification protocols for field production and wildland seed collection along with mechanical quality standards ensure that what's on the tag is what's

in the bag. Seed certification is a process provided by Seed Certifying Agencies, which are members of the Association of Official Seed Certifying Agencies (AOSCA). For varieties that have been formally released a blue certified seed tag should be attached to the bag to indicate the seed is certified. Not all seed has been characterized into a formal variety or cultivar. Accessions (a group of seed collections) that have not been formally released as a variety are referred to as Pre-Variety Germplasm. These materials can be categorized in a variety of ways. The two most common are: 1) SOURCE IDENTIFIED SEED (yellow tag): Lists original collection location as identified by state, county, and elevation or other geographical description, though nothing is known or claimed about germplasm performance or special traits; 2) SELECTED SEED (green tag): Developer claims promise of superior and/or identifiable traits as contrasted with other germplasm accessions or selections of the same species. 3) TESTED SEED (blue tag): Requires progeny testing by the developer to prove that superior and/or identifiable traits of interest are heritable in succeeding generations (Utah Crop Improvement Association, Utah State University 2020).

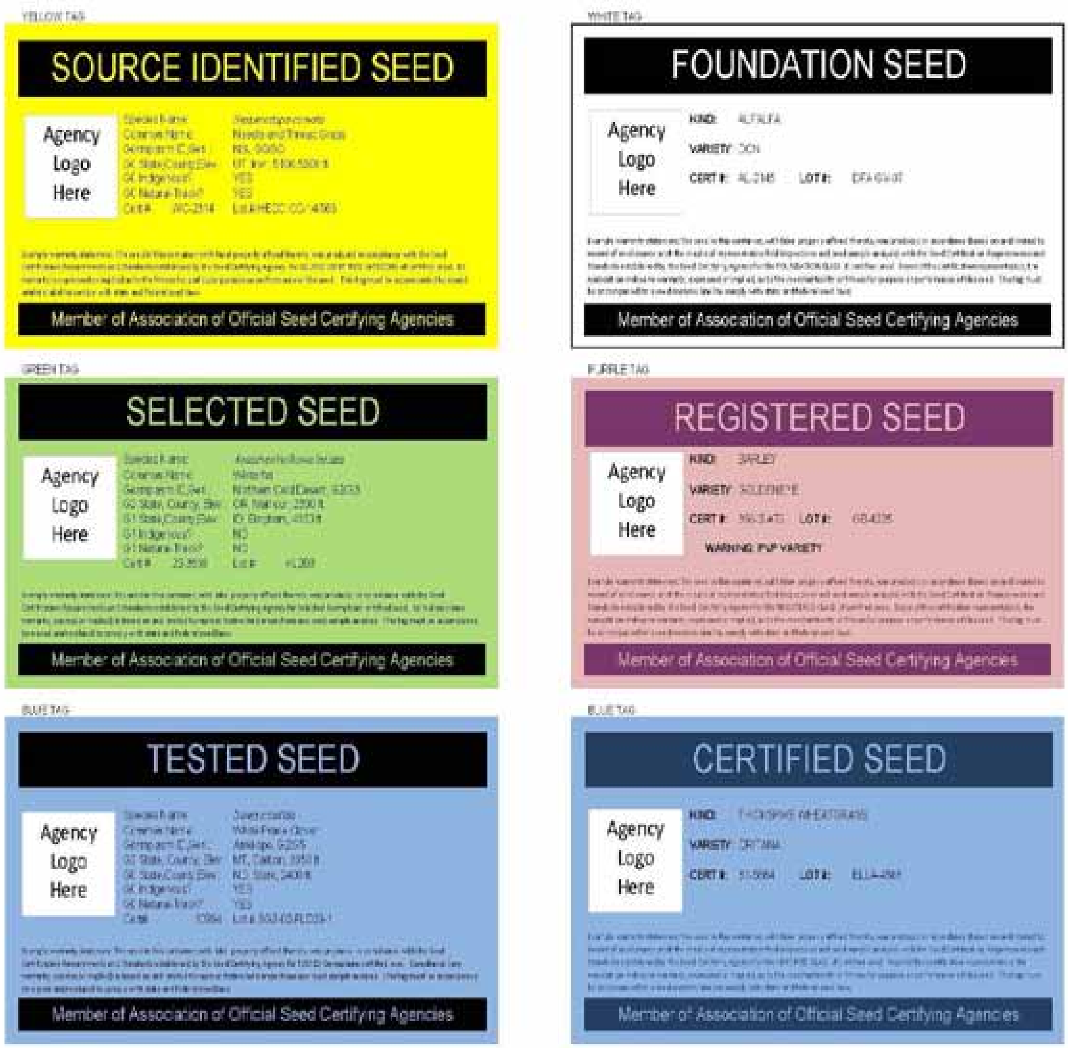

Figure 13. Examples of AOSCA pre-variety germplasm (Source identified, Selected class, Tested class) and Variety (Foundation, Registered, Certified variety) certification tags. (Utah Crop Improvement Asscociation, Utah State Universtiy 2020).

Determining proper seeding rates includes considering a multitude of factors. It is important to use a proper seeding rate to get the desired outcome. Too much seed can result in competition between seedlings and a failure to properly establish. It is also a waste of money and resources to use more seed than needed. Conversely, not planting enough seed can result in a poor stand.

In rangeland settings, a high percentage of seeds that are sown fail to germinate, emerge, or establish into mature plants due to various abiotic and biotic ecological factors. Often less than 10% of viable seeds sown result in mature plants (Monsen and Stevens 2004a). Some of these factors include: drought, soil crusting, extreme temperatures, poor seedbed conditions, unfavorable moisture, frost, animal depredation, insects, disease, competition from other plants, and infertile soil (Madsen et al. 2016).

Using PLS and converting rates from pounds/acre to the amount of live seeds/ft^2 is useful in determining seeding rates. Seed size differs across species. The average number of seeds per pound are easily found for most species in NRCS plant guides or other sources. Using the number of seeds per pound, the PLS rate of pounds/acre can be converted to the number of live seeds/ft^2. Recommendations for live seeds/ft^2 vary from 20-50 live seeds/ft^2, with recommendations that are higher for species with smaller seeds (>500,000 seeds per pound) and lower for larger seeds (<500,000 seeds per pound; St. John et al. 2007, Taliga 2011, Majerus et al. 2013). Lambert (2005) recommended rates of 60-80 live seeds/ft^2. Finding the proper rate within this variation of recommendations can depend on your field conditions and site potential.

The proper seeding rate also depends on the method of sowing (Monsen and Stevens 2004a). Rangeland drilling has been conventionally thought to better establish seeded species over broadcasting, likely due to furrows capturing water and seed burial improving germination and survival. Seeding rates are usually recommended to be higher for broadcasting than drilling. Properly calibrated drilling delivers seed consistently to a certain soil depth. Drilling was generally designed for larger seeded forage grass species. Smaller seeded species, such as big sagebrush, have been less effective with conventional drilling techniques. Smaller seeds generally need to be seeded at shallower depths or even on the soil surface with some soil disturbance. Therefore, when determining sowing methods and specific techniques, it is important to understand proper seeding depths and germination requirements for the species being seeded. Newer drills may be equipped with partitioned seed boxes to separate seeds of different sizes to be seeded in different furrows. Imprinter wheels can be added to press small seeds into the soil rather than drilling them too deep (Ott et al. 2016, Ott et al. 2017). Many native seeds are light and fluffy making seeding difficult with a drill unless it contains agitators in the seed boxes and curved picker wheels that help with seed flow into the drops.

Broadcasting requires 20-50% more seed to establish proper stands of seeded species (Monsen and Stevens 2004a). However, broadcasting after preparing the soil with a pitter or rough surface seeder, which provides microsites, produces results similar to drill seeding with an equivalent amount of seed (Johnston and Chapman 2014). Generally, broadcasting is only advisable when some technique is used to cover the seed or when seed will fall into safe sites with good soil to seed contact, especially at sites with lower amounts of precipitation (Ott et al. 2003, Juran et al. 2008). Broadcasting seed is typical in locations where drilling is unfeasible. This includes steep slopes, uneven terrain, and terrain with many obstacles such as rocks, trees, or debris.

Figure 14. Tractor mounted broadcast seeder and chain harrow to cover seed. (Photo by Daniel D. Summers/UDWR).

Seeding rates can also depend on site potential and conditions. When weed invasion is unlikely and recovery of native residual plants is possible, seeding rates may be lowered. On the other hand, where invasive plant species are a high risk, higher seeding rates may be deemed necessary (Monsen and Stevens 2004a).

Landscape and project level planning also need to be considered when determining seeding rates. Budgetary constraints may dictate that ideal seeding rates may not be feasible especially on large scale projects such as post-fire rehabilitation. Areas that have a greater chance of recovery may need to be prioritized. In some cases, in which high value seed (such as native forbs) are limited to finite amounts, prioritizing where this seed is planted on the project may be more important than spreading across the entire project. Targeting locations where establishment is more likely may be an important consideration.

Seeds of different size, shape, density, and purity can require more complex planting methods. With complex seed mixes, equipment may need to be modified or seeds of different sizes or purities may need to be separated and sown separately.

Due to the inconsistency of success in rangeland restoration seeding efforts, the field of seed enhancement technologies is developing to increase the success of seeding. Seed enhancement technologies physically alter or add materials to the seed to assist with delivery, germination, emergence, and/or growth (Erickson et al. 2021). These technologies include:

increasing soil water availability, enhancing seedling emergence in crusted soil, controlling the timing of germination, improving delivery of seeds to the soil, protecting seeds and seedlings from pre-emergent herbicides, and predator deterrents (Madsen et al. 2016, Anderson et al. 2021). Most of these enhancement technologies are not yet widely applied. However, using seed enhancements to inoculate legumes with beneficial rhizobia is a common practice (Monsen and Stevens 2004a).

Figure 15. Seed enhancement technologies are emerging to increase the success of seeding. (Photo by Matthew D. Madsen/Brigham Young University).

Existing Seeding Policies and Position Statements

Land management agencies, particularly federal government entities, may possess specific policies, procedures, or other guidance that provide direction for reseeding, reclamation, and restoration actions that occur on lands under their jurisdiction. BLM, Forest Service, and NRCS are examples of entities that have these. It is advisable to contact the local offices of any land management agencies operating in your area to find out what processes will be required for reseeding activities on their lands. For example, BLM Resource Management Plans and USFS Forest Plans and Amendments should be checked for specific guidance when planning any project. Also, each office could also have specific NEPA documents that address seeding and seed sources, so a project proponent would want to work with the local BLM Field Office or Forest Ranger District in which the project will be located to be sure to comply with Regional, State, Forest, District, and Field Office-level guidance. Issues related to reseeding such as use of natives vs. introduced species would be contained in Resource Management Plans, Forest Plans, or other NEPA related planning documents.

Although not a full list, here are some specific agency regulations and resources that are available that can provide guidance when planning and implementing reseeding projects for mule deer.

Executive Order 13112, Safeguarding the Nation from the Impacts of Invasive Species, requires all federal agencies prevent and control these species and minimize their economic, ecological, and human health impacts. Under the Executive Order, invasive species means, with regard to a particular ecosystem, a non-native organism whose introduction causes or is likely to cause economic or environmental harm, or harm to human, animal, or plant health (Executive Order 13112, 2016).

Bureau of Land Management (BLM)

National Seed Strategy for Rehabilitation and Restoration 2015-2020 (USDI Bureau of Land Management 2020a): identifies national goals and objectives for assessing native seed needs for federal lands, identifying capacity to produce native seed sources, increasing the supply and availability of native seed sources for federal lands, and developing tools for land managers to make informed seeding decisions for restoration.

Integrated Vegetation Management Handbook (H-1740-2) (USDI Bureau of Land Management 2008): Provides guidance on a variety of reseeding related topics including:

- Assessing vegetation condition
- Addressing vegetation in project planning, implementation, monitoring and adaptive management
- Selecting treatments and effectiveness monitoring
- Best management practices
- Using native plant materials

United States Forest Service (USFS)

Forest Service Manual – FSM 2000 – National Forest Resource Management, Chapter 2070 – Vegetation Ecology (2008) (USDA Forest Service 2008): Outlines the authorities, laws, executive orders, and regulations the U.S. Forest Service is required to follow when managing vegetation resources on National Forest System (NFS) lands. Also outlines responsibilities of USFS staff in implementing the guidance.

Stated objectives include (USDA Forest Service 2020):

- Native plants are defined as all indigenous terrestrial and aquatic plant species that evolved naturally in a defined native ecosystem.
- Native plant materials will be the first choice in revegetation for restoration and rehabilitation of native ecosystems where timely natural regeneration of the native plant community will not occur.
- Non-native, non-invasive plant species may be used when:
    - Needed in emergency conditions to protect basic resource values,
    - As an interim, non-persistent measure designed to aid in the re-establishment of native plants,
    - When native plant materials are not available, and
    - In permanently altered plant communities.
- Under no circumstances will non-native invasive plant species be used as plant materials for restoration, rehabilitation, or reconstruction of native ecosystems.
- The best information available should be used to choose genetically appropriate native plant materials for the site to be restored.
- A reliable source of native plant materials, either as seed or other vegetative propagules is essential for the successful implementation of the native plant materials program.

FSM 2900 – Invasive Species Management (USDA Forest Service 2011): Outlines the authorities, laws, executive orders, and regulations the U.S. Forest Service is required to follow for the prevention, detection, control, and restoration effects from aquatic and terrestrial invasive species including plants. Also outlines responsibilities of USFS staff in implementing the guidance.

Stated objectives include:

- Take proactive approaches to manage NFS lands to protect native species and ecosystems from the introduction, establishment, and spread of invasive species.
- Conduct integrated invasive species management activities to limit adverse effects of invasive species on NFS lands.
- Proactively manage NFS lands to increase the ability of those areas to be self-sustaining and resistant to the establishment of invasive species, and where necessary, implement restoration, rehabilitation, or revegetation activities to prevent or reduce the likelihood of the reoccurrence or spread of invasive species.

Policy statement includes:

- Ensure that all Forest Service management activities are designed to minimize or eliminate the possibility of establishment or spread of invasive species on the NFS or adjacent areas.

Natural Resources Conservation Service (NRCS) (2020)

The NRCS does not have formal policy or position statements regarding revegetation and restoration actions. Rather, they use Field Office Technical Guides (FOTG's) as the primary scientific references for the conservation work they plan and fund using Federal Farm Bill programs (e.g., Conservation Reserve Program - CRP; and the Environmental Quality Incentives Program - EQIP). FOTG's contain technical information about the conservation of soil, air, water, and related plant and animal resources. FOTG's have been constructed for localized geographic areas nationwide and should be consulted for the specific area where a reseeding project is being planned. FOTG's can be found at the following link on the national NRCS website: https://efotg.sc.egov.usda.gov/

FOTG's contain a variety of information and technical assistance that could be helpful when planning a reseeding project for mule deer including: 1) general reference information (state maps, watershed descriptions, and land resource areas), 2) natural resources information (NRCS soil surveys, Ecological Site Descriptions, Forage Suitability Groups, Wildlife Habitat Evaluation guides, etc.), 3) conservation management systems, and 4) conservation practice standards and guidelines which define different conservation practices and where they apply.

Additional information related to plant materials can be found on the NRCS website at:
https://www.nrcs.usda.gov/wps/portal/nrcs/site/plantmaterials/home/

Seedbed Preparation and Seeding Techniques

Seedbed preparation is an important aspect to consider in the development of any seeding project to improve mule deer habitat. The primary purposes behind seedbed preparation are to create the best possible conditions to promote the establishment of the species being seeded. Seedbed attributes such as the ability to control competition, moisture retention, and seedbed firmness are all important to consider. However, rough conditions such as rock, debris, and terrain often limit the types and number of techniques that can be used in habitat restoration projects. Factors such as budgets and project timelines also often limit the number of techniques and treatments that can be used for seedbed preparation (Monsen and Stevens 2004a).

Control of competition is important in all habitat restoration seeding, but particularly in the arid and semi-arid habitats with limited moisture resources critical to seedling establishment; these habitats dominate mule deer winter range (Monsen and Stevens 2004a). Competition in these habitats can come in a number of forms including invasive annual species, encroaching woody species, and aggressive introduced or weedy perennial species. Invasive annual species and aggressive perennial herbaceous species can limit the establishment of seeded species, particularly desirable shrub and forb species (Marlette and Anderson 1986, Allen 1995, Gunnell et al. 2010). Germino et al. (2018) and Davidson et al. (2019) found that sagebrush seedling presence was inversely related to exotic annual grass cover and to higher cover percentages of perennial bunchgrass cover. Seeding enhanced sagebrush occupancy at lower elevations despite increased competition from exotic annual grasses. Encroachment and invasion of tree species such as Pinyon pine (*Pinus* spp.) and Juniper (*Juniperus* spp.) into big game habitat inhibit both the herbaceous and desirable shrubs, as well as hinder physical seeding efforts (Archer et al. 2011). The methods of controlling or decreasing competition are as varied as the forms of competition, and multiple methods may be needed in order to reduce competition adequately.

Figure 16. Mule deer feeding near a tree masticator. (Photo courtesy of the Utah Watershed Restoration Initiative).

Determining the need for seeding and control of weedy species can be difficult due to varying site conditions and ecological potential. Understanding how the site will respond to disturbance from treatment is important for planning what actions to take. Identifying the ecological site, current vegetation, disturbance history, treatment type and other elements are critical factors in decision making (Miller et al. 2014, 2015). Understanding and mapping of physiographic factors and plant-community and soil-surface characteristics (annual and perennial grass cover, fertile islands, and pedoderm classifications) are also of importance when planning for successful seeding treatments (Germino et al. 2018).

Weedy species can have a large negative impact on a seeding. Annual grass species such as cheatgrass, medusahead (*Taeniatherum caput-medusae*), and ventenata (*Ventenata dubia*) are of particular concern in many moisture-limited habitats and pose particular challenges for control. Using the score sheets from Miller et al. (2014, 2015) can help determine what actions need to be taken when cheatgrass is present or there is a potential threat of establishment within a seeding project. A number of control methods have been used for these competitive invasive annual grass species, particularly cheatgrass, with varying success (Monaco et al. 2017).

Herbicides in conjunction with seeding have proven to be one of the more consistent control methods, but still with a broad range of varying success and failure (Monaco et al. 2017). Combining an herbicide with a complementary technique for reducing weed seed density may have more success. Burying the seed (Wicks 1997), using surface obstructions to limit seed movement (Davies and Sheley 2007, Davies et al. 2010, Johnston 2018), judicious use of fire (Davies and Sheley 2011), and well-timed disturbance (Johnston 2015) are complementary techniques that can help reduce the density of weed seeds.

The topic of herbicides and their appropriate use is an expansive and constantly evolving topic that is too complex for the scope and intent of this guide, but there are a number of resources to help determine and develop an appropriate plan for integrated pest management (IPM) for a specific area or project. The publication "Weed Control in Natural Areas in the Western United States" (Ditomaso et al. 2013) provides general information on control options for a number of weedy species throughout the West. All herbicides approved for use in the United States also have a label that defines their intended and appropriate use and can be used as a reference in project planning. Always follow herbicide labels. The most important step in planning an IPM is to consult with local, regional or agency experts such as state or county weed programs, university or agricultural extension specialists, or local and regional weed control guides that can provide the most current information.

An example of importance of understanding the effects of herbicides are pre-emergent herbicides that are often used to control invasive annuals such as cheatgrass. Imazapic or Plateau® (BASF, Ludwigshafen, Germany) has been commonly used to control annuals, while, indaziflam or Rejuvra® (Bayer, Cary, NC, USA) is a pre-emergent that is just being released and offers much longer control of annuals. Sebastian et al. (2017) showed that indaziflam application to sites with mature native vegetation increased native species growth and provided three or more years of annual grass control. However, indaziflam's ability to inhibit germination for long periods of time also inhibits the ability of desirable perennials to germinate and establish. To achieve long-term annual invasive grass control and establishment of perennials, one potential option is to apply imazapic prior to seeding, plant in a furrow made after herbicide application and then apply indaziflam 2 years later (Terry et al. 2021). Each of these herbicides can be a valuable tool when used in the right circumstances. In any situation with herbicides, it is critical to understand how the chosen herbicide is going to effect the target control species and how it will affect the desirable residual vegetation or seeded species. Consulting with specialists will help assure the proper herbicide is used for the desired effect.

Figure 17. Helicopter applying herbicide. (Photo by Daniel D. Summers/UDWR).

Encroachment and infilling of tree species is another common problem in mule deer habitat. While trees are important for thermal and escape cover, an overabundance of trees can have a number of negative impacts on big game ranges including reduced shrub and herbaceous understories (Naillon et al. 1999). Treatment of tree species is often dictated by the degree of encroachment and infilling, or ‘Phase’ (Miller et al. 2019). Pinyon and juniper encroachment phases are described here: Phase I – trees are present but shrubs and grasses are the dominant vegetation that influence ecological processes (hydrologic, nutrient, and energy cycles) on the site; Phase II – trees are co-dominant with shrubs and herbs, and all three vegetation layers influence ecological processes on the site; Phase III – trees are the dominant vegetation and the primary plant layer influencing ecological processes on the site (see Figure 18). Shrubs no longer dominate the understory (Tausch et al. 2009). Often seeding is recommended with treatments of more heavily encroached habitats in Phase II or Phase III. Treatments

such as shredding or mastication (also known as Bull Hog) or chaining are commonly used and may not eliminate all of the competing plants entirely, but the reduction in competition allows for the establishment of seeded species (Monsen and Stevens 2004a).

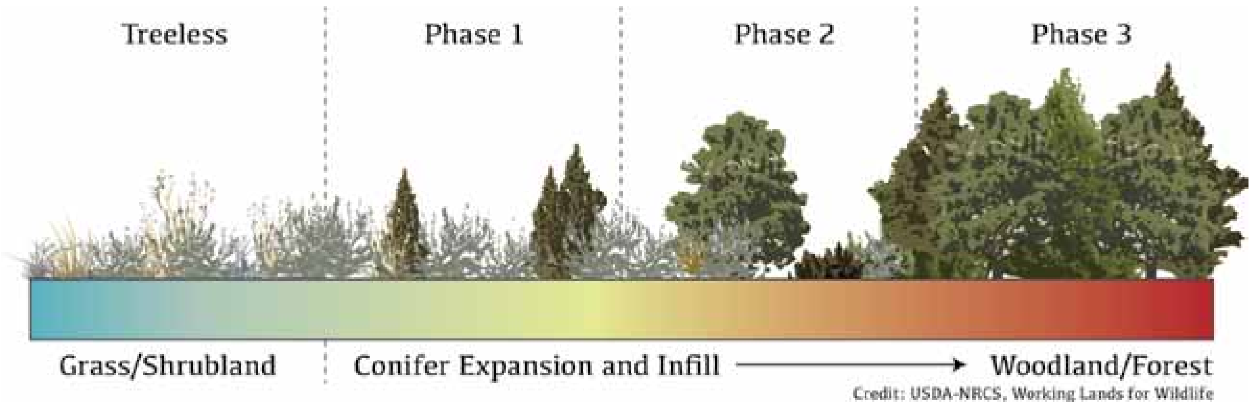

Figure 18. Graphic showing conifer invasion in grass/shrubland. (USDA-NRCS, Working Lands for Wildlife).

Figure 19. Example of tree encroachment and infilling. Left photo was taken in 1902, while the right photo was taken in 2020. (Left photo from Kay 2003; Right photo by Jim Lamb/UDWR)

If control of an entire site is not feasible, targeted control of competition and interseeding may be a practical approach. "Scalping" is a technique that removes vegetation and seed competition by creating a furrow and removing the surface soil to prepare a seedbed for desired seeding. Seeding can typically be done in conjunction with this treatment (Monsen 2004, Steven and Monsen 2004). This method can be used in annual grass dominated communities to establish desirable perennial species or in perennial grass communities to help diversify with forb and shrub species (Plummer et al. 1968). Control of competition will likely only be temporary, but may allow for establishment of desired species.

Figure 20. Modified bulldozer for interseeding in grass dominated slopes. (Photo by Daniel D. Summers/UDWR).

Proper control of competition can also assist in other important aspects of seedbed preparation. This includes moisture conservation by reducing water used by less desirable or weedy species thereby increasing soil water availability for seeded species. The conservation of soil moisture should be a primary emphasis of any preparation and seeding activity as it directly relates to the success of seeding effort (Allen 1995). Common mechanical practices for seedbed preparation such as plowing, disking or chaining will increase drying and reduce soil moisture, but these effects can be negated through thoughtful application. As stated by Monsen and Stevens (2004a), timing of treatment is the most practical way to maximize soil moisture by conducting treatments prior to the season when most precipitation is generally received. In most areas in the Intermountain West this will likely be late fall, but areas dominated by more summer monsoonal precipitation patterns may need to be treated in the spring or early summer.

Figure 21. Big sagebrush growing in rows created by interseeding to reduce competition with grasses. (Photo by Daniel D. Summers/UDWR).

In the Great Plains, timing your planting with known soil temperatures to promote germination of your seed mix along with adopting standard commonly used agricultural techniques to build and maintain soil moisture assists in successful establishment. In many cases in this region, seedings are occurring on previously or currently farmed lands, and best practices are to use a no-till drill, seed with a 3 box native grass into herbicide-treated crop residue. Purchasing seed that is mixed properly and separated by type, (large-seeded species, fluffy seeded species, and small smooth seeds are all bagged individually) is important. This allows the use of separate seed boxes and planting at the correct depth. In these grasslands spring plantings are most common and will generally result in rapid establishment if good site preparation focused on controlling competition and soil moisture conservation is used so long as a native grass drill with precise seed metering and depth control is used to sow the project.

Figure 22. Rangeland drill (left) and no-till drill (right). (Photo by Jason L. Vernon/UDWR).

Creating areas of water catchment and ways to retain rainfall and entrap snowfall are other methods for increasing available soil moisture. Catchment areas are typically created through mechanical means such as pitting or trenching which create physical catchment areas for rain and runoff events. Chaining can also create areas of water catchment. These catchment areas can also create favorable microsites for seed germination by reducing moisture loss and decreasing temperature near the germinating seedlings. Moisture retention and shading may also be accomplished through the maintenance of surface mulch, litter or standing cover crop (Monsen and Stevens 2004a). Treatments such as shredding of pinyon/juniper trees are particularly good at creating surface mulch as long as the litter piles are spread across the site and not piled too deeply. Shredding has been shown to be an effective method in establishing seeded species (Young et al. 2013, Bybee et al. 2016, Havrilla et al. 2017, Monaco and Gunnell 2020). Creating or maintaining a community structure that ensures entrapment of snowfall helps create microsites for increased germination, particularly in small-seeded, surface germinating species. This is an important aspect of natural recruitment in many arid shrub communities in the Intermountain West. Large litter and downed trees from chaining treatments can also provide some of this structure for snow entrapment, and can effectively remain on a site for over 25 years (Monsen and Stevens 2004a).

Figure 23. Bulldozers pulling an anchor chain to cover aerially broadcast seed after a wildfire. (Photo by Daniel D. Summers/UDWR).

Seedbeds that are loose and friable at the surface while maintaining a firm underlying base are preferred for their ability to maintain soil moisture and also for ease in controlling seeding depth. Many undisturbed sites have these characteristics preserved and can be directly drill seeded, or some other mechanical means, such as a chain or harrow, can be used to incorporate the seed. If physical soil disturbance is required, care should be taken to ensure proper soil moisture. Physical soil treatments should not be used when soils are too wet as this can cause compaction and crusting which may reduce infiltration and inhibit seedling germination. If soils are too dry, a fluffy seedbed may be created that is susceptible to wind erosion and which is difficult to control seeding depth. Different compaction equipment is available to compress loose soils and modifications on many seed drills such as packer wheels and depth-bands can assist with packing and proper placement of seed in loose soils (Monsen and Stevens 2004a). Monsen and Stevens (2004a) also noted that dry, loose seedbeds should be expected to settle, which may result in satisfactory or unsatisfactory stands depending on the methods used in planting.

Table 1 Description, primary use, and limitations of some major seedbed preparation equipment. Adapted from Monsen and Stevens 2004a.

Equipment	Typical cost of implementation	Description	Primary area of use	Limitations
Disk-plow	$20-40/acre	Single gang of a few to several disks mounted on a frame.	Deep plowing of rock-free and debris-free soil. Controls deep rooted plants.	Restricted to fairly rock-free and large debris-free sites. Slow speed. Large amount of power required to operate.
Off-set disk	$20-40/acre	Two rows or gangs of disks set at an angle to each other	First gang of disks turn soil and vegetation. Second gang turns soil and vegetation in opposite directions. Vegetation is cut up and broken. Controls most grasses, forbs, and small nonsprouting shrubs. Works well on dry, heavy, and moderately rocky soils.	Cannot be operated in soil with large rocks and on slopes over 30 percent. Fairly slow operational speed.
Smooth anchor chain	$50-80/acre (one pass) $50-120/acre (two passes)	Anchor chain weighing 40 to 160 lb per link, 90 to 350 ft long, with swivels on either end and sometimes in the middle.	Moderate soil scarification. Uproots and breaks off trees and shrubs and releases understory vegetation. Covers seed. Cost per acre to operate is moderate. Can be operated on uneven, rocky terrain. Ideal for removing trees, releasing understory shrubs, grasses and forbs, and covering seed.	Will not control sprouting shrubs. A less than acceptable job of killing nonsprouting shrubs and trees. Will ride over young, flexible trees.
Ely anchor chain	$50-80/acre (one pass) $50-120/acre (two passes)	Anchor chain weighing 40 to 160 lb per link, 90 to 350 ft long, with steel bars or railroad rails welded perpendicular to chain links. Swivels on either end and sometimes in the middle.	Uproots and breaks off trees and shrubs. Releases understory vegetation. Percent kill of shrubs and trees is higher than with a smooth chain. Does an excellent job of scarifying soil surfaces and covering seed. Can be operated on rough, rocky terrain. Cost to operate is moderate.	Has tendency to hook and drag trees, and rolls downed trees and shrubs to middle of the chain. This lifts the chain off the ground resulting in poor soil scarification. Can uproot and kill some understory vegetation.
Chain harrow	$100-120/acre	Combination of an Ely anchor chain and a header bar with or without wheels, which can be pulled by a single tractor or dozer. Swivels on either end of the chain.	Scarifies soils surface, removes small brittle shrubs, and covers seed. Ideal for interseeding desirable species into sparse vegetation stands. Works well on rocky land and uneven terrain. Cost of operation is low. Seeding can occur concurrently.	Does not control plants other than brittle shrubs. Soil scarification is limited on compacted soil.
Tree masticator or shredder	$200-500/acre	Rotating blades or teeth rotating on a horizontal shaft enclosed in a metal frame for safety. Attachment can be driven by loader wheeled machines or tracked excavator types.	Masticates or shreds trees or brush creating mulch. Mulch and the action of the machine can create safe spaces for seed.	Expensive and cannot operate on steep slopes.
Land imprinter and Pasture aerator	$40-50/acre	Cylinder or drums with various configurations, sizes, and shapes of angle iron welded to the drum surface. The aerator has iron welded in a staggered, spiral pattern around one or two drums and drums can be offset for greater disturbance.	Operation on rough terrain on most soil types. Less disturbance than other methods. Seed dispensers may be attached to seed concurrently. Creates small depressions for water infiltration and seed catchment.	Does not work well on rocky or compacted soil. May require periodic retreatment to maintain desired shrub densities.

Appropriate timing of seedbed preparation and seeding are important for conservation of moisture and other determinants of seeding success. Many native species require some sort of stratification period, typically cold/wet periods in the Intermountain West, to meet dormancy requirements. These stratification requirements may be relatively short (several weeks) or long (upwards of 5 months) depending on the species or ecotype that is being planted. While seed can be pre-stratified prior to seeding, and is often done so for propagation in nurseries, doing so becomes impractical on larger projects. Often non-dormant species such as alfalfa, fourwing saltbush (*Atriplex canescens*), winterfat and a number of cool season grasses may be spring sown, but narrow planting windows and uncertain precipitation often make seeding large areas unfeasible (Monsen and Stevens 2004a).

Another consideration for a successful seeding is seed coverage and planting depth. As stated by Monsen and Stevens (2004a), determining the appropriate seeding depth presents a paradox. While a seed planted nearer the surface typically needs less energy for emergence, they also experience greater fluctuations in temperature and soil moisture. Seeds planted deeper in the soil are often insulated from these fluctuations, but require more energy to emerge. In both cases the primary objective is to have firm, consistent contact between the seed and soil to provide the needed moisture, but also meet the other requirements of germination including light, temperature and available energy from the seed for emergence. How deep a seed needs to be planted in restoration settings is most often dictated by the species being seeded and the soil properties of the site. As a general guideline, seeding depth should be 2-3 times the diameter of the seed (Monsen and Stevens 2004a). Seeding depths will rarely exceed one half inch (1.3 cm) for grasses, and are often less for forbs.

The use of diverse mixes of species may complicate the seeding process, requiring seeds of different sizes and germination requirements to be applied in separate mixes, possibly using different seeding methods. Unfortunately, diverse mixes are often seeded at depths that meet only the requirements of the primary grass species to the detriment of smaller and larger seeded species. When seeding diverse mixtures of species, consideration should also be given to separate row seeding (i.e., seeding different species in different rows or swaths; Ott et al. 2016). This strategy allows for the accommodation of different methods for different seed requirements and can also provide some benefit to slower growing species. However, row spacing also needs to be a consideration as some species establishment, reproduction and recruitment can be influenced by plant spacing (Monsen and Stevens 2004a).

Table 2 Description, primary use, and limitations of some major seeding equipment. Adapted from Monsen and Stevens 2004a.

Equipment	Typical cost of implementation	Description	Primary area of use	Limitations
Rangeland Drills	$15-25/acre	Seed boxes placed over furrow openers that allows for direct placement of seed and control of seeding depth. More heavy duty design than typical agricultural drill to allow for use on rough terrain. Can be either minimum-till or deep furrow. Pulled by either rubber-tired tractor or dozer. Drills can often be pulled in tandem or triple set-up to increase planting width.	Rangeland sites and rough terrain where dense litter has not accumulated. Dependent on seed boxes and furrow openers, can be used to accommodate different seeding depths and separate row seeding.	Limited to fairly flat terrain, and areas that are relatively free of rock, litter, trees and shrubs. Relatively slow, costly form of seeding.
Broadcast – Ground	$10-20/acre	Blower or rotary (more common) spreader used to distribute seed. Either hand-held or mounted to a vehicle.	Used in areas inappropriate for drill seeding. Can be used to seed large areas or small areas inaccessible to other equipment. Often done in conjunction with seedbed preparation. Much less expensive than drill seeding.	Limited to areas where people or vehicles can go. May have limited success if not done in conjunction with seedbed preparation or seed burying strategy.
Broadcast – Aerial	$6-20/acre	lower or rotary spreader used to distribute seed from a fixed wing aircraft or helicopter.	Used in areas inappropriate for drill seeding or ground broadcast. Can be used to seed large areas. Fixed wing aircraft are usually most efficient at seeding large areas. Helicopters can seed small, irregular areas. Often done in conjunction with seedbed preparation. Much less expensive than drill seeding.	Should not operate under less than favorable weather conditions. Irregular seeding can occur with poor marking and wind drift. Fixed-wing aircraft limited to areas with access to air strip and cannot typically operate at higher elevations. May have limited success if not done in conjunction with seedbed preparation or seed burying strategy.
Dribblers	Usually mounted on tractor in conjunction with chaining or mastication.	Seed box that dispense seed onto crawler tractor tracks. The seed is carried forward and pressed into the soil by the track.	Ideal for planting species that require firm seedbeds or whose seed is in short supply or extremely costly. Generally used in conjunction with other treatments such as chaining, or pushing trees and shrubs.	May not bury larger seeds deep enough. When done in conjunction with operations such as chaining, seeding only occurs in limited areas.
Imprinter Seeders	$15-25/acre	Seed placed in front of either smooth or cultipacker wheels that press the seed into the soil surface. Can be incorporated with either broadcast or drill seeding.	Used in relatively flat, smooth topography. Excellent for seeding small seeded species that need a firm seedbed.	Limited to areas of relatively flat and smooth topography. Moist soil may build up on the rollers.
Scalper Interseeder	N/A	Consists of a one- or two-way scalper or furrow opener to remove competition in a swath and a heavy-duty seeder. Can incorporate broadcast or dribbler surface seeding.	Used in areas to seed desirable species into existing vegetation. Used in cheatgrass or other annual communities, monotypic grass stands, perennial communities, burned areas, and disturbed sites.	Limited to areas relatively free of rock, roots, and stumps. Scalps or furrows may be viewed as aesthetically unpleasing.
ATV Interseeder	N/A	Small drill designed to be pulled behind an ATV or UTV.	Used in areas where full sized drills are limited by rock and debris. More maneuverable in confined areas. Useful in seeding species with special requirements or whose seed is in short supply or extremely costly.	Limited to small scale seeding areas. Still has some of the limitations of the larger drills.
Hydroseeder	$1,500-$4,000/acre	A hydraulic sprayer used to apply seed, fertilizer, soil amendments and fiber mulch to the soil surface. Consists of a truck or trailer, tank, pump, discharge nozzle and engine.	Generally used to seed steep slopes or very rocky areas.	Seed is not placed in the soil. Seed and seedlings can dry out. Some seedlings cannot grow through the mulch. Seed can be damaged by agitators and pumps. Precocious germination can occur as a result of moisture in the mulch. High expense and large water requirements.

Figure 24. Aerial seeding using fixed wing aircraft. (Photo courtesy Utah Watershed Restoration Initiative)

Equipment for both seedbed preparation and seeding is diverse and variable, using a myriad of strategies to meet various demands. Often seeding is done in conjunction with the seedbed preparation techniques. Treatments such as drill seeding and broadcast seeding before or after chaining can accomplish both tasks. A sampling of common equipment is presented in Tables 1 and 2, but is not an exhaustive list. For a more comprehensive review of revegetation equipment, see Monsen et al. (2004), Volume I or the online revegetation equipment catalog at https://greatbasinfirescience.org/RevegCatalog/index.html. Decisions in the selection of the most appropriate equipment are as diverse as the landscape itself and based primarily on project objectives, budgets and timelines.

Post-Treatment Maintenance

Post-treatment management is usually necessary to provide for maximum establishment and development of seeded and desirable indigenous species (Monsen and Stevens 2004b). Three areas that are critically important to address immediately following reseeding are: 1) management of grazing, 2) control of noxious weeds and other invasive species, and 3) managing human activity. These management challenges all have the potential to affect the long-term success of any reseeding project.

Grazing Management

Anytime reseeding is included as part of restoration or rehabilitation efforts of a particular site, management of grazing, both from domestic and wild ungulates should be carefully considered. As a general rule of thumb, seeded sites should not be grazed by domestic livestock for a minimum of two growing seasons following seeding. The minimum period of grazing rest following seeding will vary depending on several factors that include but are not limited to: species seeded; climatic conditions immediately preceding, during, and following treatment; soil type; and the presence of noxious weeds and other non-desirable species (Monsen and Stevens 2004b). For instance, areas that have a lower site potential due to less fertile or highly erodible soils, or reseedings done during drier climatic cycles will likely require a longer period of rest. One method to test if a site is ready to be grazed is the pull test on a seeded species and if it can be pulled up easily, including its roots, then it shouldn't be grazed. After grazing is reinstituted, the level and timing of grazing should be managed carefully to allow seeded species, especially forbs and shrubs, to establish and persist and should be done when grazing is least damaging. There is a lack of data to guide management on grazing decisions after restoration actions.

In addition to managing domestic livestock grazing, excessive use by big game, including mule deer, can result in harm to reseeding efforts (Monsen and Stevens 2004b). Tools to disperse wild ungulates or to reduce their numbers short term may need to be employed in order for reseeded areas to successfully establish and to meet restoration goals. Some of these include short-term reduction in populations, exclusion from seeded areas using fencing or exclosures, or herding of animals away from seeded areas.

Control of invasive weed species

Newly seeded areas can be a magnet for noxious weeds and other invasive plant species because reseeding almost always involves ground disturbing activities to prepare an adequate seedbed prior to seeding. Invasive species, including many noxious weeds, are often early colonizers, are highly competitive, are prolific seed producers, and favor disturbed areas. Early detection and rapid response (EDRR) is a key tenet of invasive species management, where "detection" is the process of observing and documenting an invasive species, and "response" is the process of reacting to the detection once the organism has been authoritatively identified and response options have been assessed (U.S. Department of the Interior 2020).

Invasive and noxious weed species already inhabit many critical habitats throughout the range of mule deer. For instance, invasive plants are one of the most significant stressors to the sagebrush biome, particularly invasive annual grasses such

as cheatgrass, as they colonize new areas following disturbances from vectors such as human development. Prior to any reseeding activity, land managers should be aware of the presence of, or the potential for, invasive species to occupy a site and then plan to minimize that risk as part of their reseeding efforts. There are many ways in which this can be accomplished and may include using a decision matrix or set of management framework criteria to identify priority areas for management, the current level of risk for invasive species on the site, and what management strategies are available and most appropriate for the given area that can provide the highest return on investment. Chambers et al. (2017b) provide a good example of how this might apply for the sagebrush biome.

A variety of tools are available for managing invasive species including use of chemicals, mechanical implements, and biological agents. The specific tool(s) chosen to manage invasive species will vary by the species being targeted, onsite characteristics of the seeding area (e.g., soils, precipitation, and topography), available funding, and policies and regulations of the treatment area location.

Any realistic plans to contain invasive and noxious weeds will likely require building partnerships. Coordination across land ownerships and jurisdictions to develop shared priorities and to leverage resources in controlling invasive species should be a crucial part of any planning process before seeding, as well as for post seeding management. For example, many states have cooperative weed management areas (CWMA's) which are diverse and locally run partnerships focused on managing invasive species issues. In Utah, CWMA's exist for a specific invasive species (e.g., squarrose knapweed) or for multiple invasive species issues within a geographic area and are composed of state, federal, county, and private partners all working together to provide knowledge and resources to control invasive species in their given jurisdictions. CWMA's have been highly beneficial for maintaining or improving thousands of acres of mule deer habitats.

For additional information on invasive species issues and available tools to help in planning and implementing invasive species management, visit the National Invasive Species Information Center at https://www.invasivespeciesinfo.gov.

Managing Human Activity

Many reseeding activities require access roads and trails to the project area, and as such, management of human activity can be an issue. Unneeded roads and trails should be closed and seeded as soon as practicable following treatment. Oftentimes a newly seeded site provides large open areas not previously accessible to human activity, and once treatment has occurred, these areas can become playgrounds for people. Unwanted roads and trails can become vectors of unwanted problems including soil erosion, sources for noxious weeds, dispersed camping, illegal off-highway vehicle use, fires, and concentration areas for livestock (Monsen and Stevens 2004b). Reseeding projects can be thought of as an opportunity to rehabilitate user created roads and trails and other human related impacts where local travel plans allow.

Post-Treatment Monitoring

Post-treatment vegetation monitoring is an integral part of any management project; the data collected can serve several purposes and is part of the adaptive management process. Perhaps the most obvious and objective reasoning for monitoring seeded mule deer habitat is to determine whether or not a treatment was successful.

“Success” itself is not a rigidly defined or standardized concept, but instead dependent upon the original objectives designated for each individual project (Wirth and Pyke 2007). The timeline for determining success is also plastic and project-dependent. According to the BLM Burned Area Emergency Stabilization and Rehabilitation Handbook (USDI Bureau of Land Management 2007) concerning post-fire rehabilitation, projects should be monitored for the first three years following treatment. This timeframe may be useful for determining initial establishment of plant species. However, longer term monitoring is likely required to yield conclusive data concerning shifts in species dominance and overall plant community trends (Knutson et al. 2014). Similar monitoring timeframes are likely appropriate for most treatment types in addition to those implemented following a fire. Longer term monitoring may be necessary in determining the success of establishing longer lived, slower growing species such as shrubs. Shaw et al. (2015) recommend monitoring shrub planting stock treatments during the initial two to three years following treatment to analyze community progression with intermittent monitoring afterwards.

Proper vegetation monitoring can also bring attention to any unintended/undesired effects precipitated by treatment including, but not limited to: increased amounts and/or monocultures of annual and less desirable perennial grass species, shrub mortality and failure to establish, the presence of noxious weeds, increases in erosion due to a lack of vegetation cover, and poor biodiversity in the plant community that can lead to decreased resilience. Early detection of unforeseen problems provides the opportunity for land managers to intervene and mitigate issues. Furthermore, conclusions drawn from monitoring data may act as guidelines for the design of similar projects in the future (Elzinga et al. 1998), potentially increasing cost-effectiveness of treatment.

Figure 25. Repeat photos of tree mastication and seeding project; pre-treatment (left) and 12 years post-treatment (right). (Photos courtesy of UDWR)

Study sites can be temporary, in which each sampling is analyzed independently, or permanent, which allows for consistent comparison between sample periods and observation of vegetation trends. The number and type of study sites are dependent on the data desired and should be determined before data is collected. Untreated control studies in tandem with those in treated areas may also be useful when additional data is desired for further comparison (Wirth and Pyke 2007).

One of the important and often overlooked aspects of monitoring is sample size. Statistically defensible information is needed to guide management decisions. Heterogeneous characteristics of rangelands can complicate monitoring and one sample size does not fit all sampling needs. Customizing plot sampling method, size and density will improve monitoring effectiveness. Determining a threshold of standard error and customizing the amount of samples required to meet that threshold can create more effective monitoring and defensible decisions (Applestein et al. 2018).

Once study site location and number have been decided upon, a number of sampling methods may be employed: these techniques measure a variety of qualitative and quantitative attributes. Methods may be used individually or in combination with each other depending on the data to be collected. Methodological information and guidelines are widely available and will therefore not be included in detail here. Instead, we provide a general overview of monitoring methods, along with their strengths and weaknesses (Elzinga et al. 1998, Coulloudon et al. 1999, Wirth and Pyke 2007).

Table 3. Categories and types of field techniques with associated uses, strengths, and weaknesses. Table compiled using material from Elzinga et al. (1998) and Wirth and Pyke (2007).

Method	Type(s)	Use(s)	Strength(s)	Weakness(es)
Census	• Complete Population Counts	Provides count of individual plants in area.	• Complete counts are actual and not extrapolated.	• Size of plants, difficulty in ID, larger areas, and clonal organisms may result in decreased accuracy.
Cover	• Quadrat • Line Intercept • Point Intercept	Measures vegetation and basic ground cover.	• Species ID not required for general vegetation cover. • May indicate potential for erosion. • Captures data on lifeforms difficult to measure with other methods (rhizomatous and small plants, etc.).	• Ocular estimates may result in observer error. • May fluctuate depending on environmental factors.
Density	• Quadrats • Strips	Measures plant numbers (individuals, clones, etc.) in defined units (miles, acres, etc.).	• Effective method for estimating loss and recruitment. • Can be compared between plots of different sizes.	• Does not measure vigor of plant community. • Does not inherently account for age classes.
Frequency	• Nested Frequency • Quadrat Frequency	Measures the abundance of plants, ground cover units, etc.	• Less sensitive to changes in precipitation, season, etc. • Accommodates all growth forms. • More long-term stability in data. • May require little training.	• Data only comparable between quadrats of the same size. • Values influenced by size of quadrats.
Photo/Video	• Photopoints • Photoplots • Video • Remote sensing	Provides visual overview of monitoring area.	• Illustrates structure and condition of overall plant community. • Monitors larger areas in less time than traditional quantitative methods. • Data collection not restricted to field.	• Possible data inaccuracies due to difficulty in species ID, visual limitations, photo scale, etc.

Census

Census methods such as complete population counts are appropriate when the number of individuals of a certain plant species in an area is desired. These techniques are advantageous in that the counts obtained are actual values and leave nothing to be extrapolated using formulas and calculations.

However, practical application may be influenced by outside factors, thereby affecting accuracy. When larger areas are sampled or in cases where target species are small, there is increased potential for individual plants to be overlooked. Misidentification can also influence totals when similar species are present in the sample area. Data may be further affected by trouble in determining what constitutes an "individual" in the case of clonal organisms such as quaking aspen.

Cover

Field techniques measuring cover values include, but are not limited to, quadrat methods, line intercept, point intercept, and line-point intercept: each of these may be more suited to some growth forms over others. Data is often recorded for vegetation and basic ground components such as litter, bare soil, etc.

Using cover techniques to collect data is advantageous for a number of reasons. For example, species identification is not necessary to record general vegetation cover if that is the level of data desired, in turn allowing for a wider range of capable observers. One should keep in mind, however, that species identification may be required for more detailed inventories or to assess diversity. Furthermore, cover methods can capture data for plants of certain growth habits (e.g., rhizomatous and small plants) which may not be optimally recorded by other methods. In addition, cover data may be used to indirectly evaluate the potential for undesirable erosion, as vegetation cover and associated litter lessen the effects of precipitation and wind on soil movement (Duran Zuazo and Rodriguez Pleguezuelo 2008).

Cover-measuring methods also have associated weaknesses that must be taken into consideration. As some cover measurements are ocular estimates dependent on perception, these methods have potential for observer bias, but some methods such as cover classes mitigate for bias and simplify estimation. In addition, vegetation cover can fluctuate depending on precipitation, season, and other factors, making it harder to compare and interpret data collected over several sample periods.

Density

Density is the number of units (clones, stems, individuals) per unit area (square feet, miles, hectares, acres). Data collected through density measurements are particularly useful when analyzing losses and recruitment into a plant community of a particular species. Comparing density of different species is typically not useful, but comparing density of the same species over time can help understand the direction of the community. As density is an estimate extrapolated from the actual collected values, data collection may in theory take less time than required for complete population counts. In addition, data collected from different sized plots are directly comparable assuming units/area are the same for each plot.

However, density in and of itself does not take vigor or age class into account, and may paint an inaccurate picture if seedlings are counted as mature plants. As such, it is necessary to document seedlings separately; if desired, further age classes (young, mature, decadent) and vigor can also be recorded.

Frequency

Techniques such as quadrat and nested frequency can assist in determining the percentage of plots occupied by a given plant species in a designated area. Ease of implementation and the relative speed at which measurements can be taken make frequency a valuable technique that is used in many monitoring projects. Frequency methods are also very repeatable, a trait which may be desired for long-term monitoring. Nested rooted frequency in particular can yield more consistent and comparable data over several sample periods. Unlike cover data, nested rooted frequency measurements change very little due to precipitation, weather, and season. Furthermore, growth forms pose little limitation on frequency data, and this method may be used with herbaceous species, trees, shrubs, litter, rock, etc.

As with every monitoring method, frequency does have disadvantages. Frequency data in general is very dependent on the size and shape of the quadrats employed and is only comparable when these quadrat attributes are consistent. One must also consider that both distribution of the plant population across the study site and density of plants influence frequency data. It can therefore be difficult to infer whether changes over time are due to shifts in distribution or increases/decreases in a plant population. Furthermore, determining changes over time typically requires frequencies between 20% and 80%.

Photo/Video

Qualitative data provided by visual records such as photo points, photo plots, remote sensing, and/or videography can prove to be a worthwhile addition to any monitoring project. Actual images of study sites can easily communicate the overall landscape, structure, and health of vegetation in a manner that may not be possible with numerical data alone. Repeat photos can be very effective in sharing changes over time with the public. Visual evidence of vegetation and soil changes are very valuable. A reference point in the foreground along with landmarks in the background can help ensure that the same photograph is retaken over time.

Quantitative data can be collected through photographic monitoring. Free software such as Samplepoint (2018) is available for manual image analysis. This technique uses photographs and a grid point intercept with manual identification of plant at the grids to get quantitative data on vegetation. Sampling time in the field is much shorter, while post processing in the office is longer. The photograph also serves a permanent record of the data.

Determining a sampling protocol for an individual project depends on the project objectives and what information is needed after the project. Understanding the strengths and weaknesses of the various techniques that are available is helpful in determining what methods to utilize. The resources of manpower, available time, and funding are also considerations.

Case Study: Partnerships in Restoration

Habitat restoration for mule deer is most effective when done at large spatial scales. Individual deer populations often have distinct summer, winter, and migratory areas that can span thousands of acres or stretch more than 100 miles, encompassing many habitat types and land ownerships. Consequently, large-scale habitat restoration is necessary to produce significant improvement in population performance. Large-scale restoration projects, however, are often expensive, require specialized equipment and technical expertise, take multiple years to complete, and require support from many partners. These challenges often limit the number of large-scale restoration projects that occur on the ground.

These challenges can be overcome when consistent funding is available, strong partnerships are formed, and specialized equipment and plant materials are available. Utah's Watershed Restoration Initiative (UWRI) is an example that has yielded astonishing results of successful large-scale restoration since 2005.

The Utah Partners for Conservation and Development (UPCD) acts as the guiding authority for the UWRI. This group is composed of 15 individuals that act as either Department heads or State Directors of their respective natural resource-oriented organizations. More importantly, these individuals have the ability to direct agency priorities and funding. UPCD members agreed in early 2006 to sponsor UWRI to help facilitate cooperative conservation efforts across the state of Utah. UWRI is composed of 5 regional working groups across the state. The working groups are open to anyone interested in watershed improvement and consist of federal and state natural resource and land management agencies, municipal and county governments, NGO's, and private individuals. Because UPCD Board Members commit agency funding to UWRI, it is often the only pathway for many to access their own agency's habitat restoration budgets. Pooling limited resources with other funds within the partnership leverages dollars that can cross land ownership boundaries and facilitate work at larger scales than any one entity could do alone. Having a partnership open to all is what makes UWRI so successful. Anyone can submit a habitat project for funding or provide technical assistance to others in the planning and implementation of partner projects to maximize their effectiveness. As part of the process, each UWRI regional working group ranks their own projects using a statewide UPCD approved scoring sheet. Project rankings are then submitted to the Statewide UWRI Coordinator who then applies funding from appropriate funding sources from both UPCD and partner organizations. Funding partners are encouraged to apply funds to the highest ranked projects first in order to gain matching funds. UWRI state funds are then used to fill in the deficits starting with the highest ranked projects continuing down the rankings until funds are depleted.

Figure 26. Presenting project proposals to partners with the Utah Watershed Restoration Inititative. (Photo courtesy of Utah Watershed Restoration Inititative).

Wildland restoration requires more than just funding, it requires the use of specialized equipment and available desired plant materials to put back on

the landscape. The Utah Division of Wildlife Resources (UDWR) and its partners have invested in a state-of-the-art seed warehouse with temperature controls, seed mixing capabilities, and humidity controlled spaces to improve seed viability during storage. Personnel at this facility work in the field of plant development and habitat restoration research. They also build and maintain numerous pieces of specialized restoration equipment. All of these restoration tools are housed in Ephraim, Utah at the Great Basin Research Center and Seed Warehouse. Having available plant materials, specialized equipment, and dedicated restoration staff allows the UDWR to assist UWRI partners with successful habitat restoration projects.

The Utah Watershed Restoration Initiative has been a huge success. Since 2006, UWRI partners have completed nearly 2,300 projects, treating nearly 2 million acres statewide. Restoring watersheds protects and rehabilitates vital habitat for wildlife; reduces catastrophic wildfire risks; increases water quality and quantity; increases forage for sustainable agriculture and provides economic benefits for local communities. To learn more about UWRI and its partners please visit watershed.utah.gov.

The Oregon Sage-Grouse Conservation Partnership (SageCon) is another example of a partnership program. This is a collaborative effort started in 2010 to leverage funding across Oregon's sagebrush landscapes and build interagency agreements that balance natural resource protection with local livelihoods. The partnership is structured to develop policy agreements and focus investments across public and private lands to build up community capacity to address major threats from fire to invasive plants. The focus of this partnership is implementing Oregon's Sage-Grouse Action Plan (Oregon State University Libraries & Press and Institute for Natural Resources 2021).

Broad partnerships like Utah's Watershed Restoration Initiative are not available in all locations, but local partnerships can still be forged and can be beneficial to getting projects on the ground across jurisdictional boundaries. Projects to improve mule deer habitat often are beneficial to other wildlife species and livestock producers and for weed and fuels management. Through common goals such as these, various state and federal agencies, as well as individuals can come together to improve habitat. Understanding and using each other's strengths can yield impressive results.

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Appendix 1.
Preferred Plants for Mule Deer and Black-Tailed Deer by Ecoregion.

Species	Benefit (F=Forage, C=Cover, B=Both)	Native? (Y or N)	References
<u>CALIFORNIA WOODLAND AND CHAPPARAL ECOREGION</u>			Sampson and Jespersen 1963, Holl et al. 1979
Trees and Shrubs			
Acacia, Catclaw (*Acacia greggii*)	B	Y	
Acacia, White Thorn (*Acacia constricta*)	B	Y	
Apache Plume (*Fallugia paradoxa*)	F	Y	
Arizona ash (*Fraxinus velutina*) [4-5]	C	Y	
Aspen, Trembling (*Populus tremuloides*)	B	Y	
Big-leaf maple (*Acer macrophyllum*)	B	Y	
Bitter cherry (*Prunus emarginata*) [1-2]	B	Y	
Black cottonwood (*Populus trichocarpa*) [3-4]	C	Y	
Blue elderberry (*Sambucus caerulea*) [2-4]	B	Y	
Blue witch (*Solanum umbelliferum*) [1-3]	B	Y	
Buckwheat (*Eriogonum* spp.) [2-3]	F	Y	
Budsage (*Artemisia spinescens*) [3-4]	B	Y	
Buffaloberry (*Shepherdia argentea*) [3-4]	C	Y	
Bush poppy (*Dendromecon rigida*) [3-4]	B	Y	
California boxelder (*Acer negundo* var. *californicum*) [3-4]	B	Y	
California buckeye (*Aesculus californica*) [1-2]	B	Y	
California coffeeberry (*Rhamnus californica*) [2-4]	B	Y	
California hazelnut (*Corylus cornuta* var. *californica*) [3-4]	C	Y	
California laurel (*Umbellularia californica*) [2-3]	B	Y	
California wild grape (*Vitis californica*) [3-4]	C	Y	
California wild rose (*Rosa californica*) [3-4]	C	Y	
California yerba santa (*Eriodictyon californicum*) [3-4]	C	Y	
Catclaw acacia (*Acacia greggii*)	B	Y	
Ceanothus, Blueblossom (*Ceanothus thyrsiflorus*) [2-3]	B	Y	
Ceanothus, Buckbrush (*Ceanothus cuneatus*) [3]	B	Y	
Ceanothus, Deerbrush (*Ceanothus integerrimus*) [1-2]	F	Y	
Ceanothus, Desert (*Ceanothus greggii*)	B	Y	
Ceanothus, Littleleaf (*Ceanothus parvifolius*) [2]	B	Y	
Chamise (*Adenostoma fasciculatum*) [2-3]	B	Y	
Chaparral pea (*Pickeringia montana*) [1-2]	F	Y	
Chaparral whitethorn (*Ceanothus leucodermis*) [1-2]	B	Y	
Cliffrose (*Cowania* [=*Purshia*] *mexicana*)	B	Y	

Common snowberry (*Symphoricarpos albus*) [3-4]	C	Y
Coyote brush or chaparral broom (*Baccharis pilularis*) [4-5]	C	Y
Currant, Mountain pink (*Ribes navadense*) [3-5]	B	Y
Currant, Wax (*Ribes cereum*) [3-4]	B	Y
Desert bitterbrush (*Purshia glandulosa*) [1-2]	B	Y
Dogwood (*Cornus sericea*) [3-4]	B	Y
Ephedra, Green (*Ephedra viridis*) [3-4]	B	Y
Ephedra, Nevada (*Ephedra nevadensis*) [3-4]	B	Y
Evergreen huckleberry (*Vaccinium ovatum*) [3-4]	B	Y
Fairy duster (*Calliandra eriophylla*)	B	Y
Fendlera or Fendlerbush (*Fendlera rupicola*)	B	Y
Fremont cottonwood (*Populus fremontii*) [3-4]	B	Y
Fremont silktassel (*Garrya fremontii*) [2-3]	B	Y
Fremontia or flannel bush (*Fremontia californica*) [1]	F	Y
Goatnut (*Simmondsia chinensis*) [2]	F	Y
Gooseberry, Canyon (*Ribes menziesii*) [3-5]	B	Y
Gooseberry, Fuchsia flowering (*Ribes speciosum*) [3-5]	B	Y
Gooseberry, Hillside (*Ribes californicum*) [3-4]	B	Y
Gooseberry, Red flowering (*Ribes sanguineum*) [3-5]	B	Y
Gooseberry, Sierra (*Ribes roezlii*) [3-5]	B	Y
Gooseberry, White-stemmed (*Ribes inerme*) [3-5]	B	Y
Gray horsebrush (*Tetradymia canescens*) [3-5]	B	Y
Hackberry, Desert (*Celtis pallida*)	B	Y
Hackberry, Mountain (*Celtis reticulata*)	B	Y
Hackberry, Western (*Celtis douglasii*) [3-4]	B	Y
Hollyleaf cherry (*Prunus ilicifolia*) [2-3]	B	Y
Hollyleaf redberry (*Rhamnus crocea* var. *ilicifolia*) [1-2]	F	Y
Ironwood (*Olneya tesota*)	B	Y
Jojoba (*Simmondsia chinensis*)	B	Y
Juniper, Alligator (*Juniperus deppeana*)	C	Y
Juniper, California (*Juniperus californica*) [3-4]	C	Y
Juniper, Western (*Juniperus occidentalis*) [3-4]	C	Y
Kidney wood (*Eysenhardtia polystachya*)	B	Y
Madrone (*Arbutus arizonicus,* A. *glandulosa*)	B	Y
Madrone (*Arbutus menziesii*) [3-5]	B	Y
Manzanita, Eastwood (*Actostaphylos glandulosa*) [4-5]	C	Y
Manzanita, Hoary (*Arctostaphylos canescens*) [4]	C	Y
Manzanita, Mariposa (*Arctostaphylos mariposa*) [4]	C	Y
Manzanitia, Mission (*Arcostaphylos bicolor*)	C	Y
Manzanita – point leaf manzanita (*A. pungens*)	C	Y

Mesquite (*Prosopis glandulosa*)	B	Y
Mountain Mahogany (*Cercocarpus* spp.)	B	Y
Mountain Mahogany, Birchleaf (*Cercocarpus betuloides*)	B	Y
Mountain Mahogany, Curlleaf (*Cercocarpus ledifolius*) [1]	B	Y
Mountain Mahogany, Western (*C. betuloides*) [1]	B	Y
Mountain whitethorn (*Ceanothus cordulatus*) [1-2]	B	Y
Mule fat (*Baccharis viminea*) [4-5]	C	Y
Oak, Arizona White (*Quercus arizonica*)	B	Y
Oak, Blue (*Quercus douglasii*) [1-2]	B	Y
Oak, California black (*Quercus kelloggii*) [1-2]	B	Y
Oak, California scrub (*Quercus dumosa*) [1-2]	B	Y
Oak, Canyon live (*Quercus chrysolepis*) [3-4]	B	Y
Oak, Coast live (*Quercus agrifolia*) [3-4]	B	Y
Oak, Emory (*Quercus emoryi*)	B	Y
Oak, Gambel (*Quercus gambelii*)	B	Y
Oak, Interior live (*Quercus wislizenii*) [1-2]	B	Y
Oak, Mohr Shrub (*Quercus mohriana*)	B	Y
Oak, Oregon (*Quercus garryana*) [2-3]	B	Y
Oak, Turbinella (*Quercus turbinella*)	B	Y
Oak, Valley (*Quercus lobata*) [3-4]	B	Y
Oak, Wavyleaf (*Quercus undulata*)	B	Y
Ocotillo (*Fouquieria splendens*)	B	Y
Oregon ash (*Fraxinus latifolia*) [4-5]	B	Y
Oregon Grape (*Berberis repens*)	B	Y
Pacific dogwood (*Cornus nuttallii*) [3-4]	B	Y
Pacific ninebark (*Physocarpus capitatus*) [4-5]	C	Y
Palo Verde (*Cercedium* spp.)	B	Y
Poison oak (*Toxicodendron diversilobum*) [2-3]	B	Y
Rabbitbrush, Low (*Chrysothamnus viscidiflorus*) [3-4]	B	Y
Rabbitbrush, Roundleaf (*Chrysothamnus teretifolius*) [3-4]	B	Y
Rabbitbrush, Rubber (*Chrysothamnus nauseosus*) [3-4]	B	Y
Range ratany (*Krameria erecta*)	F	Y
Ratany (*Krameria parvifolia*)	F	Y
Red shanks (*Adenostoma sparsifolium*) [4-5]	C	Y
Sagebrush, Big (*Artemisia tridentata*) [2-4]	B	Y
Sagebrush, Black (*Artemisia nova*) [2-3]	F	Y
Sagebrush, Coast (*Artemisia californica*) [4]	C	Y
Sagebrush, Silver (*Artemisia cana ssp. bolanderi*) [3-4]	B	Y
Salal (*Gaultheria shallon*) [3-4]	B	Y
Saltbush, Allscale (*Atriplex polycarpa*) [2]	F	Y

Saltbush, Australian (*Atriplex semibaccata*) [3]	F	Y
Saltbush, Fourwing (*Atriplex canescens*) [2-3]	F	Y
Sedge (*Carex* spp.)	F	Y
Shrubby cinquefoil (*Potentilla fruticosa*) [3]	B	Y
Silktassel (*Garrya wrightii*)	F	Y
Skunk bush (*Rhus trilobata*) [3-4]	B	Y
Spiny hop-sage (*Grayia spinosa*) [2-3]	B	Y
Sumac, Littleleaf (*Rhus microphylla*)	B	N
Sumac, Sugar (*Rhus ovata*)	B	Y
Tanoak (*Lithocarpus densiflorus*) [1-2]	B	Y
Thimbleberry (*Rubus parviflorus*) [3-4]	B	Y
Toyon (*Heteromeles arbutifolia*) [2-3]	B	Y
Twinberry (*Lonicera involucrata*) [2-3]	B	Y
Vine maple (*Acer circinatum*) [2-4]	B	Y
Western chokecherry (*Prunus virginiana* var. *demissa*) [1-2]	B	Y
Western redbud (*Cercis occidentalis*) [4-5]	C	Y
Western serviceberry (*Amelanchier alnifolia*) [2-3]	B	Y
White alder (*Aesculus rhombifolia*) [3-5]	B	Y
Wild mock orange (*Philadelphus lewisii*) [3-4]	B	Y
Willow, Arroyo (*Salix lasiolepis*) [3]	B	Y
Willow, Brewer's (*Salix breweri*) [3]	B	Y
Willow, Lemmon's (*Salix lemmonii*) [3]	B	Y
Willow, Narrow-leafed (*Salix exigua*) [3]	B	Y
Willow, Nuttall (*Salix scouleriana*) [3]	B	Y
Willow, Valley (*Salix hindsiana*) [3]	B	Y
Willow, Yellow (*Salix lasiandra*) [3]	B	Y
Winter fat (*Eurotia lanata*) [2-3]	F	Y
Wright's silk-tassel (*Garrya wrightii*)	C	Y
Yucca (*Yucca* spp.)	F	Y
Forbs, Grasses, and Succulents		
Deer vetch (*Lotus* spp.) [3-4]	B	Y
Deer weed (*Porophyllum gracile*)	F	Y
Lupine (*Lupinus* spp.)	F	Y
Metastelma (*Metastelma arizonicum*)	F	Y
Penstemon (*Penstemon* spp.)	F	Y
Prickly pear cactus (*Opuntia engelmannii*)	F	Y
Spurge (*Euphorbia* spp.)	F	Y

Note: [1]excellent, [2]good, fair, [4]poor, [5]useless.

<u>COLORADO PLATEAU WOODLAND AND CHAPARRAL ECOREGION</u>

Trees and Shrubs

Apache Plume (*Fallugia paradoxa*)**	F	Y	Short (1970), Kufeld et al. (1973), Bartmann (1983), McArthur and Monsen (2004a,b), Monsen et al. (2004a,b), Shaw et al. (2004), and Stevens and Monsen (2004).
Aspen, Trembling (*Populus tremuloides*)*	B	Y	
Birch, Bog (*Betula glandulosa*)**	B	Y	
Bitterbrush, Antelope (*Purshia tridentata*)*	B	Y	
Blackbrush (*Coleogyne ramosissima*)***	F	Y	
Blueberry (*Vaccinium* spp.)*	B	Y	
Budsage (*Artemsia spinescens*)**	F	Y	
Ceanothus, Desert (*Ceanothus greggii*)**	B	Y	
Ceanothus, Fendler (*Ceanothus fendleri*)**	B	Y	
Ceanothus, Martin (*Ceanothus martini*)**	B	Y	
Chokecherry (*Prunus virginiana*)*	B	Y	
Cliffrose, Stansbury (*Cowania stansburiana*)*	B	Y	
Cottonwood, Narrowleaf (*Populus angustifolia*)**	B	Y	
Currant, Golden (*Ribes aureum*)*	B	Y	
Currant, Wax (*Ribes cereum*)**	B	Y	
Dogwood, Redosier (*Cornus stolonifera*)*	B	Y	
Elderberry, Blue (*Sambucus cerulea*)**	B	Y	
Ephedra, Green or Mormon Tea (*Ephedra viridis*)***	F	Y	
Fir, Douglas (*Pseudotsuga menziesii*)***	B	Y	
Fir, White (*Abies concolor*)***	B	Y	
Grape, Oregon (*Mahonia repens*)**	F	Y	
Greasewood, Black (*Sarcobatus vermiculatus*)***	B	Y	
Hopsage, Spiny (*Grayia spinosa*)**	B	Y	
Horsebrush, Gray (*Tetradymia canescens*)***	F	Y	
Juniper, Creeping (*Juniperous horizontalis*)***	F	Y	
Juniper, Rocky Mountain (*Juniperus scopulorum*)***	C	Y	
Juniper, Utah (*Juniperus osteosperma*)***	C	Y	
Juniper, Western (*Juniperus occidentalis*)***	C	Y	
Mahogany, Curlleaf Mountain (*Cercocarpus ledifolius*)*	B	Y	
Mahogany, True Mountain (*Cercocarpus montanus*)*	B	Y	
Maple, Rocky Mountain (*Acer glabrum*)**	B	Y	
Manzanita, Greenleaf (*Arctostaphylos patula*)***	B	Y	
Ninebark, Mallowleaf (*Physocarpus malvaceus*)**	B	Y	
Oak, Gambel (*Quercus gambelii*)**	B	Y	
Pine, Pinyon (*Pinus edulis*)***	C	Y	
Pine, Ponderosa (*Pinus ponderosa*)***	C	Y	
Rabbitbrush, Dwarf (*Chrysothamnus depressus*)**	F	Y	
Rabbitbrush, Low (*Chrysothamnus viscidiflorus*)**	F	Y	

Rabbitbrush, Rubber (*Chrysothamnus nauseosus*)**	B	Y
Rose, Woods (*Rosa woodsii*)**	B	Y
Sagebrush, Big (*Artemisia tridentata*)**	B	Y
Sagebrush, Bigelow (*Artemsia bigelovii*)**	F	Y
Sagebrush, Black (*Artemisia nova*)**	F	Y
Sagebrush, Low (*Artemisia arbuscula*)**	F	Y
Sagebrush, Silver (*Artemsia cana*)**	B	Y
Saltbush, Four-wing (*Atriplex canescens*)**	F	Y
Serviceberry, Saskatoon (*Amelanchier alnifolia*)*	B	Y
Serviceberry, Utah (*Amelanchier utahensis*)*	B	Y
Shadscale (*Atriplex confertifolia*)**	F	Y
Snowberry (*Symphoricarpos* spp.)*	F	Y
Sumac, Rocky Mountain (*Rhus glabra*)**	B	Y
Sumac, Skunkbush (*Rhus aromatica*)**	B	Y
Willow (*Salix* spp.)*	B	Y
Winterfat (*Ceratoides lanata*)**	F	Y
Yucca, Soapweed (*Yucca glauca*)**		Y

Forbs, Grasses, and Succulents

Aster (*Aster* spp.)**	F	Y/N
Alfalfa (*Medicago sativa*)*	F	N
Balsamroot, Arrowleaf (*Balsamorhiza sagittata*)**	F	Y
Bluebell, Tall (*Mertensia arizonica*)**	F	Y
Bluegrass, Kentucky (*Poa pratensis*)**	F	N
Bluegrass, Mutton (*Poa fendleriana*)**	F	Y
Bluegrass, Sanderg (*Poa secunda*)**	F	Y
Brome, Nodding (*Bromus frondosus*)**	F	Y
Brome, Smooth (*Bromus inermis*)**	F	N
Buckwheat (*Eriogonum* spp.)*	F	Y
Burnet, Small (*Sanguisorba minor*)*	F	N
Cinquefoil (*Potentilla* spp.)*	F	Y/N
Clover, Strawberry (*Trifolium fragiferum*)*	F	N
Crownvetch (*Coronilla varia*)*	F	N
Cryptantha (*Cryptantha sericea*)**	F	Y
Dropseed, Sand (*Sporobolus cryptandrus*)**	F	Y
Eriogonum, Sulfur (*Eriogonum umbellatum*)*	F	Y
Eriogonum, Spearleaf (*Eriogunum lonchophyllum*)	F	Y/N
Fescue (*Festuca* spp.)**	F	Y
Fescue, Idaho (*Festuca idahoensis*)**	F	Y
Foxtail, Creeping (*Alopecurus arundinaceus*)**	F	N

Galleta Grass (*Hilaria sericea*)**	F	Y/N
Geranium (*Geranium* spp.)**	F	Y
Globemallow (*Sphaeralcea* spp.)**	F	Y
Goldenweed, Nuttall (*Haplopappus nuttallii*)**	F	Y
Grama, Black (*Bouteloua eriopoda*)**	F	Y
Grama, Blue (*Bouteloua gracilis*)**	F	Y
Grama, Sideoats (*Bouteloua curtipendula*)**	F	Y
Groundsel, Butterweed (*Senecio serra*)**	F	Y
Helianthella, Oneflower (*Helianthella uniflora*)**	F	Y
Hymenopappus, Fineleaf (*Hymenopappus filifolius*)**	F	Y
Junegrass (*Koeleria* spp.)**	F	Y
Kochia, Forage (*Kochia prostrata*)**	F	N
Lomatium (*Lomatium* spp.)**	F	Y
Lupine, Silky (*Lupinus sericeus*)**	F	Y
Lupine, Tailcup (*Lupinus caudatus*)**	F	Y
Needle and Thread Grass (*Stipa comata*)**	F	Y
Orchardgrass (*Dactylus glomerata*)**	B	N
Parsnip, Cow (*Heracleum lanatum*)**	F	Y
Penstemon (*Penstemon* spp.)**	F	Y
Phlox (*Phlox* spp.)**	F	Y
Ricegrass, Indian (*Oryzopsis hymenoides*)**	F	Y
Sage, Fringed (*Artemisia frigida*)**	F	Y
Sagewort (*Artemisia ludoviciana*)**	F	Y
Sainfoin (*Onobrychis viciaefolia*)*	F	N
Sedge (*Carex* spp.)**	F	Y
Squirreltail, Bottlebrush (*Elymus elymoides*)**	F	Y
Sweetclover, Yellow (*Melilotus officinalis*)**	F	N
Sweetvetch, Utah (*Hedysarum boreale*)*	F	Y
Timothy (*Phleum pretense*)**	F	N
Wheatgrass, Bluebunch (*Pseudoroegneria spicata*)**	F	Y
Wheatgrass, Fairway Crested (*Agropyron cristatum*)**	F	N
Wheatgrass, Intermediate (*Agropyron intermedium*)**	F	N
Wheatgrass, Slender (*Agropyron trachycaulum*)**	F	Y
Wheatgrass, Standard Crested (*Agropyron desertorum*)**	F	N
Wheatgrass, Thickspike (*Agropyron dasystachyum*)**	F	Y
Wheatgrass, Western (*Agropyron smithii*)**	B	Y
Wildrye, Great Basin (*Elymus cinereus*)**	F	Y
Yarrow, Western (*Achillea millefolium*)**	F	Y

*Note: * Generally preferred species; ** Preferred during certain seasons or growth stages; *** Species that are commonly eaten by mule deer but would seldom be expected to meet maintenance energy and/or nitrogen requirements.*

<u>COASTAL RAINFOREST ECOREGION</u>

Trees and Shrubs

Alder, Red (*Alnus rubra*)	B	Y	Brown 1961, Ulappa 2020
Alder, Sitka (*Alnus viridis*)	B	Y	Hanley et al. 2014
Blackberry, Cut-leaf (*Rubus laciniatus*)	F	N	Brown 1961
Blackberry, Himalayan (*Rubus armeniacus*)	B	N	Ulappa 2020
Blackberry, trailing (*Rubus ursinus*)	F	Y	Brown 1961, Ulappa 2020
Broom, Scot's (*Cytisus scoparius*)	B		Brown 1961
Cascara	B		Brown 1961, Ulappa 2020
Crabapple (*Malus fusca*)	B		Hanley et al. 2014.
Cranberry	F		Brown 1961
Cedar, Alaska Yellow (*Chamaecyparis nootkatensis*)	B		Kirchhoff and Larsen 1998
Cedar, Western Red (*Thuja plicata*)	B		Kirchhoff and Larsen 1998, Brown 1961
Cherry (*Prunus* spp.)	B		Brown 1961
Devil's Club (*Oplopanax horridum*)	B		Hanley et al. 2014, Kirchhoff and Larsen 1998
Dogwood	B		Brown 1961
Douglas-fir (*Pseudotsuga menziesii*)	B		Brown 1961
Douglas Spirea	B		Brown 1961
Elderberry (*Sambucus* spp.)	B	Y	Brown 1961, Ulappa 2020
Fir, Grand (*Abies grandis*)			
Fir, Pacific Silver (*Abies amabilis*)			
Fir, subalpine (*Abies lasiocarpa*)			
Fir, White (*Abies concolor*)			
Gorse (*Ulex europaeus*)			
Hazelnut (*Corylus cornuta*)	B	Y	Ulappa 2020,
Hemlock, Western (*Tsuga heterophylla*)	B	Y	Hanley et al. 2014, Kirchhoff and Larsen 1998, Brown 1961
Huckleberry (*Vaccinium* spp.)	B	Y	Hanley et al. 2014, Kirchhoff and Larsen 1998, Brown 1961, Ulappa 2020
Huckleberry, Red (*Vaccinium parvifolium*)	B	Y	Hanley et al. 2014, Kirchhoff and Larsen 1998
Madrone, Pacific (*Arbutus menziesii)*	B	Y	Brown 1961
Manzanita (*Arctostaphylos* spp.)	B	Y	
Maple, vine (*Acer circinatum*)	B	Y	Brown 1961, Ulappa 2020
Maple, big-leaf (*Acer macrophyllum*)	B	Y	Brown 1961
Myrtlr, Pachistima	B	Y	Brown 1961
Oak, Oregon White (*Quercus garryana*)	B	Y	

Oak, California Black (*Quercus kelloggii*)			
Oregon Grape	B	Y	Brown 1961
Poplar	B	Y	Brown 1961
Redflowering Current	B	Y	Brown 1961
Redwood, Coast (*Sequoia sempervirens*)			
Rose	B	Y	Brown 1961
Rusty Menziesia (*Menziesia ferruginea*)	B	Y	Hanley et al. 2014, Kirchhoff and Larsen 1998
Salal (*Gaultheria shallon*)	B	Y	Brown 1961
Salmonberry (*Rubus spectabilis*)	B	Y	Hanley et al. 2014, Kirchhoff and Larsen 1998, Brown 1961, Ulappa 2020
Snowberry	B	Y	Brown 1961
Spruce, Sitka (*Picea sitchensis*)	C	Y	Kirchhoff and Larsen 1998
Thimbleberry (*Rubus parviflorus*)	B	Y	Brown 1961
Willow (*Salix* spp.)	B	Y	Brown 1961
Yew, Pacific	B	Y	Brown 1961, Hanley et al. 2014
Forbs, Ferns, Lichens, Grasses, and Succulents			
Annual Agoseris	F	Y	Brown 1961
Beadruby	F	Y	Brown 1961
Bleedingheart	F	Y	Brown 1961
Bramble, Five-leaved (*Rubus pedatus*)	F	Y	Hanley et al. 2014, Kirchhoff and Larsen 1998
Bunchberry (*Cornus canadensis*)	F	Y	Hanley et al. 2014, Kirchhoff and Larsen 1998
Common Pearly Everlast	F	Y	Brown 1961, Ulappa 2020
Clover	F	Y	Brown 1961
Coltsfoot	F	Y	Brown 1961
Deer fern (*Blechnum spicant*)	F	Y	Hanley et al. 2014, Kirchhoff and Larsen 1998, Brown 1961
Deerfoot vanillaleaf	F	Y	Brown 1961
Deer vetch	F	Y	Brown 1961, Ulappa 2020
Domestic Grain	F	N	Brown 1961
False lily of the valley (*Maianthemum dilatatum*)	F	Y	Hanley et al 2014, Kirchhoff and Larsen 1998
Fireweed (*Chamerion angustifolium*)	B	Y	Kirchhoff and Larsen 1998, Brown 1961, Ulappa 2020
Foamflower (*Tiarella trifoliata*)	F	Y	Hanley et al. 2014, Kirchhoff and Larsen 1998

Fringed Willowherb (*Epilobium ciliatumb*)	F	Y	Ulappa 2020
Goldthread, Spleenwort-leaved (*Coptis asplenifolia*)	F	Y	Hanley et al 2014, Kirchhoff and Larsen 1998
Grasses	F	Y/N	Brown 1961
Groundsel, Common (*Senecio vulgaris*)			
Horsetail	F	Y	Brown 1961
Hypnum	F	Y	Brown 1961
Insideout flower	F	Y	Brown 1961
Knapweed (*Centaurea* spp.)			
Knapweed, Diffuse (*Centaurea diffusa*)			
Lady-fern (*Athyrium filix-femina*)	F	Y	Hanley et al. 2014, Kirchhoff and Larsen 1998, Brown 1961
Legumes (unidentified)	F		Brown 1961
Lichens (unidentified)	F	Y	Brown 1961
Lungwart (*Lobaria* spp.)			Hanley et al. 2014, Kirchhoff and Larsen 1998
Marsh Peavine	F	Y	Brown 1961
Moss (unidentified)	F	Y	Brown 1961
Mushrooms (unidentified)	F	N	
Nepeta	F	Y	Brown 1961
Skunk cabbage (*Lysichiton americanus*)	F	Y	Hanley et al. 2014, Kirchhoff and Larsen 1998
Spreading wood fern (*Dryopteris expansa*)	F	Y	Hanley et al. 2014
Oregon Aster	F	Y	Brown 1961
Oregon Bigroot	F	Y	Brown 1961
Oxalis, Oregon (*Oxalis oregana*)	F	Y	Brown 1961, Ulappa 2020
Pacific silverweed (*Argentina egedii*)	F	Y	Hanley et al. 2014.
Pepper, Chili (*Capsicum spp.*)			
Pineappleweed	F	Y	Brown 1961
Plantain	F	Y	Brown 1961
Rockweed alga (Fucus furcatus)	F	Y	Hanley et al. 2014
Ragwort, Tansy (*Senecio jacobaea*)			
Sedges (*Carex spp*)	F	Y	Hanley et al. 2014, Kirchhoff and Larsen 1998
Sheep Sorrel	F	Y	Brown 1961
Spotted Catsear	F	Y	Brown 1961, Ulappa 2020
Starflower	F	Y	Brown 1961
Star-thistle, Yellow (*Centaurea solstitialis*)	F	Y	Brown 1961
Strawberry	F	Y	Kirchhoff and Larsen 1998, Brown 1961
Sword-fern (*Polystichum munitum*)			

Thistle, Bull (*Cirsium vulgare*)	F	Y	
Thistle, Canada (*Cirsium arvense*)	F	N	Brown 1961
Thistle, Scotch (*Onopordum acanthium*)	F	Y	
Twisted Stalk (*Streptopus* spp.)	F	Y	
Violets (*Viola* spp.)	F	Y	
Western Meadowrue	F	Y	
Western Yarrow	F	Y	
Wild ginger (*Asarum caudatum*)	F	Y	
Witch’s hair lichen (*Alectoria sarmentosa*)	F	N	
<u>GREAT PLAINS ECOREGION</u>			
Trees and Shrubs			Anderson (1949), Anderson et al. (1965), Boecker et al. (1972), Coop (1977), Dusek (1971), Jackson (1990), Kamps (1969), Keller (1975), Knowles (1975), Komberec (1976), Krysl et al. (1980), Sowell et al. (1985), Sullivan et al. (1988), Uzell (1958), USDA (2008) Integrated Taxonomic Information System, Wood (1987), and Wood et al. (1989)
Barberry, Creeping (*Mahonia repens*)			
Bitterbrush, Antelope (*Purshia tridentata*)	B	Y	
Buffaloberry, Silver (*Shepherdia argentea*)	B	Y	
Clematis, Western White (*Clematis ligusticifolia*)	F	Y	
Chokecherry (*Prunus virginiana*)	B	Y	
Cottonwood, Eastern (*Populus deltoides*)	B	Y	
Dogwood, Redosier (*Cornus sericea*)	B	Y	
Douglas-fir (*Pseudotsuga menziesii*)	B	Y	
Ephedra (*Ephedra* spp.)	F	Y	
Gooseberry, Inland (*Ribes oxyacanthoides*)	B	Y	
Grape (*Vitis* spp.)	F	Y	
Greasewood, Black (*Sarcobatus vermiculatus*)	B	Y	
Hackberry, Netleaf (*Celtis laevigata*)	B	Y	
Hawthorn, Black (*Crataegus douglasii*)	B	Y	
Juniper, Creeping (*Juniperus horizontalis*)	F	Y	
Juniper, Rocky Mountain (*Juniperus scopulorum*)	C	Y	
Lotebush (*Ziziphus obtusifolia*)	B	Y	
Mahogany, Alderleaf Mountain (*Cercocarpus montanus*)	B	Y	
Mesquite (*Prosopis* spp.)	B	Y	
Oak, Sand Shinnery (*Quercus havardii*)	B	Y	
Pine, Ponderosa (*Pinus ponderosa*)	C	Y	
Plum, Chickasaw (*Prunus angustifolia*)	B	Y	
Plum, American (*Prunus americana*)	B	Y	
Plum, Creek (*Prunus rivularis*)	B	Y	
Western Sandcherry (*Prunus pumila*)	B	Y	
Rabbitbrush, Rubber (*Ericameria nauseosa*)	B	Y	
Raspberry, Red (*Rubus idaeus*)	F	Y	

Rose (*Rosa* spp.)	B	Y
Sagebrush, Big (*Artemisia tridentata*)	B	Y
Sagebrush, Sand (*Artemisia filifolia*)	B	Y
Sagebrush, Silver (*Artemisia cana*)	B	Y
Sagewort, Gray (*Artemisia ludoviciana*)	F	Y
Saltbush, Fourwing (*Atriplex canescens*)	F	Y
Saltbush, Nuttall's (*Atriplex nuttallii*)	F	Y
Saltbush, Shadscale (*Atriplex confertifolia*)	F	Y
Serviceberry, Saskatoon (*Amelanchier alnifolia*)	B	Y
Silverberry (*Elaeagnus commutata*)	B	Y
Snakeweed, Broom (*Gutierrezia sarothrae*)	F	Y
Snowberry, Western (*Symphoricarpos occidentalis*)	F	Y
Sumac, Skunkbush (*Rhus aromatica*)	B	Y
Currant,Wax (*Ribes cereum*)	B	Y
Currant, Golden (*Ribes aureum*)	B	Y
Willow (*Salix* spp.)	B	Y/N
Forbs, Grasses, and Succulents		
Alfalfa (*Medicago sativa*)	F	N
Alumroot, Roundleaf (*Heuchera cylindrica*)	F	Y
Aster (*Aster* spp.)	F	Y/N
Barley (*Hordeum vulgare*)	F	N
Balsamroot, Arrowleaf (*Balsamorhiza sagittata*)	F	Y
Bedstraw, Northern (*Galium boreale*)	F	Y
Beebalm (*Monarda* spp.)	F	Y
Beeblossom, Scarlet (*Gaura coccinea*)	F	Y
Bellflower, Bluebell (*Campanula rotundifolia*)	F	Y
Biscuitroot (*Lomatium* spp.)	F	Y/N
Bladderpod (*Lesquerella* spp.)	F	Y
Bluegrass (*Poa* spp.)	F	Y/N
Bluestem, Little (*Schizachyrium scoparium*)	F	Y
Bluestem, Silver (*Bothriochloa saccharoides*)	F	Y
Buckwheat, Fewflower (*Eriogonum pauciflorum*)	F	Y
Bundleflower, Illinois (*Desmanthus illinoensis*)	F	Y
Burdock, Common (*Arctium minus*)	F	N
Camphorweed (*Heterotheca subaxillaris*)	F	Y
Cholla (*Cylindropuntia* spp.)	F	Y
Coneflower, Upright Prairie (*Ratibida columnifera*)	F	Y
Croton (*Croton* spp.)	F	Y

Daisy, Engelmann (*Erigeron engelmannii*)	F	Y
Dandelion, Common (*Taraxacum officinale*)	F	Y
Dayflower (*Commelina* spp.)	F	Y/N
Flax (*Linum* spp.)	F	Y
Filaree (*Erodium* spp.)	F	N
Geranium, Sticky (*Geranium viscosissimum*)	F	Y
Globemallow, Scarlet (*Sphaeralcea coccinea*)	F	Y
Grama, Blue (*Bouteloua gracilis*)	F	N
Junegrass, Prairie (*Koeleria macrantha*)	F	Y
Knotweed (*Polygonum* spp.)	F	Y/N
Krameria, Trailing (*Krameria lanceolata*)	F	Y
Lettuce, Blue (*Lactuca tatarica*)	F	Y
Licorice, American (*Glycyrrhiza lepidota*)	F	Y
Milkwort, White (*Polygala alba*)	F	Y
Milkvetch or Locoweed (*Astragalus* spp.)	F	Y
Muhly (*Muhlenbergia* spp.)	F	Y
Musineon, Leafy (*Musineon divaricatum*)	F	Y
Needle and thread (*Hesperostipa comata*)	F	Y
Needlegrass, Green (*Nassella viridula*)	F	Y
Nightshade, Silverleaf (*Solanum elaeagnifolium*)	F	Y
Onion, Wild (*Allium* spp.)	F	Y
Phlox, Hood's (*Phlox hoodii*)	F	Y
Pricklypear (*Opuntia* spp.)	F	Y
Primrose (*Primula* spp.)	F	Y/N
Pussytoes (*Antennaria* spp.)	F	Y
Ragweed (*Ambrosia* spp.)	F	Y/N
Ricegrass, Littleseed (*Piptatherum micranthum*)	F	Y
Rockcress, Holboell's (*Arabis holboellii*)	F	Y
Rye, Cereal (*Secale cereale*)	F	N
Sagebrush, Fringed (*Artemisia frigida*)	F	Y
Salsify, Common (*Tragopogon dubius*)	F	N
Sandwort (*Arenaria* spp.)	F	Y/N
Sedge (*Carex* spp.)	F	Y
Sedge, Sprengel's (*Carex sprengelii*)	F	Y
Signalgrass, Plantain (*Urochloa plantaginea*)	F	N
Stoneseed, Narrowleaf (*Lithospermum incisum*)		
Sunflowers (*Helianthus* spp.)	F	Y
Sundrops, Yellow (*Calylophus serrulatus*)	F	Y
Thermopsis, Prairie (*Thermopsis rhombifolia*)		

Toad-flax, Bastard (*Comandra umbellata*)	F	Y	
Violet (*Viola* spp.)	F	Y/N	
Wallflower, Sanddune (*Erysimum capitatum*)	F	Y	
Wheatgrass, Bluebunch (*Elymus spicatus*)	F	Y	
Wheatgrass, Slender (*Elymus trachycaulus*)	F	Y	
Wheatgrass, Thickspike (*Elymus lanceolatus*)	F	Y	
Wheatgrass, Western (*Pascopyrum smithii*)	F	Y	
Wildrye, Virginia (*Elymus virginicus*)	F	Y	
Winterfat (*Krascheninnikovia lanata*)	F	Y	
Yarrow, Common (*Achillea millefolium*)	F	Y/N	
Yucca, Soapweed (*Yucca glauca*)	F	Y	

<u>INTERMOUNTAIN WEST ECOREGION</u>

Trees and Shrubs			Cox et al. 2009
Aspen, Quaking (*Populus tremuloides*)	B	Y	
Bitterbrush, Antelope (*Purshia tridentata*)	B	Y	
Bitterbrush, Desert (*Purshia glandulosa*)	F	Y	
Buffaloberry, Russett (*Shepherdia canadensis*)	F	Y	
Ceanothus (*Ceanothus* spp.)	B	Y	
Chokecherry (*Prunus virginiana*)	B	Y	
Cliffrose (*Purshia mexicana*)	B	Y	
Cottonwood (*Populus* spp.)	B	Y	
Elderberry (*Sambucus* spp.)	F	Y	
Mountain-mahogany, Curl-leaf (*Cercocarpus ledifolius*)	B	Y	
Mountain-mahogany, True (*C. montanus*)	B	Y	
Oak, California Black (*Quercus kelloggii*)	B	Y	
Oak, Gambel (*Q. gambelii*)	B	Y	
Pine, Jeffrey (*Pinus jeffreyi*)	C	Y	
Pine, Ponderosa (*P. ponderosa*)	C	Y	
Rabbitbrush (*Chysothamnus* spp., *Ericameria* spp.)	F	Y	
Rabbitbrush, Rubber (*Ericameria nauseosa*)	C	Y	
Rose, Wild (*Rosa* spp.)	F	Y	
Sagebrush, Big (*Artemisia tridentata*)	B	Y	
Sagebrush, Basin (*Artemisia tridentata tridentata*)	C	Y	
Sagebrush, Black (*Artemisia nova*)	F	Y	
Sagebrush, Low (*Artemisia arbuscula*)	F	Y	
Sagebrush, Fringed (*Artemisia frigida*)	F	Y	
Sagebrush, Mountain Big (*Artemisia tridentata vaseyana*)	B	Y	

Sagebrush, Silver (*Artemisia cana*)	B	Y
Sagebrush, Spiked (*Artemisia tridentata spicaformis*)	B	Y
Sagebrush, Tall Threetip (*Artemisia tripartita tripartita*)	B	Y
Sagebrush, Wyoming Big (*A. tridentata wyomingensis*)	F	Y
Saltbush, Fourwing (*Atriplex canescens*)	F	Y
Serviceberry (*Amalanchier* spp.)	B	Y
Skunkbush (*Rhus trilobata*)	B	Y
Snowberry (*Symphoricarpos* spp.)	F	Y
Willow (*Salix* spp.)	B	Y
Winterfat (*Krascheninnikovia* spp.)	F	Y

Forbs, Grasses, and Succulents

Alfalfa (*Medicago sativa*)	F	N
Aster-like (*Aster* spp.)	F	Y
Balsamroot, Arrowleaf (*Balsamorhiza sagittata*)	F	Y
Biscuitroot (*Lomatium* spp.)	F	Y
Bluegrass (*Poa* spp.)	F	Y
Bluegrass, Sandberg (*Poa secunda*)	F	Y
Brome (*Bromus marginatus, B. carinatus*)	F	Y
Brome, Smooth (*Bromus inermis*)	B	N
Buckwheat (*Eriogonum* spp.)	F	Y
Burnet, Small (*Sanguisorba minor*)	F	N
Clover (*Trifolium* spp.)	F	Y
Fescue (*Festuca* spp.)	F	Y
Fescue, Idaho (*Festuca idahoensis*)	F	Y
Fireweed (*Chamerion angustifolium*)	F	Y
Geranium, Sticky (*Geranium viscosissimum)*	F	Y
Globemallow (*Sphaeralcea* spp.)	F	Y
Goldenweed (*Stenotus* spp.)	F	Y
Grama, Blue (*Bouteloua gracilis*)	F	Y
Grass, Mutton (*Poa fendleriana*)	F	Y
Junegrass (*Koeleria macrantha*)	F	Y
Lupine (*Lupinus* spp.)	F	Y
Milkvetch, Cicer (*Astragalus cicer*)	F	N
Needlegrass (*Stipa* spp.*, Heterostipa* spp. *Achnatherum* spp.)	F	Y
Penstemon (*Penstemon* spp.)	F	Y
Phlox (*Phlox* spp.)	F	Y
Ricegrass, Indian (*Achnatherum hymenoides*)	F	Y
Sainfoin (*Onobrychis viciifolia*)	F	N

Sagewort (*Artemisia* spp.)	F	Y	
Sedge (*Carex* spp.)	F	Y	
Squirreltail, Bottlebrush (*Elymus elymoides*)	F	Y	
Sunflower (*Helianthella* spp., *Helianthus* spp.)	F	Y	
Strawberry (*Fragaria* spp.)	F	Y	
Tansyaster (*Machaeranthera* spp.)	F	Y	
Vetch (*Vicia spp., Astragalus* spp.)	F	Y	
Wheatgrass, Bluebunch (*Pseudoroegnaria spicata*)	F	Y	
Wheatgrass, Western (*Pascopyrum smithii*)	F	Y	
Wildrye, Basin (*Leymus cinereus*)	F	Y	
NORTHERN FOREST ECOREGION			
Trees and Shrubs			
Alder (*Alnus* spp.)	B	Y	Geist 1981
Aspen, Quaking (*Populus tremuloides*)	F	Y	Kufeld 1973
Bearberry (*Arctostaphylos* spp.)	C	Y	
Birch, White (*Betula papyrifera*)	B	Y	
Bitterbrush, Antelope (*Purshia tridentata*)	B	Y	
Buffaloberry, Canada (*Shepherdia canadensis*)	F	Y	
Buckthorn (*Rhamnus* sp.)	B	Y	DeCesare et al. 2020
Ceanothus, Redstem (*Ceanothus sanguineus*)	B	Y	
Cedar, Western Red (*Thuja plicata*)	B	Y	Geist 1981
Chokecherry (*Prunus virginiana*)	F	Y	
Current (*Ribes* sp.)	B	Y	Geist 1981, DeCesare et al. 2020
Douglas-fir (*Pseudotsuga menziesii*)	C		
Fir (*Abies* spp.)	C	Y	
Fir, Subalpine (*Abies lasiocarpa*)	F	Y	Kufeld 1973
Grape, Oregon (*Berberis ripens*)	B	Y	
Hawthorn (*Crataegus* spp.)	B	Y	
Hazelnut, Beaked (*Corylus cornuta*)	C	Y	
Hemlock (*Tsuga* spp.)	B	Y	DeCesare et al. 2020
Juniper (*Juniperus* spp.)	B	Y	
Larch (*Larix* spp.)	B	Y	
Mountain-mahogany, Curl-leaf (*Cercocarpus ledifolius*)	C	Y	
Ninebark (*Physocarpus* spp.)	B	Y	DeCesare et al. 2020
Pine (*Pinus* spp.)	C	Y	
Pine, Lodgepole (*Pinus contorta*)	C	Y	
Pine, Ponderosa (*Pinus ponderosa*)	C	Y	Geist 1981
Poplar, Balsam (*Populus balsamifera*)	B	Y	

Rabbit-brush (*Chrysothamnus* spp.)	F	Y	DeCesare et al. 2020
Raspberry, Red (*Rubus* spp.)	F	Y	Geist 1981
Red-osier Dogwood (*Cornus sericea ssp. sericea*)	B	Y	
Rocky mountain maple (*Acer glabrum*)	F	Y	Geist 1981
Rose, Wild (*Rosa acicularis*)	F	Y	Merems 2018
Rose, Dwarf (*Rosa gymnocarpa*)	F	Y	DeCesare et al. 2020
Rose (*Rosa* spp.)	B	Y	Berg 1983
Sagebrush (*Artemisia* spp.)	F	Y	Geist 1981, Merems 2018
Serviceberry (*Amelanchier* spp.)	F	Y	Berg 1983
Silverberry, Wolf Willow (*Elaeagnus commutata*)	B	Y	DeCesare et al. 2020
Snowbrush (*Ceanothus velutinus*)	C	Y	Geist 1981
Snowberry (*Symphoricarpos albus*)	F	Y	
Spirea (*Spirea* sp.)	F	Y	Merems 2018
Spirea, Shinyleaf (*Spirea lucida*)	C	Y	
Spruce (*Picea* spp.)	B	Y	Berg 1983, Geist 1981
Willow (*Salix* spp.)	B	Y	
Forbs, Grasses, and Succulents			
Alfalfa (*Medicago* sp.)	F	N	DeCesare et al. 2020
Alumroot (*Heuchera* spp.)	F	Y	DeCesare et al. 2020
Angelica (*Angelica* spp.)	F	Y	DeCesare et al. 2020
Aster (*Symphyotrichum* spp.)	F	Y	Bouckhout 1972
Balsamroot (*Balsamorhiza sagittata*)	F	Y	DeCesare et al. 2020
Barley, Foxtail (*Hordeum jubatum*)	F	Y	Kufeld 1973
Beardtongue (*Penstemon* spp.)	F	Y	DeCesare et al. 2020
Biscuitroot (*Lomatium* spp.)	F	Y	Berg 1983, DeCesare et al. 2020
Bluegrass, Fowl (*Poa palustris*)	F	Y	DeCesare et al. 2020
Broom snakeweed (*Gutierrezia sarothrae*)	F	Y	DeCesare et al. 2020
Buckwheat (*Eriogonum* spp.)	F	Y	Merems 2018
Cinquefoil, Sticky (*Potentilla glandulosa*)	F	Y	Merems 2018
Cinquefoil, Slender (*Potentilla gracilis*)	F	Y	DeCesare et al. 2020
Clover (*Trifolium* spp.)	F	N	Bouckhout 1972, Geist 1981
Cow parnsip (*Heracleum maximum*)	F	Y	DeCesare et al. 2020
Daisy (*Erigeron* spp.)	F	Y/N	Merems 2018
Danthonia, Onespike (*Danthonia unispicata*)	F		Merems 2018
Dogbane, Spreading (*Apocynum androsaemifolium*)	F	Y	Bouckhout 1972
False Hellebore (*Veratrum eschscholtzii*)	F	Y	Berg 1983
Fescue (*Festuca* spp.)	F	Y	DeCesare et al. 2020
Fireweed (*Chamerion angustifolium*)	F	Y	DeCesare et al. 2020

Globemallow, scarlet (*Sphaeralcea coccinea*)	F	Y	DeCesare et al. 2020
Goldenrod (*Solidago* spp.)	F	Y	DeCesare et al. 2020
Hawksbeard (*Crepis* spp.)	F	Y	Merems 2018
Hawkweed (*Hieracium* spp.)	F	Y/N	Kufeld 1973
Lupine (*Lupinus* spp.)	F	Y	DeCesare et al. 2020
Oatgrass (*Trisetum* spp.)	F	Y/N	DeCesare et al. 2020
Orchardgrass (*Dactylis glomerata*)	F	N	DeCesare et al. 2020
Oxeye daisy (*Leucanthemum vulgare*)	F	N	Merems 2018
Parsnipflower Buckwheat (*Eriogonum heracleoides*)	F	Y	DeCesare et al. 2020
Plantain (*Plantago* sp.)	F	Y/N	DeCesare et al. 2020
Rye grass (*Elymus* sp.)	F	Y	Merems 2018
Shootingstar (*Dodecatheon* spp.)	F	Y	DeCesare et al. 2020
Strawberry (*Fragaria* spp.)	F	Y	DeCesare et al. 2020
Sweet-vetch (*Hedysarum* spp.)	F	Y	DeCesare et al. 2020
Timothy grass (*Phleum pratense*)	F	N	DeCesare et al. 2020
Wheatgrass (*Pascopyrum* spp.)	F	Y	DeCesare et al. 2020
Wheatgrass, bluebunch (*Pseudoroegneria spicata*)	F	Y	DeCesare et al. 2020
Wild oat (*Avena fatua*)	F	Y	Merems 2018
Wyeth Biscuitroot (*Lomatium ambiguum*)	F	Y	Merems 2018
Yarrow, Common (*Achillea millefolium*)	F	Y	
<u>SOUTHWEST DESERTS ECOREGION</u>			Heffelfinger (2006), Heffelfinger et al. (2006), Lehr (1978).
Trees and Shrubs			
Acacia, Catclaw (*Acacia greggii*)	B	Y	
Acacia, White Thorn (*Acacia constricta*)	B	Y	
Apache Plume (*Fallugia paradoxa*)	B	Y	
Aspen, Trembling (*Populus tremuloides*)	B	Y	
Buckbrush (*Ceanothus* spp.)	B	Y	
Catclaw (*Mimosa biuncifera*)	B	Y	
Ceanothus (*Ceanothus* spp.)	B	Y	
Ceanothus, Desert (*Ceanothus greggii*)	B	Y	
Ceanothus, Fendler (*Ceanothus fendleri*)	B	Y	
Chamise (*Adenostoma fasciculatum*)	B	Y	
Cliffrose (*Purshia mexicana*)	B	Y	
Ebony (*Pithecellobium leptophyllum*)	F	Y	
Fairy duster (*Calliandra eriophylla*)	F	Y	
Fendlera or Fendlerbush (*Fendlera rupicola*)	B	Y	
Goldeneye, Skeletonleaf (*Viguiera stenoloba*)	B	Y	
Guayacan (*Porlieria angustifolia*)	B	Y	

Hackberry, Desert (*Celtis pallida*)	B	Y
Hackberry, Mountain (*Celtis reticulata*)	B	Y
Holly-leaf Buckthorn (*Rhamnus crocea*)	B	Y
Ironwood (*Olneya tesota*)	B	Y
Jojoba (*Simmondsia chinensis*)	C	Y
Juniper (*Juniperus* spp.)	C	Y
Juniper, Alligator (*Juniperus deppeana*)	B	Y
Kidney wood (*Eysenhardtia polystachya*)	C	Y
Madrone (*Arbutus arizonicus, A. glandulosa*)	C	Y
Manzanita (*Arctostaphylos pungens*)	C	Y
Manzanitia, Mission (*Arcostaphylos bicolor*)	B	Y
Mesquite (*Prosopis glandulosa*)	B	Y
Mountain Mahogany (*Cercocarpus* spp.)	B	Y
Mountain Mahogany, Birchleaf (*Cercocarpus betuloides*)	B	Y
Oak (*Quercus* spp.)	B	Y
Oak, Arizona White (*Quercus arizonica*)	B	Y
Oak, Emory (*Quercus emoryi*)	B	Y
Oak, Gambel (*Quercus gambelii*)	B	Y
Oak, Mohr Shrub (*Quercus mohriana*)	B	Y
Oak, Turbinella (*Quercus turbinella*)	B	Y
Oak, Wavyleaf (*Quercus undulata*)	F	Y
Ocotillo (*Fouquieria splendens*)	B	Y
Oregon Grape (*Berberis repens*)	B	Y
Palo Verde (*Cercedium* spp.)	F	Y
Ratany (*Krameria parvifolia*)	B	Y
Sage, White (*Salvia apiana*)	B	Y
Sagebrush, Big (*Artemisia tridentata*)	F	Y
Sedge (*Carex* spp.)	F	Y
Silktassel (*Garrya wrightii*)	B	Y
Sumac, Littleleaf (*Rhus microphylla*)	B	Y
Sumac, Threeleaf or Skunkbush (*Rhus trilobata*)	B	Y
Forbs, Grasses, and Succulents		
Bladderpods (*Lesquerella* spp.)	F	Y
Brickellia (*Brickellia californica*)	F	Y
Buckwheat (*Eriogonum* spp.)	F	Y
Copperleaf (*Acalypha pringlei*)	F	Y
Dalea (*Dalea* spp.)	F	Y
Desert Vine (*Janusia gracilis*)	F	Y

Ditaxis (*Ditaxis neomexicana*)	F	Y
Dogweed, Common (*Dyssodia pentachaeta*)	F	Y
Filaree (*Erodium cicutarium*)	F	N
Globemallow (*Sphaeralcea* spp.)	F	Y
Grass, Squirreltail (*Sitanion hystrix*)	F	Y
Gumhead (*Gymnosperma glutinosum*)	F	Y
Lupine (*Lupinus* spp.)	F	Y
Milkvetch or Locoweed (*Astragalus* spp.)	F	Y
Milkvetch, Slender (*Astragalus recurvus*)	F	Y
Mistletoe (*Phoradendron* spp.)	F	Y
Needleleaf Bluets (*Hedyotis acerosa*)	F	Y
Spurge (*Euphorbia* spp.)	F	Y
Vetch, Deer (*Lotus* spp.)	F	Y