(*Yermo xanthocephalus*) Desert Yellowhead Species Status Assessment

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Executive Summary

This report summarizes the results of a species status assessment (SSA) completed for *Yermo xanthocephalus* (desert yellowhead), a federally threatened plant species, to assess the species' overall viability using the three conservation biology principles of resiliency, redundancy, and representation (together, the 3Rs). Specifically, we identified the species' ecological requirements for survival and reproduction at the individual, population, and species levels, and described the beneficial and risk factors influencing desert yellowhead. We evaluated the changes in resiliency, redundancy, and representation from historical to the current time, and forecasted changes into the future.

Desert yellowhead is an endemic herbaceous perennial plant that occupies two areas in Fremont County, Wyoming. The two populations are located approximately 8 kilometers (km; 5 miles (mi)) apart and both are on lands administered by the Bureau of Land Management (BLM). Desert yellowhead is typically conspicuous compared to surrounding cushion plants and grasses, with its leathery leaves growing up to 30 centimeters (cm) (11.8 inches (in.)) tall, and 25 to 180 flower heads crowding the top of the stem of reproductive plants. Dispersal appears to be short-distance, with plants growing in clumps; plants also produce vegetative ramets that may separate from the parent plant. Plants occupy a narrow habitat of suitable soil characteristics, suitable amounts of precipitation, sufficient pollination, and mild temperatures. The seedling stage appears to have the highest level of mortality; established plants can survive for many years.

In this SSA Report, we evaluated the current condition of the species, as informed by past and present circumstances, and based on the 3Rs. To assess resiliency, we reviewed the ability of populations to withstand stochastic events such as wildfires and invasions of non-native invasive species, as measured by the current condition of the individual-level and population-level needs (soil, precipitation, temperature, pollination, survival, and reproduction). Presently, both populations appear stable (one highly resilient and one moderately resilient), which is likely due to the conservation actions implemented by the BLM to protect occupied habitat from mineral extraction activities.

To assess redundancy, we evaluated the contribution of the two known populations to the ability to withstand catastrophic events. These two populations can potentially be affected by catastrophic events, such as mineral development, increased drought and other effects related to climate change, wildfire, biovandalism, or sudden, intense, and long-lasting competition with invasive species.

To assess adaptive capacity (representation) we evaluated variation within the species in terms of how the two populations differ in placement on the slope, soil characteristics, density of surrounding vegetation, and aspect. We lack genetic information about this species at an individual and population level. Based on our evaluation, we characterized desert yellowhead as currently having moderate to high levels of resiliency, low levels of redundancy, and low levels of representation.

To assess the potential future status of the species in the face of uncertainty on what the future conditions may be, we devised risk scenarios by evaluating information on management, climate change, wildfire, and invasive species. We developed four plausible future risk scenarios largely driven by management of the populations:

1) Continuation scenario – mineral withdrawal of habitat surrounding one population is maintained while the second population continues to be vulnerable to opal mining, management protections are in place under the Lander BLM's Resource Management Plan, and the current trajectory and trend of the above-listed stressors continue into the future;

2) Improvement scenario – mineral withdrawals of habitat surrounding both populations are secured and/or renewed, management protections are in place under the Lander BLM's Resource Management Plan, other stressors are avoided or minimized, and climate change has a smaller effect; and

3) Worst scenario – mineral withdrawals of habitat surrounding both populations expire and/or are not secured, other management protections are not in place, and climate-change driven stressors increase.

4) Mixed scenario – to see if management or climate will be driving population resiliency: mineral withdrawals of habitat surrounding both populations expire and/or are not secured, other management protections are not in place, but climate-change has a smaller effect.

Based on these future scenarios, we predict that the future condition of the species can range from high levels of the 3Rs to low levels of the 3Rs, affected significantly by the presence or absence of the mineral withdrawals protecting the habitat upon which these populations occur.

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Chapter 1. Introduction, Data, and Analytical Framework

This report is the species status assessment (SSA) conducted for the federally threatened desert yellowhead (*Yermo xanthocephalus*). This species represents a monotypic genus of the subtribe Tussilagininae, of the tribe Senecionaeae, of the family Asteraceae. The desert yellowhead is a tap-rooted perennial herb found in two populations approximately 8 km (5 mi) apart in Fremont County, Wyoming. The first population was discovered in 1990 and the second in 2010.

1.1 Regulatory History

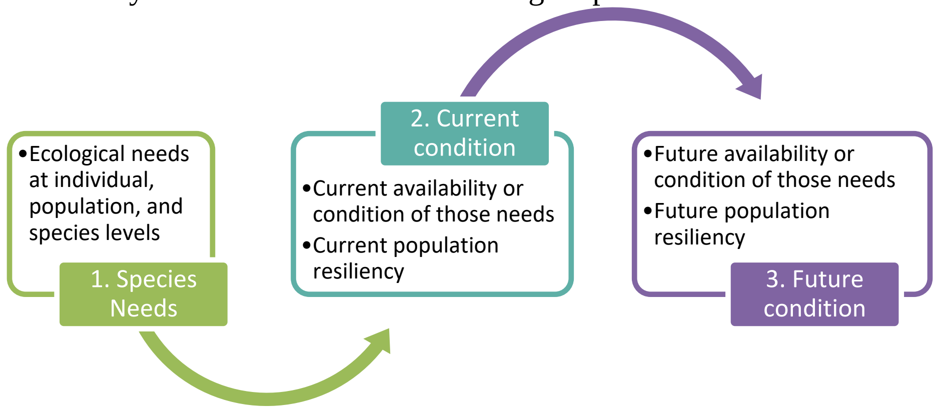
We, the U.S. Fish and Wildlife Service (Service) added desert yellowhead as a Category 2 candidate for listing under the Endangered Species Act of 1973, as amended (ESA), 16 U.S.C. 1531 et seq. in 1993 (58 FR 51144; September 30, 1993). This status was removed when the Category 2 program was cancelled in 1996, but the Service reclassified desert yellowhead as a Priority 1 candidate species in 1997 (62 FR 49398; September 19, 1997). The Service proposed listing desert yellowhead as a threatened species in 1998 (63 FR 70745; December 22, 1998), with the final listing rule in 2002 (67 FR 11442; March 14, 2002). Critical habitat was proposed for desert yellowhead in 2003 (68 FR 12326; March 14, 2003) and was designated in 2004 (69 FR 12278; March 16, 2004). A Recovery Outline was developed for desert yellowhead in 2010, assigning a recovery priority number of 7 (monotypic genus with a moderate degree of threat and high recovery potential; USFWS 2010, entire). We initiated a 5-year review in 2011 (76 FR 35906; June 20, 2011) and finalized the 5-year review in 2012 (USFWS 2012, entire).

1.2 Analytical Framework

This SSA Report was written with the help of a core team of biologists in the Wyoming Ecological Services Field Office and Region 6 Regional Office as well as a technical team composed of species experts from state (Wyoming Natural Diversity Database (WYNDD) and Wyoming Department of Agriculture) and federal (BLM) partners. Data were collected from partners, peer-reviewed literature, and previous Service documents on the species (listing decision (2002), critical habitat decision (2004), and 5-year review (2012)). Much of what is known about the desert yellowhead comes from only a few key sources, namely the discovery and status reports published by WYNDD in the 1990s and 2000s, the report depicting an immense 12-year study into the species' ecology from the Scotts published in 2009, and demographic studies conducted by the Doak lab in the 2010s.

Using the SSA Framework (Smith *et al*. 2018, entire), this SSA Report is a summary of the analysis; which entails three iterative assessment stages (Figure 1). This SSA Report provides an in-depth review of the species' biology and stressors, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain long-term viability. The intent is for the SSA Report to be easily updated as new information becomes available and to support all functions of the Endangered Species Program from Candidate Assessment to Listing to Consultations to Recovery. As such, an SSA Report is a living document upon which other future documents, such as recovery plans, 5-year reviews, and delisting proposals will be based. This SSA Report for the desert yellowhead is intended to provide the biological support for a 5-year review and a possible decision on whether to propose delisting the species due to recovery. Importantly, the SSA Report does not result in a decision by the Service on whether this taxon should be proposed for listing or delisting under the ESA. Instead, this SSA Report provides a review of the available information strictly related to the biological status of the desert yellowhead. The 5-year review and any delisting decision will be made by the Service after reviewing this report and all relevant laws, regulations, and policies, and the results of a proposed decision will be announced in the Federal Register, with appropriate opportunities for public input, should public input be necessary.

Figure 1. Iterative analytical framework for conducting a Species Status Assessment.



The SSA Report assesses the ability of desert yellowhead to maintain viability over time. To assess desert yellowhead viability, we used the three conservation biology principles of resiliency, redundancy, and representation, or the "3Rs" (Smith *et al*. 2018, entire). These principles are generally described later in this chapter, and more specifically for desert yellowhead in *Chapter 2*. Our approach for assessing desert yellowhead viability involved four stages. First, we described the species' ecology in terms of the 3Rs. Specifically, we identified the ecological requirements for survival and reproduction at the individual, population, and species levels; this is described in detail in *Chapter 2*. Second, we determined the baseline condition of the species using its ecological requirements in *Chapter 3*. That is, we assessed the species' current condition in relation to the 3Rs, and identified past and ongoing factors (stressors and conservation actions) that led to the species' current condition. Third, using these current conditions in combination with the predictions for future factors, both positive and negative, that may influence the species, we projected the likely future condition of desert yellowhead in *Chapter 4*. Finally, in *Chapter 5* we described the viability of desert yellowhead over time through a synthesis of current (influenced by past and ongoing factors) and future conditions analyses.

Viability is the ability to sustain populations over time. Therefore, a species must have a sufficient number and distribution of healthy populations to withstand changes in its biological (e.g., novel diseases, predators) and environmental (e.g., climate; wet or dry, warm or cold years) stochasticity, and catastrophes (e.g., wildfire, severe and prolonged droughts). Viability is not a single state—viable or not viable; rather, there are degrees of viability: less to more viable or low to high viability. Generally speaking, the more resiliency, redundancy, and representation a species has, the more protected it is against changes in the environment, the more it can tolerate stressors (one or more factors that may be acting on the species or its habitat, causing a negative effect), the better able it is to adapt to future changes, and thus, the more viable it is. The 3Rs framework (assessing the health, number, and distribution of desert yellowhead populations relative to the frequency and magnitude of environmental stochasticity and catastrophic events across its historical range of adaptive diversity) is useful for describing a species' degree of viability through time.

1.2.1 Resiliency

Resiliency is the ability to sustain populations in the face of environmental variation and stochastic events. Environmental variation includes normal year-to-year variation in rainfall and temperatures, as well as unseasonal weather events. Stochastic events may include fire, flooding, and storms. Simply stated, resiliency is having the means to recover from "bad years" and disturbances. To have high resiliency, a species must have healthy populations; that is, populations that are able to sustain themselves through good and bad years. The healthier the populations and the greater number of healthy populations, the more resiliency a species possesses. For many species, resiliency is also affected by the degree of connectivity among populations. Connectivity among populations increases the genetic health of individuals (heterozygosity) within a population and bolsters a population's ability to recover from disturbances via rescue effect (immigration).

1.2.2 Redundancy

Redundancy is the ability of a species to withstand catastrophic events. Redundancy protects species against the unpredictable and highly consequential events for which adaptation is unlikely. In short, it is about spreading the risk. In general, redundancy is measured at the species level, and is best achieved by having multiple populations widely distributed across the species' range. Having multiple populations reduces the likelihood that all populations will be affected simultaneously, while having widely distributed populations reduces the likelihood of populations possessing similar vulnerabilities to a catastrophic event. Given sufficient redundancy, single or multiple catastrophic events are unlikely to cause the extinction of a species. Thus, the greater redundancy a species has, the more viable it will be. For most species, the more populations and the more diverse or widespread that these populations are, the more likely it is that the ability to withstand catastrophic events will be preserved. Having multiple populations distributed across the range of the species will help preserve the breadth of adaptive diversity, and hence, the evolutionary flexibility of the species.

1.2.3 Representation

Representation is the ability of a species to adapt to near and long-term changes in the environment; it's the evolutionary capacity or flexibility of a species. Representation, as measured at the species level, is the range of variation found in a species, and this variation--called adaptive diversity--is the source of a species' adaptive capabilities. Representation can, therefore, be measured through the breadth of adaptive diversity of the species. The greater the adaptive diversity, the more responsive and adaptable the species will be over time, and thus, the more viable the species is.

Maintaining adaptive diversity includes conserving both the ecological diversity and genetic diversity of a species. By maintaining these two sources of adaptive diversity across a species' range, the responsiveness and adaptability of a species over time is preserved. Ecological diversity is the physiological, ecological, and behavioral variation exhibited by a species across its range. Genetic diversity is the number and frequency of unique alleles within and among populations.

Chapter 2. Species Ecology and Needs

In this chapter, we briefly describe desert yellowhead as a species, its taxonomy, and discuss its life history characteristics at the individual, population, and species levels. This is not an exhaustive review of the species' natural history; rather, this chapter provides information relevant to understanding the ecological basis for the SSA Report analyses conducted in *Chapters 3-5*.

2.1 Species Taxonomy and Description

Desert yellowhead was discovered by botanist Robert Dorn in the Beaver Rim area of central Wyoming (hereafter referred to as the "Sand Draw" population) in 1990 (Dorn 1991, pp. 198–201). Dorn estimated approximately 500 plants occurred in 1.0 hectare (ha) (2.5 acres (ac)) of sparsely vegetated, sandy hollows among sandstone outcrops. He determined this unusual plant was a member of the Aster family (Asteraceae), which is one of the largest plant families in the world and is comprised of many tribes (Barkley 1999, p. 661). Dorn (1991, p. 198) described this new genus and species and named his discovery *Yermo xanthocephalus*, or literally "desert yellowhead."

More recent taxonomic work has indicated that *Yermo xanthocephalus* is the only member of a monotypic genus, *Yermo*, and is the only Wyoming species in a new subtribe Tussilagininae (Cass.) (Dumort) (Barkley 1999, p. 664). A morphometric study comparing six species of subtribe Tussilagininae showed the specimens of desert yellowhead have less variation as a species than some other members of the subtribe (Van Vleet 1996, as cited in Scott and Scott 2009, p. 48) and that it did not overlap with other species, suggesting that desert yellowhead plants are very similar to each other, and are very different from other species within the same subtribe.

Desert yellowhead is a tap-rooted perennial herb. The entire plant is smooth, possessing no hair or other projections. The stems have leathery leaves and grow up to 30 centimeters (cm) (11.8 inches (in.)) tall. The leaves grow in an alternating pattern and are often folded along the vein in the middle of the leaf. Flower heads are numerous (25 to 180) and crowded on top of the stem. Each flower head contains four to seven yellow disk flowers (ray flowers are absent) surrounded by four to seven yellow, keeled involucral bracts (modified leaves below the flower head). The seeds have tufts of white hairs (Dorn 1991, pp. 198–201; Heidel 2002 pp. 4–7).

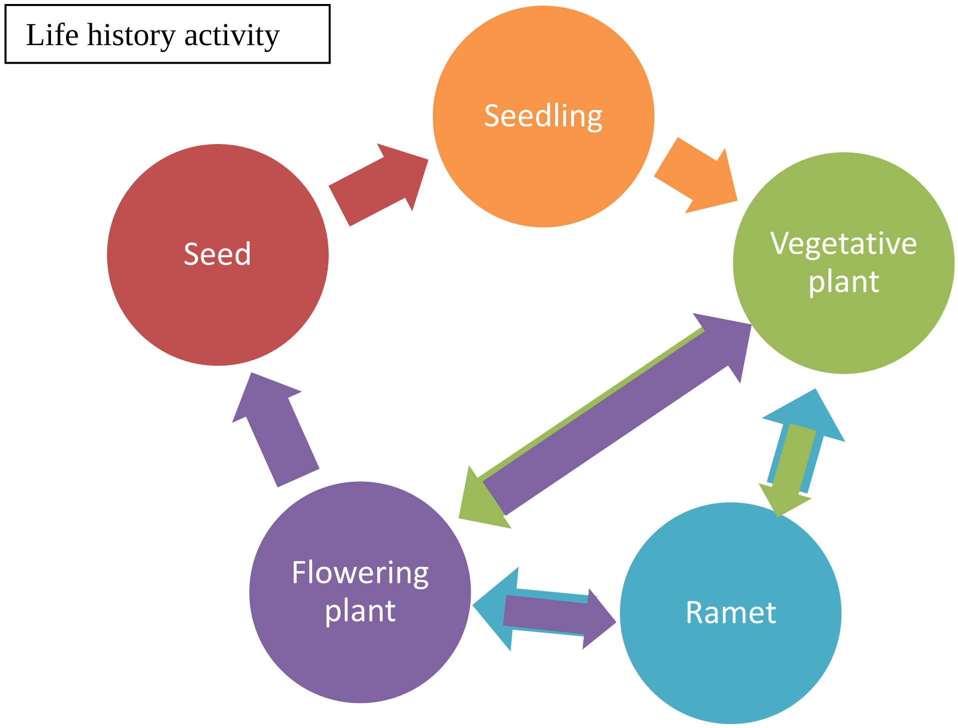
<u>Life History:</u>
The life history for desert yellowhead and an approximate phenology table are found in Figure 2. Desert yellowhead most likely follows the typical life history of an herbaceous perennial vascular plant: seeds germinate and become seedlings, seedlings survive and become vegetative

plants, vegetative plants survive to flower, flowering plants reproduce sexually and produce seeds, and flowering can repeat whether the individual is vegetative or flowering the previous year. Plants also reproduce vegetatively by production of and differential survival of ramets, or asexually-reproduced plants formed from budding of modular plants at both the vegetative and flowering life stages (Fertig 1995, p. 17). Evidence of this modular growth exists based on the branching patterns observed in mature plants (Scott and Scott 2009, pp. 11–12), and by the number of new non-seedling plants observed in transects year over year (Doak *et al*. 2016, p. 25). Assumptions regarding some life history traits, such as inference that the formation of ramets occurs regularly in desert yellowhead, are based on the best available information.

New plants establish from seed or ramet, grow for multiple years before flowering, and after first flowering often have years in which no flower production occurs (Doak *et al*. 2016, p. 4). Plants require the development of a basal cluster of leaves before flowering occurs (Scott and Scott 2009, p. 41). Based on one long-term demographic study, flowering may take place after the plant has grown for a minimum of five years (Scott and Scott 2009, p. 47). Plants can live 21 or more years, as evidenced by an established plant surviving the duration of one long-term study (Scott and Scott 2009, p. 47). Because of high levels of seedling mortality, the average lifespan may be much shorter, except for established plants. Lifespan can also be higher if one considers the differential survival of ramets that are genetically identical to the original plant and live after the original plant has died.

This species was originally described as a classic ‘K’- selected species (instead of ‘R’-selected with many offspring and short lifespan), characterized by a long-lived perennial growth form, adaptation to severe habitats, and low annual reproductive output (Fertig 1995, p. 19). However, Scott and Scott characterized desert yellowhead as being an S-R strategist (from the C-S-R Triangle from the universal adaptive strategy theory of plants’ strategies of competitor, stress tolerator, and ruderal). That is, ‘S’ for stress-tolerant and capable of surviving in disturbed habitats, and ‘R’ for ruderal, meaning an early colonizer and adapted to habitats that are severe to extreme (Scott and Scott 2009, p. 58).

A recent population viability analysis (PVA) based on both demographic monitoring and an earlier census (Scott and Scott 2009, entire) found that the growth rate varied across portions of the population; this asynchrony indicates portfolio effects, where increases in one portion of the population make up for decreases in another (Doak *et al*. 2016, pp. 11–12; Dibner *et al*. 2019, p. 7). This PVA also found that there was negative density dependence in population growth rates, which acts to stabilize population numbers because growth rates decline when population abundance becomes high (Doak *et al*. 2016, p. 12; Dibner *et al*. 2019, p. 13).



Phenology stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
seed production												
seed germination												
seedling presence												
vegetative growth/presence												
flowering												
ramet formation												

Figure 2. Desert yellowhead life history and phenology. Colors within the life history cycle match life history activities in the phenology table. Arrows indicate the progression from one life history activity to the next, where flowering plants can become vegetative for one or more years and then flower again, and both flowering and vegetative plants may produce ramets that in turn become either flowering or vegetative plants the following year. Hashed areas in the table are either unknown or non-primary periods of growth and production.

Spring flush of growth typically begins around mid-May each year in desert yellowhead habitats (Scott and Scott 2009, p. 54). Desert yellowhead usually flowers for a month or less early in the growing season, from mid-June to August, and may prolong flowering or flower for a second time in September (Scott and Scott 2009, p. 54). The growing season has an average of 124 days, with precipitation being a major predictor of flowering, followed by air temperature (Scott and Scott 2009, p. 55). In the Scott and Scott demographic study, the growing season began as early as May 9 and ended as late as October 10 (Scott and Scott 2009, p. 39). In that study, the second, September flowering was always in large plants with two or more branches or modular portions (Scott and Scott 2009, p. 55).

Pollination biology for desert yellowhead is based on preliminary observations and further research is ongoing. This species is likely pollinated by visually-oriented insects attracted to its bright yellow disk flowers and bracts (Dorn 1991, pp. 198–201). Ants and nectar-feeding butterflies were noted as frequent visitors to its flowers (Heidel *et al.* 2011, p. 21). One butterfly was identified as the small wood nymph (Nymphalidae *Cercyonis oetus*), a common species in Wyoming that typically feeds on the nectar of yellow composite flowers (Heidel *et al*. 2011, p. 21). Desert yellowhead is also potentially pollinated by skipper butterflies (Hesperiidae) (Scott and Scott 2009, p. 45). A pollination study is currently being conducted by members of the WYNDD, who have observed bees (mainly Agapostem and Bombus spp.) visiting flowers, and who will use collected pollen to estimate which bees function as pollinators for desert yellowhead (Handley, J., pers. comm. 2018a). The WYNDD study also found that desert yellowhead is capable of self-fertilization (Handley, J., pers. comm. 2018a).

Flowering levels of desert yellowhead appear to decline in drought years, but no specific studies have been conducted on this topic to date. At any given time, most of the population is composed of small vegetative plants that have both small above-ground biomass and small, shallow root systems (Scott and Scott 2009, p. 28). To be able to flower, plants need 6 or more leaves (Scott and Scott 2009, p. 40), though plants with as many as 56 leaves may not flower for many years (Scott and Scott 2009, p. 41).

Fruits of desert yellowhead are single-seeded achenes (small, dry, one-seeded fruit that does not open to release the seed; Fertig 1995, p. 19). The tufted seeds of desert yellowhead mature in the latter half of summer when they are dispersed short distances by wind (Heidel *et al.* 2011) or water (Scott and Scott 2009, p. 56). It is possible to discern viable fruits from non-viable fruits because they are more plump, darker, and larger than non-viable fruits (Scott and Scott 2009, p. 44). Viable fruit production generally appears to be low to moderate due to insect herbivory and drought-induced abortion (Fertig 1995, p. 17). About half of the seeds germinate in the same season in which they fell, without cold stratification (Scott and Hoster 2000, pp. 4–6). Germination from seed to fully-formed seedling with a primary root and 2 cotyledons (embryonic leaves) took 24 days in the lab (Scott and Scott 2009, p. 47). Seedlings can be identified as early as May and can overwinter in a quiescent or dormant state without development of primary leaves (Scott and Scott 2009, pp. 44–45). Because seedlings are present year-round and exposed to temperature and precipitation extremes, high mortality rates are typical at the seedling phase.

Unknowns regarding life history include when and how ramet formation occurs, seed dormancy and viability length, factors required for successful germination in the wild, whether established plants exhibit prolonged dormancy, and pollen limitation. We also do not have confirmation of a mycorrhizal symbiont to aid in nutrient and water uptake, though potential fungal symbionts have been documented (Heidel *et al*. 2011, Appendix D by Stephen Williams).

2.2 Distribution and Habitat

Desert yellowhead, a monotypic genus, is likely a neo endemic, meaning it is recently arisen through divergence or reproductive isolation. It occurs in two known populations (see Figure 3) with somewhat distinctive habitats. The habitats of the two populations differ not only in their topographic positions, but also in vegetation structures (Heidel *et al*. 2011, pp. 2 and 20). The occupied habitat of the Sand Draw population of desert yellowhead is restricted to shallow depressions created by erosion in outcrops of Miocene sandstones and limestones of the White River Formation (Van Houten 1964, pp. 54–78) at approximately 2057 meters (m; 6750 feet (ft)) elevation. These depressions accumulate drifting snow and may be more moist than surrounding areas. Desert yellowhead is also found on very steep erosive slopes, old road cuts, and flat, rocky areas. The vegetation of these sites is typically sparse, with less than 10 percent cover, and consists primarily of low cushion plants and scattered clumps of *Oryzopsis hymenoides* (Indian ricegrass) (Fertig 1995, p. 24).

By comparison, the Cedar Rim population is restricted to a narrow band along upper to lower escarpment slopes that are generally south-facing on gravelly silt loam derived from White River Formation at approximately 2158 m (7080 ft) elevation, which is approximately 100 m (330 ft) higher than the Sand Draw population. The vegetation at Cedar Rim is "mostly at ecotone [transition] between cushion plant rim and sagebrush grassland,"..."with 5 to 20 percent bunchgrasses, including bluebunch wheatgrass [(*Pseudoroegneria* spicata)] and junegrass [(*Koeleria* spp.)], accompanied by diverse forbs (Heidel and Handley 2010, as cited by Heidel *et al*. 2011, p. 20).

There is a relatively rich diversity of flora within and around desert yellowhead populations, encompassing 21 families, 68 genera, and 105 species (Scott and Scott 2009, pp. 30–34), though this vegetation tends to be rather sparse, and the areas occupied by desert yellowhead plants have even lower vegetative cover. It is likely that desert yellowhead is restricted to sites with low competition and is found to tolerate soil characteristics that competitors cannot tolerate.

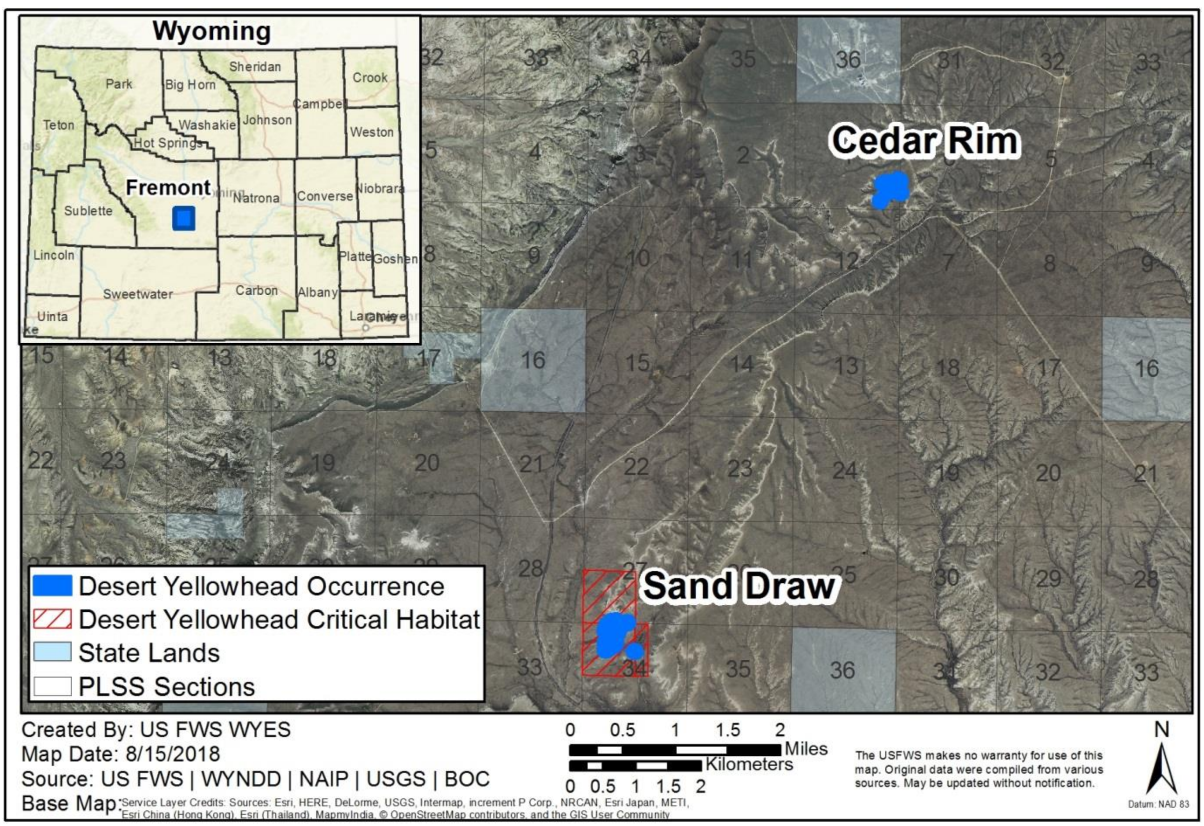
In 2010, WYNDD developed a Maximum Entropy (MaxEnt) model to predict the distribution at the state and regional level of desert yellowhead based on the habitat parameters of the Sand Draw population, which was the only population known at the time (Heidel *et al*. 2011, entire). This model was used in combination with digitized layers of all past surveys and photointerpretation of aerial imagery to predict the location of undiscovered populations of target unsurveyed potential habitat of desert yellowhead, an approach that was validated by the discovery of the Cedar Rim population in 2010. The model used in 2010 surveys was modified in 2011 using negative survey results. The key variables contributing to the revised model, ranked by percent contribution, were: potential for rock outcrop, 8-category aspect (discrete south aspect, no north aspect, and less east or west aspects), soil texture, depth to shallowest restrictive layer, annual total radiation, radiation of the lightest month, wettest quarter mean temperature, and annual relative humidity range (Heidel *et al*. 2011, pp. 12–17). Successive surveys in 2011 targeting all high probability locations produced no new populations; there is a low likelihood that additional populations of this species may exist within the geographic area.

The Sand Draw site is sheltered with winds out of the south between July and September. This wind pattern provides a potential pathway for seed dispersal from the Sand Draw population north to the Cedar Rim population, though connectivity between the two populations is not confirmed. Any connection would be low-frequency given the limited dispersal of seeds, but may be possible through pollen movement by pollinators. Additionally, the distribution of the patches of the Cedar Rim population can be seen as separate colonization events along a downwind slope of the same geological formation (Heidel *et al*. 2011, p. 32).

One hypothesis on the distribution of desert yellowhead suggests that the species was once widespread and experienced a range contraction, and therefore the species would likely be found in different habitats with a dispersal pattern independent of habitat conditions. However, a study of the soils of occupied habitat and surrounding areas found that occupied soils differ from surrounding soils (Heidel *et al*. 2011, p. 32), suggesting that the range of desert yellowhead likely has always been narrow, given that surface soils typically change on geologic timescale. Furthermore, because there are no closely related species to desert yellowhead and no distantly-related species near the two known populations, it is likely that desert yellowhead has occupied its present range for a long time (Dorn 2006, p. 634; Dorn 1991, pp. 198–201). This indicates that desert yellowhead likely always occurred in a geographically small area as a narrow endemic. In the western United States, endemism can be driven by the processes affecting arid, stressful environments and specificity to exposed soil and bedrock types (Stohlgren *et al*. 2005, p. 716), which is the type of specific habitat where desert yellowhead occurs.

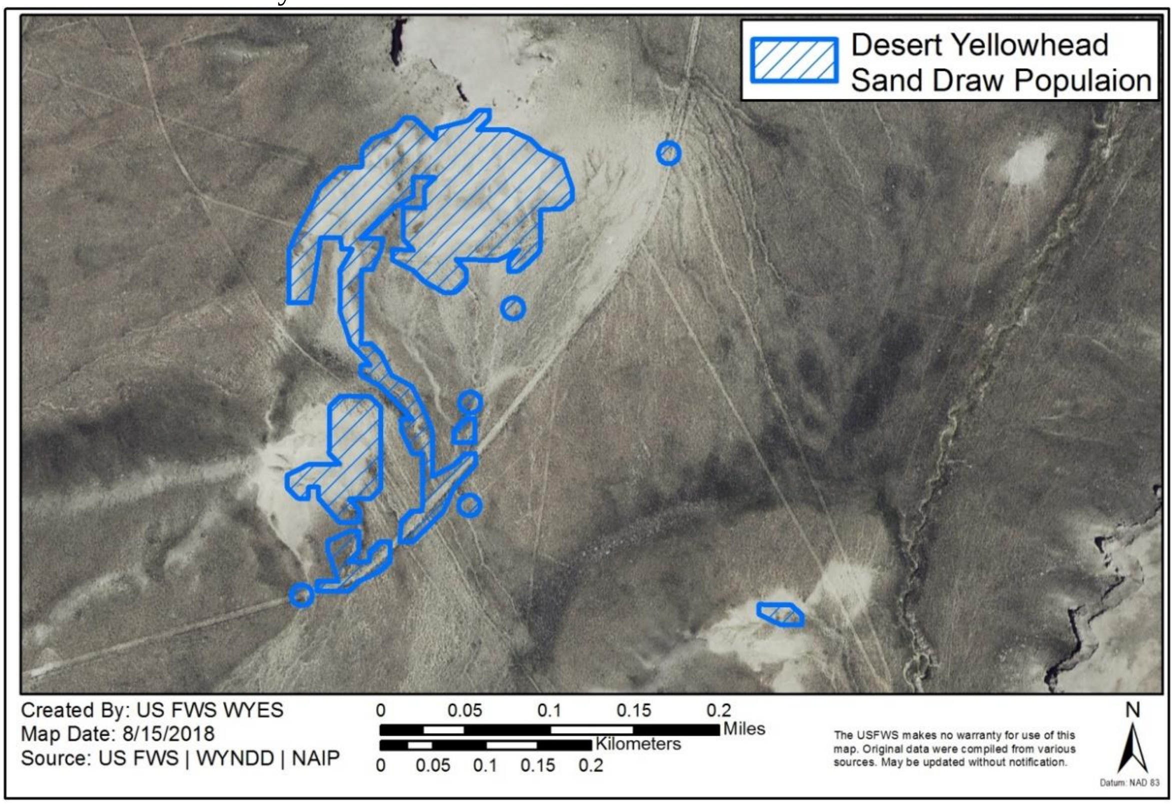
The total area occupied by the two populations of desert yellowhead is approximately 4.8 ha (11.9 ac). Both populations occur entirely on land managed by the BLM's Lander Field Office, and nearly all surrounding lands are managed by BLM with the exception of a few parcels of state land (see blue sections in Figure 3).

Figure 3. Known range of desert yellowhead in Wyoming. Both populations occur on and are surrounded by BLM-managed lands and are approximately 8 km (5 mi) apart. The Sand Draw population is contained within designated critical habitat, and a mineral withdrawal follows the critical habitat designation boundaries. The Public Land Survey System (PLSS) delineates section lines at one-mile intervals.



The Sand Draw population consists of one large patch and two smaller patches, with the farther approximately 0.28 km (0.17 mi) southeast of the main patch. The Sand Draw population covers an area of 30 ha (74 ac) though the occupied area is only 3.5–4.4 ha (8.5–10.9 ac) (Scott and Scott 2009, p. 1; Heidel *et al*. 2011, p. 4), see Figure 4. An abrupt border exists between the occupied habitat of the Sand Draw population and the surrounding sagebrush steppe (Heidel *et al*. 2011, p. 3), see Figure 4.

Figure 4. Detailed map of Sand Draw and its three distinct patches (western, northeastern, and southeastern). Note that the majority of plants occur in the main, western patch, and the presence of abandoned roadways within the site.



Desert yellowhead plants in the Sand Draw population are almost exclusively found on poorly developed soils and only occasionally on more well-developed soils. Where they are found on well-developed soils, they occur a meter or less from the soils without a well-developed soil profile. Soils are coarse-loamy over sandy-skeletal, mixed, Lithic Torrirthent that are probably derived from volcanic ash. Soils within the Sand Draw population have a higher silt content, are slightly more alkaline, are slightly lighter in color, have lower loss on ignition-determined organic matter, and have lower water retaining capacity than soils outside of the population (Scott and Scott 2009, p. 9). A characteristic view of plants growing in Sand Draw is pictured in Figure 5.

Figure 5. Desert yellowhead plants at Sand Draw following an outwash. Photo by Genevieve Skora, USFWS 2012.

The recently discovered Cedar Rim population consists of 10 patches. These patches are separated by distances of over 10 m (32.8 ft) of non-habitat, with all located within a 0.40 km (0.25 mi) long area, occupying less than 0.4 ha (1.0 ac) (Heidel *et al*. 2011, pp. 19–20; Freeland 2016, entire), see Figure 6. The community of other plants also occurring within the Cedar Rim population is pictured in Figure 7.

Figure 6. Detailed map of Cedar Rim and its 10 patches. Note the proximity of patches to each other and the presence of abandoned roadways within and near the site.

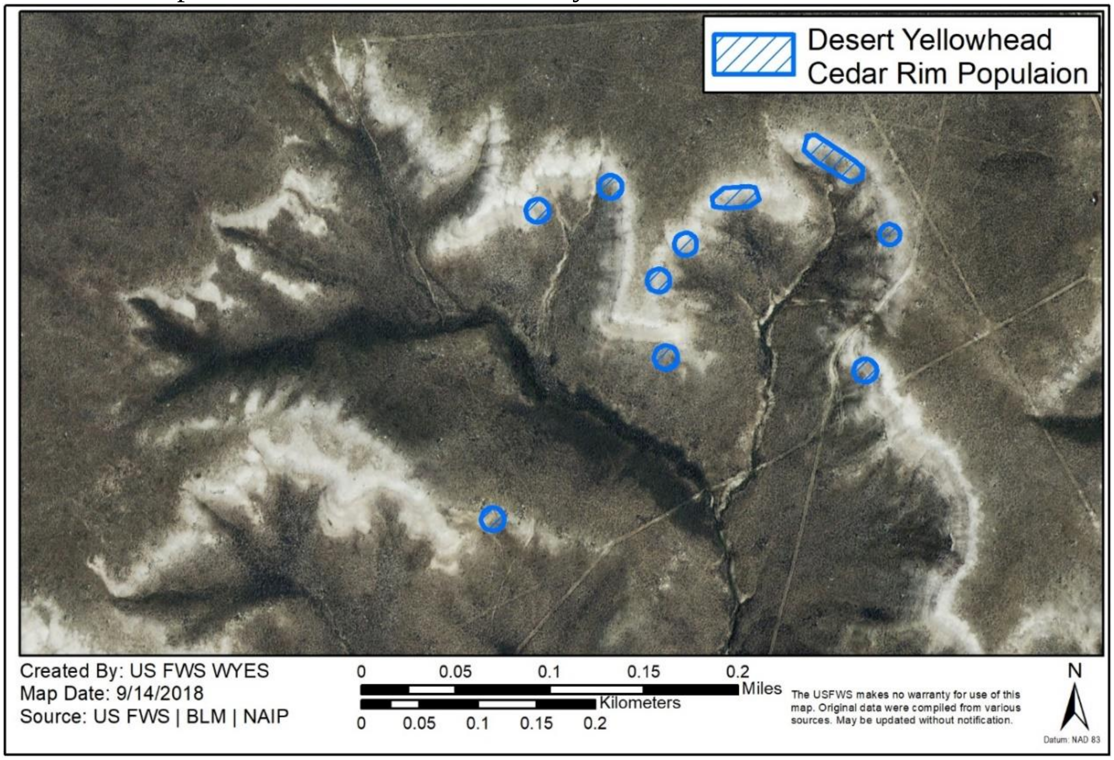


Figure 7. Desert yellowhead plants at Cedar Rim along escarpment slopes. Photo by Bonnie Heidel, WYNDD 2010.

Occupied habitat at Sand Draw, and to a lesser extent at Cedar Rim, has a higher albedo than surrounding non-habitat, that is, the proportion of light or radiation that is reflected from the soil is higher where plants occur than where plants do not, which may influence microhabitat conditions. Additional soil sampling was conducted in 2010 at both Sand Draw and Cedar Rim populations, unoccupied habitats that resembled that at population sites, and at the surrounding sagebrush steppe. The soils within the Sand Draw population are distinct from those of the surrounding steppe by at least 8 of the 17 soil properties that were tested (Heidel *et al*. 2011, p. 32). These results support the hypothesis that desert yellowhead is limited to a narrow range of soil characteristics, though there exist some differences in soil chemistry between the two occupied areas. Ten of the 17 soil properties tested showed differences between the soils of the Sand Draw population and the soils of the Cedar Rim population. In all tests except available phosphorus, the soils of the Sand Draw population differed more from the soils of the Cedar Rim population than they did from one or both of the surrounding steppe soils and the potential site soils. Only one soil variable, the soluble sodium level, was found to be similar between the two populations of desert yellowhead. Soils at both populations appear to have volcanic ash, conferring a structural difference from surrounding areas, though this was not measured or included in the study (Heidel *et al*. 2011, p. 36). These results do not support or refute the hypothesis that desert yellowhead is a habitat specialist that is limited in distribution by soil characteristics because: (1) both populations are found on soils derived from the same parent material (volcanic ash), which is structurally different from surrounding soils (higher silt content, higher alkalinity, lighter color, lower loss on ignition-determined organic matter, and lower water retaining capacity), and (2) a single soil variable, such as soluble sodium, may be an essential or limiting soil property.

Critical Habitat

On March 16, 2004 (69 FR 12278), approximately 146 ha (360 ac) of Federal land managed by the BLM in Fremont County, Wyoming was designated as critical habitat for desert yellowhead, effective as of April 15, 2004 (see Figure 3). Critical habitat receives protection under section 7 of the ESA through the prohibition against destruction or adverse modification of critical habitat with regard to actions authorized, funded, or carried out by a Federal agency.

When critical habitat was designated, there was no evidence that desert yellowhead had ever occurred outside of the occupied area. Prior to the designation of critical habitat, surveys of similar habitat in the area surrounding the Sand Draw population had not found any additional plants. In light of these facts, the Service did not feel that there was sufficient basis regarding the conservation needs of the species to designate habitat outside of the known geographic range. Therefore, the critical habitat designation only included occupied sections or portions of sections in the public land survey system (see red hatch in Figure 3). The 2010 discovery of the Cedar Rim population expanded the known range of desert yellowhead. As such, the Cedar Rim population does not occur within the previously designated critical habitat and no critical habitat has been proposed to encompass the Cedar Rim population of desert yellowhead.

2.3 Individual-level Ecology

Desert yellowhead individuals must obtain sufficient resources and have certain circumstances met before they can transition to the next life history stage or action. Table 1 provides a summary of the resources and/or circumstances that are required for individuals to complete each life history action for desert yellowhead. The key resource required for all life stages of desert yellowhead to be present at a site and be capable of moving to the next life history action are the suitable soil conditions as described above in *2.2 Habitat Description*, specifically higher albedo, higher silt content, higher alkalinity, lighter color, lower loss on ignition organic matter, and lower water retaining capacity than the surrounding unoccupied habitat (Scott and Scott 2009, p. 9).

Additionally, the ability of a surviving ramet to continue to grow after the main plant has been buried by deep sediment resulting from erosion is "a most important structural and asexual reproductive feature, increasing survival chances of desert yellowhead plants in a fluctuating environment with often unstable substrates" (Scott and Scott 2009, p. 56). Therefore, suitable soil conditions serves as the key resource need at the individual level for desert yellowhead.

A second key circumstance required for desert yellowhead is low competition, which is partially derived from the soil conditions, *i.e.*, other groups of plants cannot out-compete and replace desert yellowhead due to the specific soil characteristics and surface instability to which desert yellowhead is well-adapted (Scott and Scott 2009, p. 10). Desert yellowhead appears to be a poor competitor that cannot out-compete other species found in more stable habitats nearby (Scott and Scott 2009, p. 33).

Table 1. Resources and/or circumstances needed for individuals to complete each life history action for desert yellowhead. All life history actions require suitable soil conditions and low competition. Resource function key: H = Habitat, N = Nutrition, R = Reproduction, D = Dispersal

Life History Action	Resources and/or circumstances	Resource function
seed	suitable soil conditions derived from White River formation	H
	low competition	H/N
	wind and water–likely do not travel far from parent plant unless moved by overwash/sheetflow flooding	D
seedling	suitable soil conditions derived from White River formation	H
	precipitation (cannot dry out)	N
	mild temperatures (cannot be too hot)	N/H
	low competition	H/N
	sunlight for photosynthesis	N
vegetative plant	suitable soil conditions derived from White River formation	H
	precipitation	N
	sufficient growth for ramet production	R/D
	low competition	H/N
	sunlight for photosynthesis	N
ramet	suitable soil conditions derived from White River formation	H
	precipitation	N
	low competition	H/N
	sunlight for photosynthesis	N
flowering plant	suitable soil conditions derived from White River formation	H
	precipitation	N, R
	low competition	H/N
	sunlight for photosynthesis	N
	pollinators (small wood nymph (Nymphalidae; *Cercyonis oetus*) and skipper butterflies (Hesperiidae))	R
	sufficient growth for ramet production	R/D

Seeds: The seed stage of desert yellowhead is developed after successful pollination of flowers in summertime through September (see phenology table in Figure 2), and seed viability may be affected by sufficient precipitation during seed production, pollen quantity, and/or pollen quality

(Handey, J. pers. comm. 2018a), while germination success may be influenced by microenvironment. Seeds in a lab setting have been shown to have relatively high germination success even in the same year that they were formed (Scott and Hoster 2000, p. 5), though recent work by WYNDD indicates much lower viability (Handley, J. pers. comm. 2018a). In addition to the suitable soil conditions and freedom from competition, seeds require a vector of dispersal. Dorn 2006 (p. 634) suggested that the pappus of barbellate bristles (short, hooked, fine hairs on each seed) do not provide buoyancy needed for long-distance movement. Scott and Scott (2009, p. 56) suggested that the seeds of desert yellowhead are either wind-dispersed short distances or are carried by flooding, channelized runoff, and sheetwash. The clumped, non-random location of established plants in drainages suggests that dispersal distances are probably short (Fertig 1995, p. 18). However, the strong winds present in portions of both populations and the presence of established plants high on slopes indicate the potential for some up-slope seed dispersal or long-distance movement of seeds.

Seedlings: The seedling stage occurs after germination and until production of true leaves. Because germination can occur in the same year seeds are produced (*i.e*., July through September), desert yellowhead seedlings are capable of surviving in a quiescent or dormant state over winter before producing their first true leaves, and can sometimes survive for more than 1 year in this stage and as long as 3 years (Scott and Scott 2009, pp. 15, 52, and 57). Seedlings are extremely vulnerable to dry, hot summers and exhibit high mortality under those conditions (Scott and Scott 2009, p. 57). Seedlings may also lack the chemical defenses that make established plants unpalatable, further increasing the vulnerability of this life stage. Mortality at the seedling stage may be the greatest single limiting factor in population size. Therefore, in addition to the suitable soil conditions and freedom from competition, seedlings need mild summer temperatures and moderate amounts of precipitation as well as access to sunlight to conduct photosynthesis. Finally, while not included in Table 1, seedlings require some protection from herbivory and trampling, whether that be from sheltering under an established plant, or growing next to a rock or high on a steep slope.

Vegetative plants: Vegetative desert yellowhead plants are those that have true leaves but are not flowering. Desert yellowhead may stay in a vegetative state for 5 or more years and may be present in a flowering/vegetative cycle for 13 years (Scott and Scott 2009, p. 47). Vegetative plants are capable of surviving partial burial from sediment moved by flooding or sheetwash and are robust enough to withstand hot, dry summers that typically cause mortality in seedlings. In addition to suitable soil conditions, low competition, and sunlight for photosynthesis, vegetative plants require some level of precipitation as well as sufficient vegetative growth for ramet production.

Ramets: The ramet life history stage or action through modular, clonal growth of both vegetative and flowering plants has been documented extensively in the literature (Scott and Scott 2009, p. 12; Doak *et al*. 2016, pp. 6, 25; Dibner *et al*. 2019, p. 2). Ramets are plants that form from budding off vegetative and flowering plants that have achieved an appropriate size. Ramets can flower independently of the older plant. In addition to suitable soil conditions, low competition, and sunlight for photosynthesis, ramets require some level of precipitation to take root and thrive, which will allow a ramet to survive even if the established plant is buried in sediment. One difficulty in assessing population numbers is determining whether plants within a short distance of each other are distinct individuals or are ramets still attached to that distinct individual.

Flowering plants: Desert yellowhead plants with at least 5 years of vegetative growth are capable of stem development, which is followed by flower buds and flowering (Scott and Scott 2009, p. 54). Flowering has been documented as early as June 15 and as late as August 18, and is largely dependent on precipitation (Scott and Scott 2009, pp. 54–55). September flowering has also been documented in desert yellowhead, but always only in a few larger plants with two or more ramets, and occurs only after a primary summer flowering period (Scott and Scott 2009, p. 55). Flowering plants have a deeper taproot than younger plants, which makes them better able to withstand hot, dry summers that typically cause mortality in seedlings and prohibits vegetative plants from flowering (Scott and Scott 2009, p. 25). In addition to suitable soil conditions, low competition, suitable precipitation, and sunlight for photosynthesis, flowering plants require pollinators to move pollen from one flower to another (self-fertilization) or one plant to another.

2.4 Population-level Ecology

In this section, we discuss needs at the population level. Population-level needs are based on habitat factors that drive individual presence at a site, specifically soil, precipitation, temperature, and presence of pollinators for pollination, as well as the demographic factors of the survival and abundance of seedlings and established plants and the production and viability of seeds. Population-level needs are summarized in Table 2.

Table 2. Population-level needs based on habitat and demographic factors.

Habitat factors						Demographic factors		
suitable soil conditions	low competition	sunlight for photosynthesis	pollinators	adequate spring precipitation	mild summer temperatures	seedling survival	established plant survival	seed production

Population growth is largely dependent on annual precipitation, as based on a recent PVA. Desert yellowhead does best during years of average precipitation; population growth rate suffers in very wet or very dry years (Doak *et al*. 2016, pp. 17–18; Dibner *et al*. 2019, pp. 7, 13). Furthermore, the most important factor contributing to population growth is seedling survival, since the population does not increase dramatically despite moderate seed production and germination success (Scott and Scott 2009, p. 57). Another important factor contributing to survival is that of ramets surviving the burial of the older plant (Scott and Scott 2009, p. 56). Asexual production (*i.e.*, ramets) can help maintain unique alleles in the population, but may also signify lower genetic diversity within the population as a whole than census results would indicate.

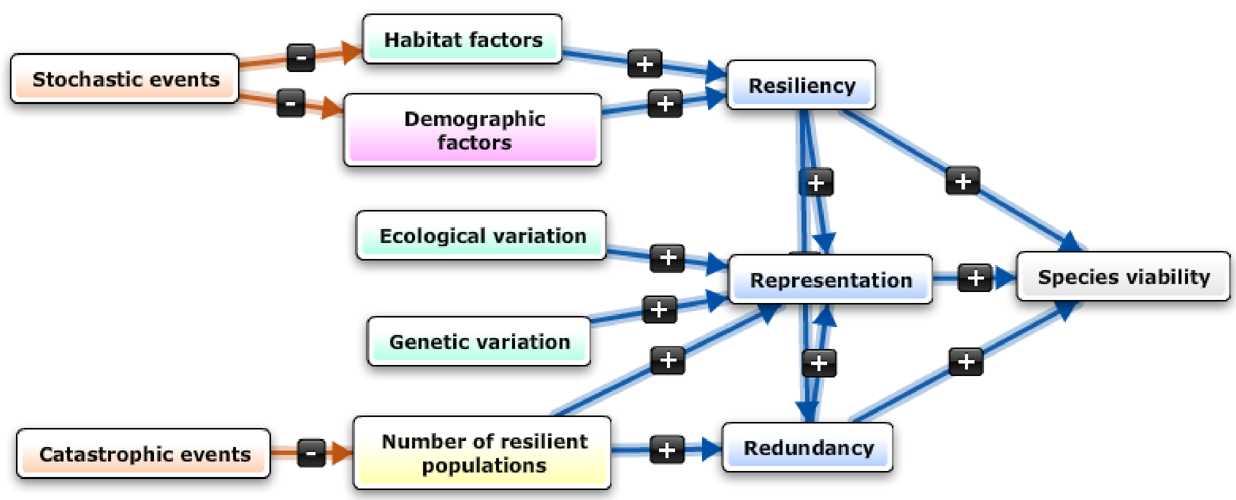
Both the Sand Draw population and the Cedar Rim population are very unlikely to be extirpated based on the demographic and climate analysis conducted by Doak *et al*. 2016. This PVA found that population growth rates varied among portions of the population, but all values were high enough to balance out substantial declines in other portions of the populations (*i.e*., portfolio effects). Negative density dependence in population growth rates were documented in the Sand Draw population, which acts to stabilize population numbers, because growth rates decline when population abundance becomes high (Doak *et al*. 2016, p. 12). The results of the PVA also suggested that seed movement from high growth rate areas can boost population abundance in areas with low growth rates (Doak *et al*. 2016, p. 29; Dibner *et al*. 2019, p. 3), depending on the ability of seeds to move via water or wind.

2.5 Species-level Ecology

In this section, we discuss needs at the species level. For the species to be viable, it needs populations that can be sustained over time; to have high viability, desert yellowhead needs a sufficient number and distribution of populations to withstand environmental stochasticity (resiliency), catastrophies (redundancy), and changes in its environment (representation).

In Figure 8, we depict that the species needs a combination of appropriate habitat factors and demographic factors in each population to have high resiliency, and that these habitat and demographic factors are affected by stochastic events. To have high levels of redundancy, desert yellowhead needs a sufficient number of highly resilient populations to protect against catastrophic events. For high levels of representation, desert yellowhead needs sufficient variation in the environmental setting where the populations occur, in terms of soil, slope, and perhaps other factors. We currently lack the information to quantify what levels of each of these factors are necessary for this species to maintain high levels of viability.

Figure 8. Species viability conceptual model, which is composed of the 3Rs. Resiliency is determined by habitat and demographic factors of each population, which are influenced by stochastic events. Representation is determined by genetic and/or ecological variation across populations. Redundancy is determined by the number of highly resilient populations, which are influenced by catastrophic events.



Chapter 3. Species Current Condition

In this chapter, we review the historical and current trends in species numbers, explain assumptions about the main drivers affecting population trends, and assess the various stressors that may have influenced the species historically and currently.

3.1 Historical and Current Population Trends

Sand Draw population: Originally, Dorn (1991) estimated that there were approximately 500 plants within a 1 ha (2.5 ac) plot (Dorn 1991, pp. 198–201). A later visual estimate of 1500 plants in the same area was made by Fertig (1995, p. 18). These estimates are likely weighted toward the far more conspicuous flowering plants, whereas later exhaustive census work showed that the great majority of plants are vegetative in any given year (Scott and Scott 2009, p. 28). Therefore, the numbers produced as estimates are not directly comparable with the census work conducted by Scott and Scott. Furthermore, we have no information on historic range or abundance of desert yellowhead for comparison.

Today, we know the Sand Draw population spans 30 ha (74 ac), though the occupied area is only 3.5–4.4 ha (8.5–10.9 ac) (Scott and Scott 2009, p. 1; Heidel *et al*. 2011, p. 4). Between 9,294 and 13,247 individual desert yellowhead plants were counted in the Sand Draw population during each census between 1995 and 2004 (Scott and Scott 2009, p. 18). During that period, the population was quite stable, losing or gaining as few as 188 plants or as many as 1,182 plants, while fluctuating around an annual mean of 11,813 plants. Less than 20 percent of the plants flowered in any year. During the study, the species did not expand outside the existing footprint by more than a few meters, suggesting that dispersal does not occur over large areas or long distances. These counts were conducted very precisely to identify separate individuals (Scott and Scott 2009, pp.14–16). Since 2005, the Sand Draw population has been studied less often, including a count of 10,343 plants in 2013 in the entire occupied area, but a 2018 count only in the southeastern patch found at least 50 plants (Handley 2018b pers. comm.).

Cedar Rim population: Upon its discovery in 2010, the Cedar Rim population of desert yellowhead was surveyed to determine minimum population size, record the extent of occupied habitat, and describe the environment and associated species at each patch. At that time, 7 of the 10 known patches of the Cedar Rim population were cursorily estimated as containing at least 400 plants (Heidel *et al*. 2011, p. 19). The eighth patch was discovered by Richard Scott later in 2010 and mapped during the 2011 field season. The ninth and tenth patches were found during the 2016 field season (Freeland 2016, p. 2).

Heidel *et al*. (2011) noted a more complex spatial pattern of the desert yellowhead plants within the Cedar Rim population than in the Sand Draw population. The Cedar Rim population has areas of relatively higher plant density than what is considered typical within the Sand Draw population; therefore, the Cedar Rim population was surveyed using different procedures than prior censuses (e.g., Scott and Scott 2009, where overlapping leaves belonged to the same plant). Instead, botanists sought to get a conservative minimum population size in 2011, (*i.e*., "lumping" instead of "splitting") and counted at least 400 individuals (Heidel *et al*. 2011, pp. 19–20).

A 2016 census of nine patches, excluding one patch that the surveyors failed to find found 739 plants (Freeland 2016, p. 2). The 2016 methods potentially counted clumps of ramets as separate individuals (*i.e*., “splitting” instead of “lumping” methods used in 2011); therefore, the values in 2016 are not directly comparable to the 2010/2011 census. Because of this difference in methods between 2016 and 2010/2011, Freeland and Handley, along with two BLM interns, attempted to replicate the 2010/2011 population estimation methods to provide a 2018 population estimate at Cedar Rim comparable to the original report. The counts between surveyors at a test patch varied widely, with the greatest spread being numbers counted by the two most experienced botanists in the group. Therefore, due to the nature of the original population estimate, Freeland and Handley concluded that an estimate of current population numbers directly comparable to 2010/2011 numbers was not possible (Freeland 2019, pers. comm.).

Overall Trends: Most studies of desert yellowhead were conducted prior to discovery of the Cedar Rim population. Due to the variation in survey methods over time for both populations, especially Cedar Rim, it is difficult to develop conclusions on trends in abundance over time. However, demographic monitoring was recently conducted at both populations and used to produce stage-based PVAs that indicate stable trends over a period of 10 years and projected out 100 years (Doak *et al*. 2016, pp. 11, 34; Dibner *et al*. 2019, pp. 7–10). This monitoring is being replicated by Handley (in progress). Despite available evidence suggesting relatively stable populations over the past 20 years, there is substantial uncertainty with population estimates because it is sometimes impossible to know whether a ramet is connected to the original plant underground without digging it up; therefore, connected plants may have been counted as unique individuals or connected individuals, depending on the census methods. In summary, based on our limited available information, the populations appear relatively stable.

3.2 Factors Affecting Current Condition

A number of factors, both positive and negative, may influence the species’ current condition. Our listing decision (67 FR 11442; March 14, 2002) suggested that a number of stressors impact the species, and additional stressors were described in the 5-year review for the species (USFWS 2012, pp. 14–31). Here, we evaluate stressors that have the potential to impact the species, as well as conservation actions that may influence the species’ current condition. We describe all factors that have been considered to affect the species’ status and viability, both historically and currently. Wildfire has not been considered a stressor on the species to-date, though there is potential that this stressor may affect desert yellowhead in the future, particularly as the surrounding sagebrush habitat becomes occupied with invasive annual grasses. For a stressor to be considered in the current condition analysis, it must have a negative effect on desert yellowhead through both exposure and response. For some stressors, such as oil and gas development, the exposure has largely been removed through conservation measures put in place by the BLM. For other stressors, such as livestock and wild ungulate grazing and trampling, we know the exposure is occurring at some level, but we cannot estimate the response (or whether it is a net positive or negative for the species), so we cannot generate an estimate of associated impacts to desert yellowhead populations.

3.2.1 Recreation, Motor Vehicles, Off-road Vehicles, & Soil Compaction

When desert yellowhead was listed, recreation, motor vehicles, and off-road vehicles/off-highway vehicles were determined to be a threat to the species through the crushing of plants, destruction of seeds, and compaction or erosion of soil. This stressor has the greatest impact in the spring and summer when plants are in flower or with fruit. Both populations of desert yellowhead are located in close proximity to the Cedar Rim Road and Wyoming State Highway 135. A two-track road bisects the Sand Draw population and dead-ends at an abandoned oil well. Individuals of desert yellowhead have been found growing within the roadbed, which appears to have created habitat for desert yellowhead within *Artemisia tridentata* (big sagebrush) stands (Scott and Scott 2009, p. 21). At Cedar Rim, the old roadway that crosses the slope and the old uranium claims do not appear to affect any patches of plants. Because of the proximity to existing roadways and because the Beaver Rim area is known for opals near the surface, individual geological collectors sometimes visit the area in search of rare or collectible rocks (opal exploration and extraction is treated separately in 3.2.3 Mineral Extraction, below). It is possible that collectors may trample or crush plants as they conduct exploratory digging, though we have no evidence of this occurring to date.

To address potential impacts resulting from this stressor, the BLM announced the closure of certain BLM-administered public lands to all types of motor vehicle use, effective March 16, 2005 (70 FR 40053; July 12, 2005). The closure affects public lands located within, and adjacent to, the 146 ha (360 ac) designated critical habitat of desert yellowhead, thereby closing the two-track road through Sand Draw to all types of motor vehicle use. The Cedar Rim population was not known at the time of issuance and is therefore not covered under the closure, though its position mid-slope along an escarpment may make it less likely to be affected by illegal cross-country vehicular travel. While BLM is unable to monitor all BLM-managed lands, only infrequent use by hunters in pickups has been documented (Scott and Scott 2009, p. 30), and no illegal use has been noted in or near Sand Draw since the closure, nor in the Cedar Rim population since it was discovered. Barriers and fencing have been determined to potentially draw more attention by recreationalists (and grazers, see 3.2.4 Livestock and Wild Ungulate Grazing and Trampling, below), so no physical deterrence for recreationalists or off-road vehicles has been erected. Because there is no exposure to or population-level response by desert yellowhead to this stressor, we do not consider it in our current condition or future scenario analyses.

3.2.2 Oil and Gas Development

When desert yellowhead was listed, habitat destruction caused by oil and gas development was listed as the most severe and immediate threat to the species. A historical summary of oil and gas leasing in the area is available in the listing decision (67 FR 11442; March 14, 2002) and 5-year review (USFWS 2012). The 2014 Lander Resource Management Plan (RMP) made both the 146 ha (360 ac) Sand Draw critical habitat and the 34 ha (85 ac) Cedar Rim area open to oil and gas leasing subject to a no surface occupancy (NSO) stipulation, which prohibits oil and gas-related surface-disturbance activities in accordance with Wyoming BLM Standard Mitigation Guidelines for Surface Disturbing Activities (BLM 2014, entire). Additionally, BLM maintains the authority and discretion to offer or defer leasing in the area depending on an appropriate National Environmental Policy Act (NEPA) (42 U.S.C. 4371 et seq.) analysis of the potential effects to the species and its designated critical habitat.

In addition to oil and gas wells, a major oil and gas pipeline corridor containing four pipelines lies immediately northeast of the no surface occupancy delineation around the Cedar Rim population, approximately 525 ft (160 m) east of occupied habitat. This corridor is utilized for the South Sand Draw oil field that lies approximately 6.5 km (4 mi) northwest of the Cedar Rim population (BLM 2017, p. 4). This right-of-way is open for additional major developments both above and below ground. Based on the Lander RMP, designated corridors are subject to the prescriptions for resource protections, except that they are open for rights-of-way even if the surrounding areas are excluded or avoided (BLM 2014 pp. 89–90). Therefore, any work within the pipeline corridor must undergo NEPA analysis and the BLM will have the authority and discretion to make changes to avoid any impacts to desert yellowhead as a result of that work. Therefore, there is no exposure to or population-level response by desert yellowhead to this stressor, and we do not consider it in our current condition or future scenario analyses.

3.2.3 Mineral extraction

When desert yellowhead was listed, mineral extraction was noted as a potential threat to the species. Locatable mineral resources, such as opals, gold, uranium, and zeolites, exist in the Beaver Rim area, which encompasses both the Sand Draw and Cedar Rim populations (67 FR 11442; March 14, 2002). Private parties can stake a mining claim, explore for, and extract locatable minerals in all BLM-managed land in accordance with the 1872 General Mining Law. The BLM's authority to regulate mineral claims under the 1872 General Mining Law is limited. Anyone may file a claim to explore and extract locatable minerals, though any activity (exploration or extraction) resulting in 2 or more hectares (5 or more acres) of surface disturbance on BLM land must file a Notice of Intent with the BLM and have an approved operating plan under 43 CFR 3809.

An area may be withdrawn from locatable mineral exploration and extraction through a Congressionally-designated mineral withdrawal. Mineral withdrawals are intended to protect small areas determined to have a resource of such a high value that any form of locatable mineral extraction would endanger the resource. The size and longevity of a mineral withdrawal is determined by the specific Congressional action designating the withdrawal, but time frames are typically 20 years. Although individual geological collectors can still harvest surface minerals, claims may not be filed within an area subject to a mineral withdrawal. A mineral withdrawal therefore prohibits exploration for or extraction of locatable minerals within the designated area for the designated period of time, which completely removes the area from consideration for extraction of locatable minerals.

Opal exploration and excavation can directly and indirectly impact desert yellowhead plants and populations. Opal exploration trenches follow the opal-bearing layers that are present in the subsurface. Trenches are 2.4–4.5 m (8–15 ft) deep, dug with an excavator, and remove approximately 450 kilograms (1000 pounds) of opal-bearing rock as a sample. Due to complete removal of the surface soil, any desert yellowhead plants within the excavated area would be eliminated by the trenching. Once the rock sample is removed, the trench is backfilled and re-seeded to reclaim the disturbance. Disturbance and reclamation creates two issues of concern: first, potential competition with desert yellowhead of non-native species planted as part of reclamation; and second, the inadvertent introduction and establishment of non-native species such as cheat grass caused by invasion of disturbed soil . The trenches may also alter topography and the microclimate and microhabitat occupied by desert yellowhead plants, create dust that decreases the fitness of desert yellowhead plants through their ability to photosynthesize or to be successfully pollinated, or eliminate potential habitat for future population movement or expansion. Direct disturbance through spills, spill cleanup, worker trampling, and off-highway vehicles is likely if trenches are dug within or adjacent to occupied habitat (BLM 2017, p. 19). Finally, if initial exploration results in discovery of a desirable or valuable opal-bearing formation, an open pit mine is often then used to excavate the opals, potentially resulting in far greater impacts than trenches.

Sand Draw: A 2001 BLM report on the mineral potential of the Sand Draw study area indicated that there was a high potential for uranium resources and a moderate potential for zeolite resources (BLM 2001, p. 1). In 2005, a large deposit of opal was discovered approximately 8 km (5 mi) northeast of the Sand Draw population in the area known as Cedar Rim which, upon being publicized, led to the registration of over 1,000 mining claims with the Fremont County Clerk in that 7.75-square-kilometer (3-square-mile) area in a two-month period (USFWS 2012, p. 15). Many were not finalized due to lack of specific location information. Because opals were not discussed in the 2001 mineral potential report of the Sand Draw area, a 2005 addendum by the BLM recommended a mineral withdrawal of the designated critical habitat area to protect the desert yellowhead due to the extent of the opal deposit and proximity to the Sand Draw population. This is based upon identification of all varieties of opal, including trace precious opal, within the Split Rock Formation where the desert yellowhead occurs (BLM 2005, entire).

Because of the perceived threat to the Sand Draw population, Congress issued a 20-year protective withdrawal of the 146 ha (360 ac) desert yellowhead critical habitat from settlement, sale, location, or entry under the general land laws, including mining laws, subject to valid existing rights (73 FR 5586; January 30, 2008). Therefore, the Sand Draw population of desert yellowhead is protected by a 20-year withdrawal from surface entry and mining of locatable minerals. However, the withdrawal does not include leasing under the fluid mineral leasing laws, which means that a private entity can still lease land for leasable fluid minerals within the Sand Draw mineral withdrawal area, but cannot develop those leasable minerals until the withdrawal expires on January 10, 2028, unless the withdrawal is renewed. The Sand Draw population is also included in a BLM designated No Surface Occupancy (NSO) area, meaning no surface-disturbing activities can occur to develop those leasable minerals. There are no active or pending mining claims currently within the Sand Draw population, its critical habitat, or the mineral withdrawal area, or any of the four surrounding sections (Larsen 2019, pers. comm.).

Cedar Rim: This desert yellowhead population was discovered in 2010. A Mineral Potential Report of the 85 ac (34.4 ha) covering the area surrounding the Cedar Rim population found that there is a moderate to high potential for opal occurrence, and that potential for exploration and development within the Cedar Rim study area is moderate to high (BLM 2017, p. 3). Exposed opal-bearing beds underlay eight of the ten patches of desert yellowhead plants within the Cedar Rim population, and additional mapped occurrences lie in all neighboring PLSS sections (BLM 2017, pp. 11–12). During the 2005 opal rush, 5 claims were officially staked with the BLM within the Cedar Rim study area to search for opal, uranium, and other valuable minerals. Additional claims include: 5 staked in 2006, 2 staked in 2009, 1 staked in 2014, and 14 staked in 2015. These claims are currently active and are located as close as 0.8 km (0.5 mi) from occupied habitat (Larsen 2019, pers. comm.). In 2014, opal claims were staked approximately 1.6 km (1 mi) south of the Cedar Rim population, occupying 1.4 ha (3.5 ac), but permitted for up to 8 ha (20 ac) of extraction activity (Freeland 2018a, pers. comm.). This claim was updated in 2018 as the Cedar Rim Opal Mine, which is a BLM-approved 8 ha (20 ac) open pit mine to excavate opals for approximately 10 years. It lies approximately 1.6 km (1 mi) southwest of the Cedar Rim population (Freeland 2018b, pers. comm.). One of the 2015 claims was staked and opal exploration trenches were proposed within the Cedar Rim population. The BLM notified the proponent that exploration of the area had the potential to adversely affect a federally listed species and consultation with the Service would be required. The proponent revised the proposal to exclude the occupied area from the trenching activities in order to avoid the need to consult on potential impacts to the desert yellowhead (BLM 2017, pp. 5–6). While only 6 of the 40 proposed exploration trenches have been developed to date (sized between 1.5 m by 1.5 m (5 ft by 5 ft) and 3.66 m by 3.66 m (12 ft by 12 ft)), the claims remains active.

The Cedar Rim population is not included in the 2008 mineral withdrawal for the area encompassing the Sand Draw population. After the discovery of the Cedar Rim population in 2010, the Service and the BLM discussed the possibility of pursuing a protective mineral withdrawal for the area surrounding the Cedar Rim population, particularly given the interest paid to the area by miners seeking uranium, opal, and other valuable minerals in and around the occupied area in 2005. Discussions regarding the establishment of a mineral withdrawal to protect the Cedar Rim population from mineral extraction are ongoing. The Cedar Rim population is included in the BLM's NSO, so no surface-disturbing activities may occur to develop leasable fluid minerals within the area encompassing the Cedar Rim population.

In assessing species-level impacts and potential impacts to currently unoccupied areas within the range of the desert yellowhead, we believe that there is relatively lower potential for mineral exploration and excavation at the Sand Draw population because, although it overlies a possible opal containing formation, it occurs outside of the mapped opal occurrence area and is included within a mineral withdrawal area. The Cedar Rim population, however, lies within the mapped opal occurrence area, is one mile from an active open pit opal mine, and does not have the protection of a mineral withdrawal: consequently, it has substantially greater potential to be exposed to mineral extraction as a stressor. Further, there are 27 active claims within the townships where the two populations of desert yellowhead occur. Based on this recent and ongoing activity in the area, mineral extraction is a real and current stressor affecting the Cedar Rim population. There is current exposure to this stressor and potential population-level response by desert yellowhead plants (e.g., removal of patches of plants). Therefore, we consider this stressor in our current condition and future scenario analyses. Because discussions between the Service and BLM to pursue a mineral withdrawal continue, we are considering the withdrawal of the mineral rights to the Cedar Rim population as part of the improvement future scenario.

3.2.4 Livestock and Wild Ungulate Grazing and Trampling

At the time of listing, grazing and trampling were listed as possible threats to the species. Livestock appear to use the habitat within the Sand Draw population as a travel corridor (Fertig 1995, p. 21), and some trampling of plants, including some in flowering or early fruiting condition, has been observed (Heidel 2002, p. 18; Scott and Scott 2009, p. 30; Handley pers. comm. 2018b). Additionally, there is evidence that male pronghorn antelope have deliberately trampled and urinated or defecating on established plants to mark territories (Handley pers. comm. 2018b). While established plants may tolerate some level of browsing or grazing, seedlings may be completely uprooted and killed by livestock and wild ungulate grazing or trampling. Cattle graze in the immediate vicinity (Heidel 2002, p. 18), but observations indicate that the plant is not palatable to grazers due to the burning and numbing sensation caused by masticating leaves (Scott and Scott 2009, p. 30). As desert yellowhead is unpalatable, it may benefit from some level of grazing through reduced competition with other more palatable species and maintenance of soil disturbance from hoofed animals.

The current Lander BLM RMP includes grazing management practices to limit livestock use of the occupied habitat, such as prohibiting mineral or water supplements within two miles of the site and supplemental feeding or herding within half a mile of the site. Wild horses have the ability to alter the landscape on which desert yellowhead occurs, and no wild horse gather activities are allowed within desert yellowhead populations (BLM 2014, pp. 488–489). No barriers prevent livestock or wildlife access to either population. Previous discussions between BLM and the Service determined that the construction of a fence could trap wildlife or livestock within occupied habitat and result in a change of the associated plant community. Therefore, the Service concluded that a better understanding of the impacts and benefits of grazing was necessary before considering modifications to current grazing allotments. There are known and potential exposures to this stressor, and individual desert yellowhead plants are sometimes impacted by grazing and/or trampling that may lead to a population-level response, and therefore we consider this stressor in our current condition and future scenario analyses.

3.2.5 Overutilization for commercial, recreational, scientific, or educational purposes

At the time of listing, the potential for overutilization for commercial, recreational, scientific, or education purposes was unknown. It was noted that due to the small extant population size and habitat, the species was vulnerable to overutilization or biovandalism. Additionally, the leaves of desert yellowhead contain a chemical that produces a mild numbing sensation in the human mouth when even tiny portions are tasted. This characteristic may indicate potential medicinal qualities that can possibly prove attractive to pharmaceutical companies. Medicinal values of related species within the subtribe Tussilagininae have been documented (Scott and Scott 2009, p. 29). Unauthorized collections can take place; however, extensive field surveys of this species have reported no evidence of this occurring. The Service currently has two approved permits for scientific purposes: one to WYNDD and one to BLM, and has determined this level of impact is compatible with the recovery of the species. While there is very minimal exposure to this stressor, there is no associated population-level response by desert yellowhead plants, and so we do not consider this stressor in our current condition or future scenario analyses.

3.2.6 Disease or Predation

At the time of listing, no information was known regarding the threat of disease to the population of desert yellowhead. In August 2010, botanists noticed a few desert yellowhead plants had turned chlorotic (the yellowing or whitening of normally green plant tissue because of a decreased amount of chlorophyll, often as a result of disease or nutrient deficiency) (Heidel *et al*. 2011, p. 21). This condition appeared to cause mortality; however, it developed after flowering and did not affect reproduction. Therefore, we consider desert yellowhead to be exposed to this stressor, but the response was minimal and not at the population level, so we do not consider disease in our current condition or future scenario analyses.

Insect predation was listed as a concern in the fruit production during the 1994 field season, and ants were noted to be frequent visitors to flowering desert yellowhead plants, apparently feeding on nectar (Heidel *et al*. 2011, p. 21). Coupled with drought, insect grazers may have a significant negative impact on the production of viable fruit (Fertig 1995, p. 20), suggesting that seedling recruitment is only high in years of suitable spring and summer moisture conditions when many viable seeds are produced. In addition to impacts from insects, individual plants have been lost due to the digging activity of badgers (Scott and Scott 2009, p. 30), and many rodent burrows have been noted within the occupied habitats (Heidel *et al*. 2011, p. 20). These predation and disturbance activities appear to fall within the range expected in a normally functioning ecosystem. Therefore, we consider the interactions with these animals to be natural events (*i.e*., exposure does occur), but it does not have a consistent negative impact on the population (*i.e*., no response by desert yellowhead plants), and we do not consider it in our current condition or future scenario analyses other than as a facet of inter-annual variability in seed production and viability.

3.2.7 Small population dynamics

At the time of listing, small population size, restricted distribution, inbreeding, and low genetic diversity of desert yellowhead were thought to exacerbate any threats currently affecting the species. Species with small population size and restricted distribution can be vulnerable to extinction by natural processes and human disturbance (Levin *et al*. 1996, p. 10). For example, random events causing population fluctuations or population extirpations become a serious concern when the number of individuals or the geographic distribution of the species is very limited. Similarly, a single human-caused catastrophe (e.g., fire) or natural environmental disturbance (e.g., extreme weather event) can destroy an entire population of desert yellowhead. However, five mechanisms may work singly or in tandem to maintain higher-than-expected levels of resilience in small, isolated populations: negative density dependence, demographic compensation, vital rate buffering, asynchronous response, and source-sink dynamics (see Dibner *et al*. 2019, p. 2 for a more robust explanation of these mechanisms).

Desert yellowhead is an endemic that is restricted to a very limited substrate. The existence of three patches within the Sand Draw population and discovery of the Cedar Rim population, with 10 small patches, may provide some level of redundancy and therefore protection to the species. However, the two populations are located within 8.0 km (5 mi) of each other, and the possibility exists that both populations could be destroyed during a single large-scale event. Furthermore, the patches at Cedar Rim are only ten(s) of meters from one another and provide only nominal redundancy because the species has an inability to disperse large distances and likely would be unable to recolonize any eradicated patch on a biologically-relevant timescale. Coupled with the poor viability of seeds collected at Cedar Rim (Handley 2018a, pers. comm), the stability of the population at present may be based entirely on the survival of established plants and the development of ramets that survive even if the parent plant dies.

The species’ low reproductive output may increase the risk of effects from stochastic events, given that desert yellowhead may not be able to rebound quickly even if environmental conditions improved after such an event. Furthermore, the recruitment of new individuals to the population appears dependent on having suitable spring and summer moisture in the same year so that viable seeds are produced, followed by a subsequent year or more of suitable spring and summer moisture so that new seedlings are able to establish.

Regardless of the species' inability to recolonize or rebound in numbers based on its present status in two patchily-distributed populations, we have found no evidence that the plant has occurred outside of the area currently occupied or in substantially larger numbers any time in the recent past, suggesting that these factors may not be a concern for this species. Furthermore, the PVA found that Sand Draw has a very low risk of catastrophic decline (below 2000 individuals over 100 years) due to the combination of portfolio effects (*i.e*., where asynchrony in growth rate across the population leads to population stability) at the population-level (Doak *et al*. 2016, pp. 11–12) and the negative density dependence of the population growth rate (Doak *et al*. 2016, pp. 16–17; Dibner *et al*. 2019, p. 13). This means that the less dense portions of the population have higher growth rate, which offsets more dense portions of the population that have low growth rate. Based on density dependence in growth rate, asynchrony of portions of the population to increase in growth rate, and source-sink patterns found at fine spatial scales for desert yellowhead, the exposure of the species to this stressor is negligible. Therefore, we do not consider small population dynamics in our current condition or future scenario analyses of population resiliency. We do, however, consider how restricted distribution and low genetic diversity affect species-level redundancy and representation.

3.2.8 Nonnative invasive plants

Nonnative species were listed as a possible threat to desert yellowhead in the listing decision. Desert yellowhead occurs on relatively barren sites with less than 25 percent total vegetative cover and may be intolerant of competition (Fertig 1995, p. 19). Competition from plants not native to the area can pose a greater threat than competition from species with which desert yellowhead has evolved. Prior to 2010, no nonnative plants had been identified within or in the general vicinity of desert yellowhead patches (Scott and Scott 2009, pp. 27–28). Recent surveys have discovered *Alyssum desertorum* (desert madwort) in one plot at Cedar Rim (Heidel *et al*. 2011, p. 29) thought it did not appear to affect neighboring desert yellowhead plants. *Bromus tectorum* (cheatgrass) was found directly above the Sand Draw population (Freeland 2017, pers. comm.). Three species, *Hyoscyamus niger* (black henbane), *Cardaria* spp. (whitetop), and *Centaurea repens* (Russian knapweed) occur within 1.6 km (1 mi) of the Sand Draw population along Cedar Rim Road and U.S. Highway 287 (Scott and Scott 2009, p. 28). Currently, the Fremont County Weed and Pest (FCWP) do not officially designate *A. desertorum* as an invasive species or a species of concern, but do recognize *B. tectorum*, *H. niger*, *Cardaria* spp., and *C. repens* as county noxious weeds (Fremont County Weed and Pest website, 2018). While there is no exposure to this stressor at present, there is potential for this stressor to impact desert yellowhead plants in the future; therefore, we consider this stressor in our current condition and future scenario analyses.

3.2.9 Climate change and drought

In the 2002 listing decision, the effect of climate change was not assessed as a potential threat to desert yellowhead, though drought was discussed as a potential stochastic event affecting fruit production and therefore population size. Changing climate was described as a stressor to the species in the 2012 5-year review (USFWS 2012, pp. 29–31). The Service has determined that the effects of climate change should be assessed in all listing and recovery decisions; therefore, we bring this potential stressor forward in this SSA Report.

In our analysis, we use expert judgment to weigh relevant information, including uncertainty, in our consideration of various aspects of climate change. In general, it is anticipated that plant species with restricted ranges may experience population declines as a result of climate change. The Intergovernmental Panel on Climate Change (IPCC) Climate Change 2014 Synthesis Report states that “most plant species cannot naturally shift their geographical ranges sufficiently fast to keep up with current and high projected rates of climate change on most landscapes” (IPCC 2014, p. 13). However, as evidenced by past climate variations, areas containing high numbers of endemics may also provide stable climatic refugia into the future (summarized in Harrison and Noss 2017, p. 207). While Fremont County, Wyoming, which has only a handful of endemic species, is not among the top endemism hotspots worldwide, the mountainous topography surrounding, and even the small-scale topographic variation along the slopes where desert yellowhead occurs, provides the climatic microrefugia for an endemic to persist (Harrison and Noss 2017, p. 212). Worldwide, climatically stable hotspots of endemism are expected to remain more stable than other regions in the future, suggesting potential that the area where desert yellowhead occurs may remain stable in the face of changing climate, as it has with changes in the past.

The current climate of the area where desert yellowhead occurs has annual total precipitation ranging from approximately 10.2 cm to just over 31 cm (4–12.25 in.), with most of that precipitation falling in March, April, and May (NOAA 2018a, entire). Local climate data for the period from 1964 to 2018 is available from a National Climatic Data Center weather station (USC00484925: Jeffrey City, WY) located at 42.47^{o}N 107.83^{o}W (elevation 1,920 m (6,298 ft)), which is 33.75 km (21 mi) southeast of the Sand Draw population.

Between 1994 and 1998, a local weather station was installed near the highest density of desert yellowhead plants within the Sand Draw population. This site was located away from the annual snowdrifts that typically form along the west rim of the shallow erosional depression. Similar to the historical climate data from the National Climatic Data Center in Jeffrey City, data collected from 1994 through 1998 within the Sand Draw population of desert yellowhead showed most of the annual precipitation occurred during the spring; the relative humidity fluctuated between a value near zero to at or near 100 percent relative humidity at least one diurnal cycle per month; daily average wind speeds were generally 16.1 km per hour or less (10 mi per hour or less), with a southerly wind occurring most frequently (Scott and Scott 2009, pp. 50–54).

Precipitation totals for the growing season (April, May, and June) at the Sand Draw population weather station (1994 to 1998) ranged from 6.58–23.80 cm (2.58–9.37 in) (Scott and Scott 2009, pp. 50–54), which is about the same as the growing season totals for the historical weather station at Jeffrey City (average of 10.44 cm (4.11 in) and ranged from 2.67–18.87 cm (1.05–7.43 in) between 1965 and 2018) (NOAA 2018). This indicates that the Jeffrey City historical weather station captures data that are generally similar to those within the population at Sand Draw.

The key feature of climate change is increased carbon dioxide (CO_2) in the atmosphere. Plants use CO_2 to grow, so increases in the concentration of CO_2 can lead to increased growth rate for plants (Donohue *et al*. 2013, p. 3031). More CO_2 in the atmosphere also allows plants to reduce the aperture of their stomata during transpiration, resulting in reduced water loss during photosynthesis. Climate change may affect the timing and amount of precipitation as well as other factors linked to habitat conditions for this species. Climate models are limited by the data included, which are typically at scales much larger than the small range of desert yellowhead. These models are therefore limited in their ability to predict what might happen within desert yellowhead populations. Nevertheless, these models represent the best available science and information to conduct our assessment, and therefore we use them to predict changes in weather into the future.

Ensemble climate models predict that by 2050, the watershed where desert yellowhead occurs (Hydrologic unit code 8: Sweetwater, 10180006) will become warmer in all four seasons (USGS 2016, pp. 1–2). Precipitation will increase in the winter and spring, decrease in summer, and remain about the same in fall (USGS 2016, p. 3). Snow water equivalent, which is a measure of the amount of moisture present in snowfall, will decline in the winter and spring, and soil water storage will decline in the summer and fall (USGS 2016, pp. 4–6). A combination of warmer climate and more precipitation in winter and spring may expand the growing season for desert yellowhead, though having less moisture in the snow and less water stored in the soil suggest that current desert yellowhead habitat could become generally drier. The theoretical reductions in water use during the growing season due to increases in atmospheric CO_2 may help this plant survive periods of drought during the summer months. However, declines in soil water storage in the summer may limit seed production and survival of seedlings, which can cause declines in recruitment. Additionally, desert yellowhead may be exposed to more extreme weather events, which are predicted to occur more frequently worldwide (IPCC 2014, p. 53). These can include more late spring snowstorms, to which desert yellowhead can be vulnerable if the plants have already begun their growing cycle, or if weather events produce a combination of conditions that occur outside the species' tolerance range and during a vulnerable life history stage.

The current climate where desert yellowhead occurs is typical for Wyoming, with harsh, dry summers and cold, wet winters. Desert yellowhead is restricted in range by its narrow edaphic conditions, where it occurs in an area with other narrow endemics, and likely never occurred outside of this small area. We have no information regarding climatic variability in this area over the past several-thousand-years or how desert yellowhead responded to changes in climate. Changing climate has the potential to affect the future viability of desert yellowhead through possible long-term changes in the timing of precipitation and warming trends, but the net result of these changes are uncertain. While some negative effects may occur from drier summers, these may be mitigated by increased plant growth rate in response to higher CO_2 concentrations, lengthening of the growing season, and increases in spring precipitation. To capture the potential effects of climate change across this range of uncertainty, we evaluate the effects of climate change across a range of possible conditions in our assessment of future scenarios.

3.2.10 Conservation Measures

The purpose of including conservation actions in this SSA Report is to assist with describing the current condition of the species, and is not intended to make management recommendations for this species. Several regulatory mechanisms are in place to protect desert yellowhead. Specifically, the species is listed as threatened under the ESA (listing 67 FR 11442; March 14, 2002) and is afforded protections under several sections of that law. Section 4 of the ESA allows for and defines critical habitat around the Sand Draw population (designation 69 FR 12278; March 16, 2004); section 7 of the ESA requires BLM to consult on projects they fund, authorize, or carry out that may affect the species; section 9 describes specific prohibitions regarding the export, transport in interstate or foreign commerce in the course of a commercial activity, sale or offer for sale in interstate or foreign commerce, removal the species, or the damage or removal of plants on federal lands without a permit; and section 10 allows for the issuance of permits to carry out otherwise prohibited activities.

In addition to protections under the ESA, the desert yellowhead is protected under several non-Service authorities, such as listing as a sensitive species under the BLM's 6840 Manual (BLM 2008, entire) and the protections under the BLM's current Lander RMP (BLM 2014, entire). Specific non-Service protections for desert yellowhead are described below chronologically.

On July 12, 2005, the BLM published a notice in the Federal Register announcing the closure of certain BLM-administered public lands to all types of motor vehicle use to protect desert yellowhead and its critical habitat (70 FR 40053). The closure affects public lands located within, and adjacent to, the 146 ha (360 ac) designated critical habitat of the Sand Draw population of desert yellowhead. This closure became effective on March 16, 2005, and remains in effect until the threat to Sand Draw population of desert yellowhead and its critical habitat by motorized vehicles has ceased.

In 2008, Public Land Order number 7688 provided for the withdrawal of public lands for the protection of desert yellowhead (FR 73 5586; January 30, 2008). The order withdrew the 146 ha (360 ac) of land identified as critical habitat surrounding the Sand Draw population from surface entry and mining for 20 years. This protection is due for renewal in 2028. The Cedar Rim population was not known at this time and discussions regarding the establishment of a mineral withdrawal for this population are ongoing.

On January 25, 2010, the BLM published an Information Memorandum regarding cooperative work between the BLM and the Service on efforts to facilitate the delisting of desert yellowhead (BLM 2010, entire). These efforts include funding the population viability analysis conducted by the WYNDD and the University of Wyoming (Doak *et al*. 2016, entire). This memorandum, while not regulatory, shows the BLM's commitment to work with the Service on conserving desert yellowhead and its habitat.

In 2013, the Service consulted with Lander BLM on its RMP (BLM 2014, entire). Through the BLM consultation and the Service's Biological Opinion on the BLM's Lander Resource Management Plan, the BLM has committed to implement several conservation measures for the protection of desert yellowhead including not authorizing projects within 0.40 km (0.25 mi) of known desert yellowhead populations without concurrence of the Service, requiring surveys for the species before authorization of potential surface-disturbing activities in suitable habitat, and prohibiting surface-disturbing activities and restricting mineral leasing activities subject to no surface occupancy within the defined no surface occupancy area (USFWS 2013, pp. 23, 30, 34, and 36). During consultation on the RMP, BLM committed to specific conservation measures for desert yellowhead and its designated critical habitat. These measures are applied to both the Sand Draw with its critical habitat and the Cedar Rim population. The BLM will:

1. Withdraw designated 146 ha (360 ac) critical habitat from mineral location and entry under the General Mining Law of 1872;

2. Not increase current permitted (livestock) stocking levels;
3. Not approve placement of mineral supplements or additional water sources for livestock, wild horses, or wildlife on public lands within 3.2 km (2 mi) of the site;
4. Not allow supplemental feeding or straw placement, and no intentional herding within 0.8 km (0.5 mi) of desert yellowhead or its designated critical habitat;
5. Work with partners in development and implementation of a monitoring plan for desert yellowhead and its designated critical habitat, which will include regular patrol of the site for unlawful uses of the land, and monitoring of invasive weed populations;
6. Prohibit biological control of weeds in desert yellowhead habitat until the impact of the control agent has been fully evaluated and determined to not adversely affect the plant, and monitor biological control vectors;
7. Apply a condition of approval on all applications for permit to drill within the desert yellowhead site and designated critical habitat, prohibiting all surface-disturbing activities (*i.e*., subject all oil and gas leases to a no-surface occupancy stipulation prohibiting oil and gas surface-disturbing activities);
8. Prohibit mineral material disposal in the designated critical habitat; and
9. Not conduct wild horse management actions (*i.e*., gather activities) within designated critical habitat (BLM 2014, pp. 488–489).

Furthermore, within the Lander RMP, the BLM committed to conservation measures for all listed threatened and endangered species, including:

1. Requiring any lessee or permittee to conduct inventories or studies to verify presence or absence of listed species before any activities can begin onsite;
2. Grazing management practices will maintain existing habitat;
3. Maintaining or improving habitat to further conservation of habitat;
4. Developing site-specific measures for BLM-authorized activities to protect listed species, including reducing footprint of development and facilities; and
5. Retaining BLM-administered lands that contain identified habitat for listed species unless it benefits the species (BLM 2014, pp. 478–479).

We expect the current Lander RMP to remain in place for another 15–20 years, and that a renewed RMP would continue to offer protections to this unique plant, regardless of its status as a federally listed species. Furthermore, the Lander RMP includes language to protect unique plant communities in the Beaver Rim Master Leasing Plan area (BLM 2014, 2000 Mineral Resources 3.6, pp. 44–48); to maintain, improve, or enhance areas of ecological importance, priority plant species and habitats, and unique plant communities (BLM 2014, 4000 Biological Resources 1.1 and 1.2, pp. 52–55); and to manage for biological integrity and habitat function to facilitate the conservation, recovery, and maintenance of plant special status species (BLM 2014, 4000 Biological Resources 11.1 and 11.2, pp. 62–69).

The Lander RMP measure Biological Resources 11.2 maintains the existing locatable mineral withdrawal for desert yellowhead critical habitat surrounding the Sand Draw population and recommends a mineral withdrawal extension prior to its expiration. This management consists of being open to oil and gas, geothermal, and other fluid mineral leasing with a NSO stipulation; closed to phosphate leasing; closed to mineral materials disposals; excluded to major rights-of-way; avoided for minor rights-of-way; and closed to motorized and mechanized travel. Finally, it prohibits surface-disturbing activities and applies an NSO stipulation to mineral leasing activities within the Cedar Rim population of desert yellowhead (BLM 2014, 4000 Biological

Resources 11.2, p. 66). These protections for desert yellowhead remain in effect, regardless of the species being listed under the ESA, as they protect special status species or unique plant communities and aim to prevent future listings (Biological Resources 11.4) (BLM 2014 p. 54).

3.2.11 Synthesis of risk factors and impacts on 3Rs and viability

The entire known range of desert yellowhead consists of two populations on BLM-managed land in southern Fremont County, Wyoming. The Sand Draw population consists of a main patch with two smaller patches and occurs on approximately 30 ha (74 ac). The Cedar Rim population consists of 10 patches and occurs in an area of less than 0.5 ha (1.2 ac). However, this species' total physical occurrence footprint covers an area of less than 4.8 ha (11.9 ac), making the species potentially vulnerable if all of the 3Rs are rated as low. The current condition of the species is described below in *3.3. Current Condition*.

At the time of listing, threats from oil and gas development and the species' limited habitat and population size were considered to be the greatest threats to desert yellowhead. Presently, the stressor of oil and gas development has been largely removed due to various conservation measures enacted by the BLM. Other threats identified at the time of listing included: mineral extraction, motor vehicles and off-road vehicles, invasive species, overutilization, predation, grazing and trampling, small population size, and restricted distribution. Primarily through conservation measures implemented by the BLM, these threats have also largely been reduced. The primary stressor currently facing desert yellowhead is opal mining within and around the habitat of the Cedar Rim population.

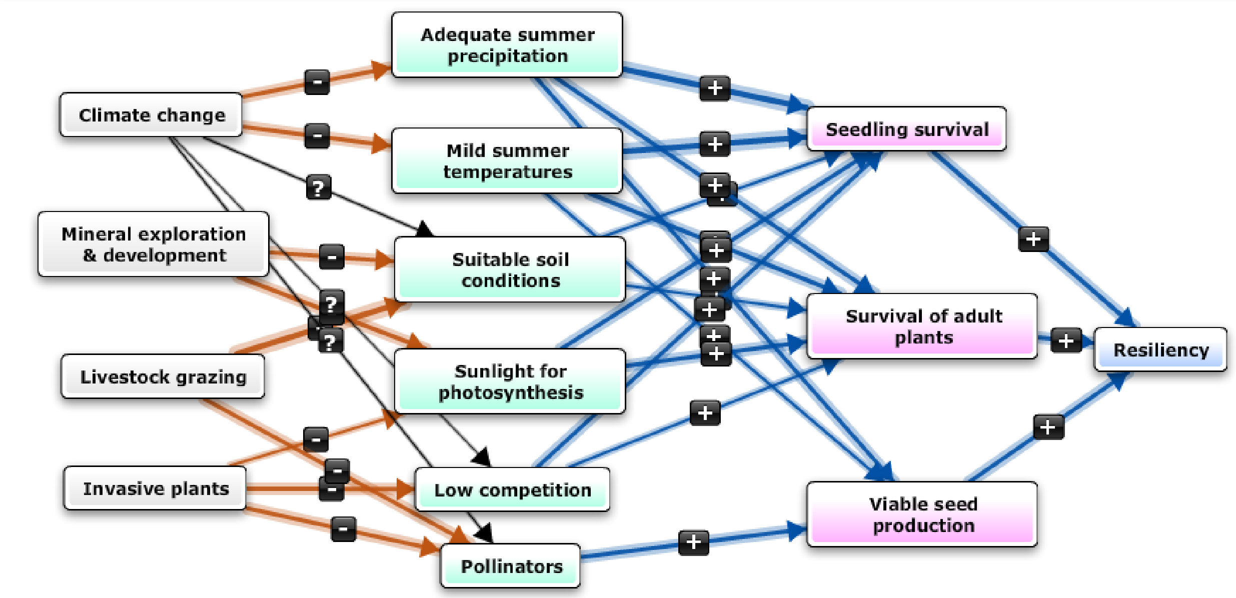
3.3. Current Condition

3.3.1 Resiliency

Resiliency is the ability of populations to tolerate natural, annual variation (stochasticity) in their environment and to recover from periodic disturbance. Levels of resiliency, therefore, may be indicated by various demographic and habitat metrics, which are typically assessed at the population level (Smith *et al*. 2018, entire).

Stressors potentially affecting the resiliency of populations of desert yellowhead are the effects of climate change, mineral exploration and development, livestock grazing, and invasive plants. Each of these factors has a negative or unknown effect on desert yellowhead habitat or plants directly, as discussed above under section *3.2 Factors affecting current condition*. These stressors impact key habitat and demographic factors, as depicted in Figure 9, and are described below in detail. Since rigorous quantitative assessment of how these stressors impact desert yellowhead populations is not possible with the best available data, we have chosen to define resiliency on a categorical scale; high, moderate, or low. Table 3 defines what we consider high, moderate and low resiliency in terms of each of the habitat and demographic factors that were presented in Table 2.

Figure 9. Conceptual model showing factors affecting resiliency of populations of desert yellowhead. Note that only factors considered to be potentially or currently affecting the species are included (*i.e.*, oil and gas development and soil compaction resulting from recreational vehicles are not included).



To calculate population resiliency, a condition category of high receives a score of 3, moderate receives a score of 2, and low receives a score of 1. The habitat factor of suitable soil condition is the key driver for population resiliency, and therefore resiliency cannot be higher than the rank of the suitable soil condition. The demographic factor of seedling survival is counted twice due to the importance of that life history stage. The summed scores can range between 10 and 30, where low condition is 10–16, moderate is 17–23, and high is 24–30. To calculate population resiliency we use the following equation:

Resiliency = suitable soil condition + low competition + sunlight for photosynthesis + pollinators + adequate spring precipitation + mild summer temperatures + (2 × seedling survival) + established plant survival + seed production

Details on how each factor contributes to overall population-level resiliency are presented in the following sections.

Suitable soil conditions: While the exact soil characteristics required by desert yellowhead are yet unknown, research indicates that the soil chemistry at each of the two known populations differs from each other and also from the surrounding landscape. The similarities in soil between the populations include albedo, soil structure, and water retention (both populations occur on coarse-loamy over sandy-skeletal, mixed, Lithic Torriorthent that are probably derived from volcanic ash), lower organic matter content than non-desert yellowhead habitats (Heidel *et al.* 2011, pp. 27–28), and relatively high soluble sodium levels in the upper horizon (Heidel *et al.* 2011, p. 33). Disturbance of currently occupied soils may make an area less than optimal or unsuitable for desert yellowhead, and ground-disturbing activities such as mineral exploration or development may completely remove the soil upon which the desert yellowhead exists. The topographic position of both populations is probably dependent upon the characteristics of the unoccupied upslope and/or upwind area at each site. Therefore, changes to soil or topography of these unoccupied areas may affect the soil conditions where the plants are found downslope or downwind.

Despite the dissimilarity in many measured soil characteristics between the two sites, we understand that the desert yellowhead cannot occur in locations that do not meet an unspecified narrow range of soil conditions. If this narrow range of soil conditions is not met, the species cannot occur in a given location, and therefore the other habitat and demographic factors are irrelevant. If the suitable soil conditions factor is in low condition for example, we therefore consider the population as a whole to be in low condition (Table 3). For Sand Draw, we assign this factor a high condition (=3) due to availability of unadulterated soil within and around occupied habitat and current protections in place. For Cedar Rim, we assign this factor a moderate condition (=2) due to the presence of opal exploration trenches immediately adjacent to the population that may be impacting the soil within the occupied habitat as well as the current vulnerability to impacts resulting from opal exploration and mining.

Low competition: Both populations are found in areas with low competition, although the overall vegetation composition differs somewhat between sites (Heidel *et al.* 2011, p. 28. Sand Draw is characterized as having 10 percent cover of all species while Cedar Rim ranges between 5–20 percent cover of all species. Both populations share a high frequency of cushion plants, though composed of different species assemblages, potentially due to differences in soil characteristics between the populations. To measure competition, we assess the presence of a shrub component to the habitat as well as whether invasive species are present. Both populations are assigned a high condition (=3) for this factor (Table 4), because there are no shrubs or invasive species affecting the populations at this time (Table 3).

Table 3. Current condition classification table for resilience. Suitable soil conditions is the overriding factor affecting resiliency of populations, where its condition determines the overall condition for the population. Seedling survival is most important demographic factor and is weighted twice in the population resiliency calculation. Note color of conditions: green for high, yellow for moderate, and orange for low.

	Habitat factors						Demographic factors		
Condition category	suitable soil conditions	low competition	sunlight for photosynthesis	pollinators	adequate spring precipitation	mild summer temperatures	seedling survival	established plant survival	seed production
High = 3	meets all soil chemistry and topography conditions for optimal growth	no shrubs or invasive species within population	sunlight not limiting	abundant pollinators present and alternate nectar sources available	average precipitation in spring (e.g. within 1 SD of average over 5-years)	average summer temperature(e.g. within 1 SD of average over 5 years)	high seedling survival (>30%)	high established plant survival (75-100%)	most achenes fertile and produce viable seed (>50%)
Moderate = 2	one or more soil chemistry or topographic conditions not optimal	presence of some shrubs or invasive plants out-competing desert yellowhead	sunlight somewhat limiting	some pollinators present; alternate nectar sources not available	variable spring precipitation (e.g. outside of 1 SD of average for 2–4 years over 5 years)	variable summer temperature (e.g. outside of 1 SD of average for 2–4 years over 5 years)	moderate seedling survival (15-30%)	moderate established plant survival (40-75%)	moderate number of fertile achenes with viable seeds (20–50%)
Low = 1	lacks suitable soil conditions necessary for species to thrive	area entirely overrun with shrub cover or invasive species	sunlight limiting (due to dust, competition or cloudiness)	inadequate pollinators present and no alternate nectar sources	highly variable spring precipitation (e.g. outside of 1 SD of average for all 5 years)	highly variable summer temperature (e.g. outside of 1 SD of average for all 5 years	low seedling survival (<15%)	low established plant survival (<40%)	low number of fertile achenes with viable seeds (<20%)

Sunlight for photosynthesis: This factor is necessary for plants to grow and reproduce. Sunlight can be obscured by dust from nearby mineral exploration and development, haze resulting from fires burning upwind, competition with shrubs and/or nonnative invasive species, and cloudiness. Should climate change affect weather patterns in the area, this may make the normally sunny area more overcast in the future. See Table 3 for a summary of the high, moderate, and low condition categories for this factor. Sunlight may be abundant (or non-limiting) if there is nothing blocking the desert yellowhead's ability to photosynthesize, which would place this factor in the high condition. It may be somewhat limiting (moderate condition) if portions of crucial growth periods are dusty or cloudy. Sunlight may be a limiting factor (low condition) for desert yellowhead if excessive dust, competition, or clouds block the species' ability to photosynthesize and plants are not able to grow. There is no indication that dust, haze, competition, or cloudiness are currently affecting either population, and so we assign both populations to the high condition (=3) for this factor (Table 4).

Pollinators: Because desert yellowhead is one of the showiest plants on the landscape, it is likely an attractant for generalist bees and butterflies. We do not know the specific pollinators of desert yellowhead. *Bombus* spp., Agapostemon bees, and two different species of butterflies have been seen visiting flowers. The presence of alternate nectar sources nearby helps to attract pollinators to the small and disjointed populations of desert yellowhead. Conversion of the surrounding landscape to become unattractive to pollinators (e.g., grassland, cropland, or oil wells) would dramatically reduce the quantity and quality of pollinator services (Potts *et al*. 2010, pp. 348–350) for desert yellowhead. See Table 3 for a summary of the high, moderate, and low condition categories for this factor. We believe that there are satisfactory alternate nectar sources near enough to both populations to attract sufficiently abundant pollinators to the desert yellowhead populations, based on the limited amount of habitat conversion from native prairie to infrastructure or desert. Similarly, a recent pollination experiment found that supplemental pollination did not improve seed production over open pollination (Handley 2018a, pers. comm.). Therefore, we assign both populations to the high condition (=3) for this factor (Table 4).

Adequate spring precipitation: The majority of precipitation that falls annually within the range of desert yellowhead occurs in the spring months of March, April, and May. This typically falls as snow and creates a snowbank that rests upon the plants in the Cedar Rim population and on the butte above the plants at the Sand Draw population. In late spring, the snowbanks melt forming rivulets where most of the plants are found. We understand that the growth rate of populations of desert yellowhead is highest during years of average precipitation, and does poorly when it is either too wet or too dry (Doak *et al*. 2016, pp. 17−18). Historical (1964 to 2018) records of precipitation from a NOAA weather station near Jeffrey City (USC00484925) found total precipitation for the spring months between 2.67–18.87 cm (1.05–7.43 in), with an average precipitation of 10.44 cm (4.11 in) and a standard deviation of 3.91 cm (1.54 in) (NOAA 2018). For a population to be ranked as high condition for this factor, spring precipitation needs to fall within one standard deviation of the average for all 5 years of a monitoring period (Table 3). To be ranked as moderate condition for this factor, spring precipitation is somewhat variable and falls outside of one standard deviation for 2−4 years in a 5-year period. To be ranked as low condition, spring precipitation is highly variable and falls outside of one standard deviation for all 5 years of a 5-year period. Based on spring precipitation totals for the Jeffrey City weather station, both populations appear to have received somewhat variable spring precipitation over the past 5 years (2014: 8.33 cm (3.28 in); 2015: 18.87 (7.43 in); 2016: 18.33 cm (7.22 in); 2017: 10.59 cm (4.17 in); and 2018: 7.77 cm (3.06 in)). Therefore, we assign both populations to the moderate condition (=2) for this factor (Table 4).

Mild summer temperatures: We do not know the precise optimal range of temperatures for the growth, survival, and reproduction of desert yellowhead, though we understand that this factor is especially important for the seedling stage, since they are susceptible to desiccation in hot, dry weather. At the 1994–1998 weather station within the Sand Draw population, average monthly temperatures were hottest in July or August (Scott and Scott 2009, pp. 50–54). The historical weather station at Jeffrey City also found that from 1964–2018, July and August were the hottest months; average monthly temperature was 20.89 degrees (^{o}) Celsius (C) (66.5 ^{o}Farenheit (F)), with a standard deviation of 1.07 ^{o}C (1.92 ^{o}F); the lowest recorded temperature was -2.2 ^{o}C (28 ^{o}F) and the highest was 36.7 ^{o}C (98 ^{o}F) (NOAA 2018). We determine mild summer temperatures to be those that are within one standard deviation of the average. To be ranked as high condition for this factor, all 5 years of the monitoring period must fall within one standard deviation of the average (Table 3). To be ranked as moderate condition for this factor, summer temperature is somewhat variable and falls outside of one standard deviation for 2-4 years in a 5-year period. To be ranked as low condition, summer temperature is highly variable and falls outside of one standard deviation for 5 or more years within a 5-year period. Based on the weather data from the Jeffrey City weather station over the past 5 years (2014: 18.2 ^{o}C (64.7 ^{o}F); 2015: 18.6 ^{o}C (65.4 ^{o}F); 2016: 18.9 ^{o}C (66 ^{o}F); 2017: 19.1 ^{o}C (66.3 ^{o}F); 2018: 19.6 ^{o}C (67.3 ^{o}F)), summer temperatures at both populations are within one standard deviation of average. Therefore, we assign both populations to the high condition (=3) for this factor (Table 4).

Seedling survival: Juvenile mortality is the major driver to population size and recruitment, and therefore is a key component of population resiliency and species viability. Because of this, in our analysis for this SSA Report, we weight the demographic factor of seedling survival twice that of the other demographic factors. The survival of seedlings is driven, at least in part, by the time of year in which the seed germinated, adequate spring and summer precipitation, and mild summer temperatures, which in combination prevents desiccation and death. For example, the largest cohort of seedlings ever recorded for desert yellowhead was in 1995, one of the wettest summers of the Scotts' 12-year study (Scott and Scott 2009, p. 37). The seedling stage can be maintained in a quiescent state for some time with overwintering taking place without the development of primary leaves (Scott and Scott 2009, p. 44). Survivorship studies were conducted by the Scotts and by the Doak lab, and we also consider survival rates of other species in the Asteraceae family. Survival rates are strongly size-dependent, with survival of the smallest size class of plants (*i.e*., seedlings) ranging between less than 5 percent to over 80 percent, but averaging around 35 percent (Doak *et al*. 2016, p. 22). We assess high survival as being over 30 percent of seedlings surviving the course of a summer, moderate survival as 15–30 percent, and low survival as less than 15 percent (Table 3). Recent work at both populations has failed to find seedlings or evidence of new recruits into the population. Therefore, we assume the current level of seedling survival is low (=1) at both Sand Draw and Cedar Rim (Table 4).

Established plant survival: Established desert yellowhead plants are responsible for reproduction, namely sexual reproduction through seeds, but also through vegetative reproduction by ramets. Survival rates have been reported in the Scott and Scott 2009 study (pp. 39–40) well as the Doak *et al*. 2016 study (pp. 19–26). Usually, only a few established plants die each year, and those that die are typically from the oldest age class (Scott and Scott 2009, p. 40). In the Doak study, established plant survival rates ranged between approximately

20 and 100 percent, averaging around 90 percent, peaking for intermediate-sized plants and falling for the largest, presumably oldest, plants. Interestingly, lowest density portions of the populations at both Sand Draw and Cedar Rim had much higher survival than high density portions, driving a higher estimated population growth (Doak *et al*. 2016, p. 22; Dibner *et al*. 2019, p. 13). Based on the Doak study's annual survival rates, we classify high established plant survival as being between 75 and 100 percent survival; moderate survival ranges between 40 and 75 percent survival; and low survival is less than 40 percent of established individuals surviving to the next year (Table 3). We assess current rate of established plant survival at both Sand Draw and Cedar Rim to be high (=3) based on the data collected in the Doak *et al*. 2016 study (Table 4).

Seed production: The production of fertile achenes with viable seeds is an important measurement of flowering plant fecundity, which is dependent on the environmental conditions of that growing season. We do not know whether a seedbank is present at either the Sand Draw or Cedar Rim population, though it is unlikely a robust seedbank exists, given the thin soil at each of these sites. For other species within the Asteraceae family, seed viability varies considerably. The Scott and Scott (2009, p. 44) study found both fertile and sterile achenes on most flowering plants and were able to visually distinguish between them based on color and fleshiness. That study found an average of 1.4 inflorescences per plant, 40.67 heads per inflorescence, 5.04 achenes per head, and 1.2 viable achenes per head in 1995 (approximately 24 percent viability; Scott and Scott 2009, p. 45), which leads to an average annual production of approximately 68 viable achenes per reproductive plant. Germination success was found to range between 44–55 percent (Scott and Scott 2009, p. 45). An on-going pollination and germination success study of seeds collected at Cedar Rim found that none of the seeds were viable (Handley 2018a, pers. comm.), which may indicate: 2018 was a poor year for Cedar Rim, a longer-term decline in recruitment, or a lack of sexual reproduction in this population as a whole. The same study found that seeds from Sand Draw had 6–16 percent viability, depending on treatment (*i.e*., bagged, hand-pollinated, or open-pollinated). These declines in production of viable seed from previous studies warrant replication and further investigation. Based on the Scotts' data, to have high seed production and viability, we determined that over 50 percent of produced achenes will be viable; moderate seed production and viability from 20–50 percent viability; and low seed production and viability t from less than 20 percent viability (Table 3). The recent work performed on seed production and viability for Sand Draw indicates that seed viability is low (Handley 2018a, pers. comm.). However, earlier work at Sand Draw indicates 24 percent viability and germination success of 44–55 percent (Scott and Scott 2009, p. 45). Therefore, we assign Sand Draw population to the moderate condition category (=2). Only a single recent study (Handley 2018a, pers. comm.) studied seed production at Cedar Rim, which indicates no viability, and therefore we assign this population to the low condition category (=1) (Table 4).

Using the conditions quantified in Table 3, we classified the current resiliency for the two known populations of desert yellowhead in Table 4. Sand Draw appears to currently have all of its habitat factors in the moderate or high category because all of its abiotic and biotic resource needs are being met, particularly that no physical disturbance such as opal mining is affecting the population. Regarding demographic factors, established plant (both vegetative and flowering) survival appears high, which is to be expected with a long-lived species. However, we assign seedling survival as low and fertility/viability of produced seeds as moderate based on the most recent, detailed study (Scott and Scott 2009, p. 45). The calculation for Sand Draw resiliency is:

3+3+3+3+2+3+2x(1)+3+2 =24. Therefore, this leads to an overall resilience level of high for the current condition of the Sand Draw population (Table 4).

Cedar Rim has not been studied with as much detail or for as long a duration as Sand Draw, which necessitates that we make more assumptions about population-level resilience for Cedar Rim, thus increasing the uncertainty of our final resiliency estimates. Regarding habitat factors, we understand that opal mining provides a real current stressor to the species, with trenches proposed within and adjacent to occupied habitat, and therefore quantify soil conditions as being moderate. The remaining habitat factors are considered moderate or high, with all other abiotic and biotic resource needs being met. Regarding demographic factors, established plant (both vegetative and flowering) survival appears high, which is to be expected with a long-lived species. Because Cedar Rim has not been studied as closely as Sand Draw but is similar to Sand Draw, we assume there are low values for seedling survival. Analysis of seeds collected at Cedar Rim in 2018 found no viable seeds, so that factor is assigned a low condition. The calculation for Cedar Rim resiliency is: 2+3+3+3+2+3+2x(1)+3+1=22. Therefore, because suitable soil conditions are currently impacted, this leads to an overall resilience level of moderate for the current condition of the Cedar Rim population (Table 4).

Table 4. Current condition for Sand Draw and Cedar Rim, including resiliency, redundancy, and representation. Colors match the condition category labels from Table 3 for high (green), moderate (yellow), and low (orange). Values indicate score for each factor contributing to resiliency, and totals indicate overall resiliency: low condition is 10 – 16, moderate is 17 – 23, and high is 24 – 30.

Resiliency										Overall Population Resiliency	Species Redundancy	Species Representation
	Habitat factors						Demographic factors					
Condition category	suitable soil conditions	low competition	sunlight for photosynthesis	pollinators	adequate spring precipitation	mild summer temperatures	seedling survival	established plant survival	seed production			
Sand Draw	3	3	3	3	2	3	1	3	2	24		
Cedar Rim	2	3	3	3	2	3	1	3	1	22		

3.3.2 Redundancy

Redundancy is the ability of a species to withstand catastrophic events. It is measured by the number and distribution of populations across the range of the species. A single catastrophic event can potentially negatively affect one or more patches of plants within either population or can completely eliminate the species if it spans the entire species' range. Stressors that may be considered catastrophic events or may affect the desert yellowhead on a catastrophic level include opal mining or other mineral extraction that destroys one or both populations, long term drought, invasion of occupied habitat by cheatgrass or other nonnative invasive plant, illegal collection or biovandalism, and a wildfire that spans the region.

It is possible that resource extraction in the past may have removed an undiscovered population, although we have no information to indicate that has happened. Extractory mining activity is occurring within approximately 1.6 km (1 mi) of the Cedar Rim population, making this stressor a very real concern for this population. However, exploratory trenches were proposed within the population but were moved upon discussion between the BLM and the mining proponent. Therefore, given the protections afforded the desert yellowhead due to its status as a federally listed species and location on BLM-administered lands, it is unlikely that a catastrophic event resulting from mining activity will remove the entire species from the landscape, particularly if future mineral withdrawals or other measures to ameliorate the effects of this stressor are implemented.

Under the SSA Framework (Smith *et al*. 2018, entire), we assess redundancy at the species level (e.g. based on how many populations a species has, how resilient they are, and how they are distributed). Based on this assessment of redundancy, desert yellowhead has two populations, each with some level of subdivision. One population has high resiliency (Sand Draw) and one has moderate resiliency (Cedar Rim). These populations are distributed within a narrow geographic range in a single county in Wyoming. Therefore, these factors result in an overall low species-wide redundancy, which is similar to many narrow endemic species. Current management has not reduced the risk of extirpation of the species due to the low number of populations and narrow distribution of the species, and no attempts have been made at establishing new populations in potential habitat to improve this redundancy.

3.3.3 Representation

Representation is the ability of a species to adapt to changing physical (climate, habitat) and biological (diseases, predators) conditions. It can be thought of as the species' adaptability. Representation is often measured in terms of genetic diversity. However, we lack genetic information for desert yellowhead despite the years-long studies conducted by the Scotts (Scott and Scott 2009, entire) and the Doak lab (Doak *et al*. 2016, entire). One complication resulting from a lack of genetic information on desert yellowhead populations is the understanding of the diversity of the population. If populations are maintained or growing mainly due to asexual production of ramets, then genetic diversity is likely low. Conversely, if populations are maintained or growing as the result of sexual reproduction and crossing, then genetic diversity is likely higher, which would result in a better capacity for the species to adapt to changing conditions.

The only information that we can currently assess regarding representation for desert yellowhead is ecological variation, specifically in terms of the diversity of habitats where plants are found in the Sand Draw and Cedar Rim populations. The locations where desert yellowhead occurs in these two habitats differ in placement on the slope, a few soil characteristics, density of surrounding vegetation, and aspect. With these rather minimal differences in environmental variation, we consider desert yellowhead to have low representation and therefore low adaptability to a changing world. However, as discussed above, the range of desert yellowhead may fall within a stable climate refugia which allowed the species to evolve in its present narrow range.

3.3.4 Synthesis of Current Condition

In summary, desert yellowhead currently consists of a two populations located 8 km (5 mi) apart. It is an S-R strategist, meaning 'S' for stress-tolerant and capable of surviving in disturbed habitats, and 'R' for ruderal, meaning an early colonizer and adapted to habitats that are severe to extreme (Scott and Scott 2009, p. 58). Both populations show some signs of human disturbance, with old roadways to oil and gas or uranium sites within each population. We do not know if the current distribution of two population reflects the historical extent of the species. Stressors affecting the species have largely been ameliorated through management under the BLM, though the Cedar Rim population continues to be vulnerable to mineral exploration and development.

Resiliency of the populations is measured by the ability of populations to respond to stochastic events. Desert yellowhead is currently characterized as having two populations: Sand Draw has high resiliency due to high levels of habitat factors and moderate to low levels of demographic factors; Cedar Rim has moderate resiliency due to the ongoing risk of mineral exploration and development impacting the soil conditions, high levels of other habitat factors, and moderate to low levels of demographic factors.

Redundancy, or the ability to withstand catastrophic events, in desert yellowhead is presently characterized by two populations, one composed of three patches and the other composed of 10 patches. Cedar Rim and Sand Draw are approximately 8 km (5 mi) apart. Therefore, based on an assessment at the species level with few populations in close proximity to each other, desert yellowhead has low redundancy.

Representation of desert yellowhead is characterized through assessment of ecological variation because we lack information regarding genetic diversity in this species. We found minor differences across the species in ecological setting, namely the slope, soil characteristics, density of surrounding vegetation, and aspect of the two populations. Recent studies showing low or no recruitment into the population suggests that population numbers are being maintained through production of ramets and not through outcrossing. Therefore, at present, we consider desert yellowhead to have low representation.

A summary of the above discussion on the 3Rs is provided in Table 4. When taken together, the current condition of desert yellowhead is characterized by varying levels of the 3Rs. That is, Sand Draw has high resiliency, Cedar Rim has moderate resiliency, and the species overall has low representation and redundancy.

Chapter 4. Analysis of Future Conditions

4.1 Introduction to Future Scenarios

Based on the analysis of potential stressors affecting the species historically and currently in *Section 3.2 Factors Affecting Current Condition*, the stressors of mineral development, nonnative invasive plants, the effects of climate change, wildfire, and a combination of these factors are considered to be risk factors with the potential to affect desert yellowhead into the future. We discussed each stressor's impact on the current condition of the species in that section, and we determined which stressors can plausibly continue or begin impacting the desert yellowhead in the future. We expect the level of impact resulting from the stressors to change based on the effects of climate change and based on the expected duration of conservation measures presently in place or the initiation of additional conservation measures in the future (see Table 5). We presume that the ongoing protections in place on BLM lands will continue at current levels due to the desert yellowhead's special status by BLM and the language specific to desert yellowhead in the section 7 consultation on the Lander RMP (BLM 2014, pp. 44–66), and thus incorporate them into our future scenarios in the form of management actions. There is a possibility that current management by the BLM will not continue if the species is delisted in the future (*i.e.*, losing ESA status but maintaining rare or unique special status in the BLM's 6840 Manual (BLM 2008, entire)), though any changes in management that jeopardize the existence of the species will likely result in the need to immediately list the desert yellowhead under the ESA again.

Other potential future conservation actions that we considered vary in their likelihood of occurring, from very likely (monitoring for and removing invasive species) to unlikely (watering plants). Additionally, none of the potential conservation actions are mandated to begin, or to be renewed, in the case of the mineral withdrawals for Sand Draw or Cedar Rim. Therefore, their level of certainty is low. We also make no assumptions about the practicality or feasibility of suggested conservation actions, or their effects on the species if they are implemented. For example, we recommend a conservation measure of fencing out grazers if livestock grazing is considered an increased stressor in the future, although some level of grazing is probably necessary for desert yellowhead to be maintained in its environment, so fencing may have both beneficial and deleterious effects. While these potential conservation actions are mentioned for the sake of exploring all possibilities, when assessing the effect of the stressors in the future, we do not include the mitigating effect of the potential conservation actions; instead, we rate the predicted future condition of each population in each scenario as though no additional conservation actions have been implemented. It can be assumed that the implementation of any conservation measures included in the final columns of Table 5 and Table 7 would only serve to improve the status of that population, but not the long-term viability of the species.

Mineral development is predicted to be the key stressor affecting desert yellowhead in the future. Non-climate-dependent, but potentially climate-linked, stressors include invasion by highly competitive native or nonnative invasive plants and wildfires (see Table 5). We are uncertain of the future impacts of these stressors on desert yellowhead; therefore, we provide a range of plausible impacts for each stressor. For example, we analyze the future impact of mineral development at three levels: no mineral development, some mineral development nearby, and mineral development within the occupied habitat of desert yellowhead or within a certain distance from one or both populations. The impact of mineral development can be mitigated in the future if the mineral withdrawal at Sand Draw is renewed and a mineral withdrawal for Cedar Rim is applied to limit mineral development within both populations of the species.

Table 5. Stressors potentially affecting desert yellowhead into the future, along with anticipated changes in stressors over time. Potential conservation actions are included here, but are not carried forward in the future scenario predictions.

Rank	Stressor	Forecasted change in effect (no effect, increase, or decrease)	Predicted effects of the stressor on resource or demographic factors	Potential conservation actions
1	**Mineral exploration and development**	→	Opal exploration and development will continue in areas not set aside by mineral withdrawal. Populations or patches directly or indirectly affected through direct removal, dust, altered hydrology, altered wind direction & intensity. Reduced habitat factors. Reduced vigor of all ages of plants.	Develop mineral withdrawal for Cedar Rim population.
2	**Effects of climate change**	↑	Longer, hotter droughts will lead to fewer seedlings surviving summer. Altered phenology may reduce pollination success. More CO_2 in atmosphere will allow plants to grow faster and reproduce more quickly. Reduced production of viable seeds.	None realistic. Watering, captive breeding & reintroductions to sites where seedlings are lost.
3	**Invasive plants**	↑	Fast-adapting species will invade desert yellowhead habitat and outcompete it for resources, which become scarcer (e.g. water, open soil). This will result in reduced dispersal and reduced vigor.	Monitor and treat invasives.
4	**Wildfires**	↑	Longer, hotter droughts will lead to higher incidences of wildfires in the area. Invasions of invasive annual grasses increase due to wildfire frequency, and wildfires become more common as habitats are taken over by fire-prone invasive grasses.	Monitor surrounding area for potential to spread fires.
5	**Livestock grazing and trampling**	→	Livestock grazing will continue to occur in populations because they are within a grazing allotment. Potential to decrease grazing in periods of extreme drought when BLM removes cattle. Seedlings disproportionately impacted from grazing and trampling.	Fence out grazers.
6	**Oil and gas development**	→	Oil and gas pressure will continue in the area surrounding populations, but occupied habitats will be avoided through consultation with BLM. May increase if administration or policy changes call for increased development. Indirect effects likely from dust, potentially resulting in reduced survival.	Enforce NSOs.
7	**Soil compaction from recreation**	→	Areas of compacted soil do not allow plants to survive and become unsuitable for colonization by new plants. Mortality of individual plants & reduced dispersal ability.	Fence out recreational vehicles.

We assessed two time frames for characterizing the future condition of desert yellowhead. We took into consideration that the PVA found little risk of the Sand Draw population facing substantial declines in abundance over a 10 year, 50 year, or 100 year period due to asynchrony among plots, density dependent growth-rate, and vital rate buffering (Doak *et al*. 2016, pp. 11–12; Dibner *et al.* 2019, p. 7). This provides an idea of the future population-level resilience of Sand Draw, but does not provide insight into resiliency of the Cedar Rim population, which has been studied in much less detail and is therefore is more difficult to predict. We also took into consideration that the status of habitat management appears more meaningful to this species than climate effects, and therefore established our future scenario horizons based on a combination of the mineral withdrawal timeline and the BLM Lander RMP revision timeline (RMPs must be renewed periodically by law). If developed and established, the mineral withdrawal at Cedar Rim is likely to occur by 2020 and will last for 20 years. Therefore, we established the future scenario horizons at 2040 (when mineral withdrawal will expire and when the BLM Lander RMP will have been renewed recently) and 2060 (when a mineral withdrawal will need to be renewed and second iteration of the BLM Lander RMP will expire).

4.2 Scenarios

In developing these future scenarios, we determined that the status of habitat management was the single most important indicator of population resiliency, followed by the effects of climate change, followed by other stressors. Therefore, management in the form of a mineral withdrawal determines the trajectory of a scenario occurring in the future. For each of the two time frames (2040 and 2060), we assessed four future scenarios: continuation, improvement, worst case, and mixed.

The climate change portions of these scenarios incorporate data from representative concentration pathways (RCP) of greenhouse gas (GHG) concentration trajectories adopted by the IPCC in the Fifth Assessment Report (AR5) in 2014 (see Table 6; IPCC 2014, entire). The RCP for the local area where desert yellowhead occurs have not been predicted, and so Table 6 present global warming increase projections. The four RCPs: RCP 2.6, RCP 4.5, RCP 6, and RCP 8.5, are named after a possible range of values of solar energy radiated back to space minus absorbed by the Earth in the year 2100 relative to pre-industrial values (+2.6, +4.5, +6.0, and +8.5 Watts per square meter, respectively), which are consistent with a wide range of possible changes in future anthropogenic (*i.e*., human) greenhouse gas (GHG) emissions. We are not assessing the likelihood of each of these possible changes due to the unknown trajectory of GHG emissions. The USGS Climate Change Viewer for the 8 digit HUC in which desert yellowhead occurs only provides GHG emissions trajectories for RCP 4.5 (continuation scenario) and RCP 8.5 (worst scenario); we predict that the RCP 2.6 (improvement and mixed scenario) will have substantially lower GHG emissions and a nearer to flat trajectory.

Table 6. IPCC AR5 global warming increase projections in degrees Celsius at the various RCP scenarios. Based on Table SPM.2 (IPCC 2013).

	2046-2065	**2081-2100**
Scenario	**Mean and *likely* range**	**Mean and *likely* range**
RCP2.6	1.0 (0.4–1.6) ^{o}C	1.0 (0.3–1.7) ^{o}C
RCP4.5	1.4 (0.9–2.0) ^{o}C	1.8 (1.1–2.6) ^{o}C
RCP8.5	2.0 (1.4–2.6) ^{o}C	3.7 (2.6–4.8) ^{o}C

Changes in precipitation are expected with climate change as well. As discussed under *3.2.9 Climate Change*, snow water equivalent, which is a measure of the amount of moisture present in snowfall, will decline in the winter and spring, and soil water storage will decline in the summer and fall (USGS 2016, pp. 4–6). The declines in soil water storage may limit viable seed production, which may cause declines in recruitment, and limit areas suitable for colonization. Insufficient precipitation during any season can also lead to mortality of individual plants and decrease overall population abundance. Increases in CO_2 will lead to plants growing larger and faster, with lower levels of transpiration and water loss, since plants have fewer and smaller stomata (Lammertsma *et al*. 2011, p. 4035). Therefore, a combination of warmer climate, more precipitation in winter and spring, and an increase in CO_2 may expand the growing season for desert yellowhead and allow plants to gain mass more quickly, resulting in plants reaching reproductive status more quickly. However, additions of CO_2 in the atmosphere may be insufficient to counter the lowered survival ability of seedlings due to desiccation from insufficient precipitation. The changes in precipitation and potential subsequent encroachment of invasive species favored by changing climate (Sandel and Dangremond 2012, p. 277) may also make the occurrence of wildfires in desert yellowhead habitat more common and/or more severe (USFWS Invasive weeds and wildland fire website 2019).

Continuation scenario: The purpose of the continuation scenario is to assess how the species would fare if present management actions and the current trajectory of climate change continued into the future with no additional actions taken to further ameliorate stressors impacting current condition. The continuation scenario assumes current BLM management of the species continues into the future, particularly maintenance of a mineral withdrawal for the Sand Draw population, and the continued development, but not implementation, of a mineral withdrawal for the Cedar Rim population. This scenario uses RCP 4.5, which represents the continuation of current rates of change and predicts that emissions will peak around 2040. Projections for RCP 4.5 indicate increases from current temperature: 1 °C (1.8 °F) increase by 2040 and 1.5 °C (2.7 °F) increase by 2060 (see Table 6) for the area where desert yellowhead occurs. We expect to see lower precipitation in the summer and more precipitation as snow in the winter and spring. Other stressors will continue to affect the species in the future at the same level as in current conditions.

Improvement scenario: The purpose of the improvement scenario is to assess how the species would fare if management actions were implemented to improve the Cedar Rim population and if climate change effects were reduced species-wide. The improvement scenario is based on continued management of the habitat of both populations, with mineral withdrawals either developed or renewed for each population, as well as a slowing of the effects of climate change. The improvement scenario is based on RCP 2.6, which assumes that global annual GHG emissions (measured in CO_2-equivalents) have peaked or will peak between 2010–2020, with emissions declining substantially thereafter. Projections for RCP 2.6 indicate about 1 °C (1.8 °F) increase from the current temperature by both 2040 and 2060 (See Table 6). Similar to the continuation scenario, we expect to see lower precipitation in the summer and more precipitation as snow in the winter and spring. Other stressors potentially affecting the species in the future are minimized or do not affect the species.

Worst scenario: The purpose of the worst scenario is to assess how the species would fare if beneficial management actions ceased and the effects of climate change increased. The worst scenario is based on BLM management that does not benefit desert yellowhead or allows adverse effects to the species, including allowing expiration of the Sand Draw mineral withdrawal and no development of the mineral withdrawal for Cedar Rim. The worst scenario is based on RCP 8.5, which assumes that emissions continue to rise throughout the 21st century. Projections for RCP 8.5 indicate increases from current temperatures: a 2.0 °C (3.6 °F) increase by 2040 and a 3.7 °C (6.6 °F) increase by 2060 (see Table 6). Similar to the continuation and improvement scenarios, we expect to see lower precipitation in the summer and more precipitation as snow in the winter and spring. Other stressors increase and have an additional negative effect on the species in the future.

Mixed scenario: The purpose of the mixed scenario is to assess the relative effect of management (e.g., habitat protections from stressors such as mineral extraction) or climate (e.g., shifts in available moisture from changing temperature and precipitation regimes) on the future condition of the species. Specifically, it presents a case where climate improves, as discussed in the improvement scenario, but management protections are removed, as discussed in the worst scenario. If the mixed scenario results in a substantially more negative outcome than the improvement scenario as well as a more negative outcome than the continuation scenario, it suggests that management of on-the-ground stressors such as opal mining are likely to be a more important driver of future conditions for desert yellowhead than shifts in climate.

4.3 Predicting Future Conditions

The results of our future scenario predictions are summarized in Table 7 and discussed in the following subsections. In predicting the future condition of the species across the 2040 and 2060 time frames and continuation, improvement, worst, and mixed scenarios, we assess changes to habitat and demographic factors as a result of mineral development, changes in the climate, invasions by nonnative invasive plants, and increased wildfire. Conservation actions that can hypothetically be implemented to mitigate the impacts of the projected stressors are noted, but are not considered in our assessment for overall viability.

4.3.1 Continuation Scenario

2040: In this scenario, management dictates much of the security of both populations. We expect that the Lander RMP will continue to be in place to protect habitat, and the mineral withdrawal for only the Sand Draw population will be renewed. The Cedar Rim population will continue to be vulnerable to opal mining pressure. The impacts that we expect to see resulting from climate change are related to spring precipitation and summer temperature that fall outside of what is typical for the desert yellowhead's habitat. Hot, dry summers or inadequate levels of soil moisture lead to a lower production of viable seeds and a decrease in the survival of seedlings. Other stages of life history activities remain unharmed at this point in the future. See Table 8 for a visual interpretation of the response of each population to habitat and demographic factors and an overall population resiliency score. This leads to an overall moderate but nearly high condition for Sand Draw (=23) and a moderate condition for Cedar Rim (=21) since it will be vulnerable to and/or already impacted by opal mining. Under this scenario, we expect redundancy and representation to be maintained at the current low levels.

2060: In this scenario, management dictates much of the security of both populations. We expect that the Lander RMP will be renewed and will continue to protect habitat, and the mineral withdrawal for Sand Draw will be renewed. However, the mineral withdrawal for Cedar Rim will not be secured, leaving this population vulnerable to opal mining pressure, which has likely occurred given the mineral potential of the area. The impacts that we expect to see resulting from climate change are related to spring precipitation and summer temperature that fall outside of what is typical for the desert yellowhead's habitat. Hot, dry summers or inadequate levels of soil moisture lead to a lower production of viable seeds and a decrease in the survival of seedlings. Other stages of life history activities remain unharmed at this point in the future. See Table 8 for a visual interpretation of the response of each population to habitat and demographic factors and an overall population resiliency score. This leads to an overall moderate condition for Sand Draw (=23) but a low condition for Cedar Rim (=20) since it likely has been impacted by opal mining. Under this scenario, we expect the already low redundancy and representation to decrease further due to the lowered resiliency and potential loss of the Cedar Rim population and its contribution to redundancy and representation.

Table 7. Summary of factors affecting desert yellowhead under future scenarios at 2040 and 2060 time frames, including effects of management, effects of climate change, and other stressors.

2040

Scenario	Management	Effects of Climate Change	Other Stressors	Conservation Actions
Continuation scenario	-RMP continues to provide protections against stressors -Sand Draw mineral withdrawal renewed in 2028 -Cedar Rim mineral withdrawal not established	-Emissions continue to rise based on RCP 4.5, peaking ~ 2040, then declining. -Summer air temp +1°C -Winter snow water equivalent -0. 5 cm. -Overall somewhat drier and longer growing season	-Fewer seedlings survive summer heat -Fewer viable seeds produced -Invasives rarely establish -No wildfires in area	-Monitor for invasive and remove when found -Monitor surrounding area for fire danger -Install fencing -Supplemental watering
Improvement scenario	-RMP continues to provide protections against stressors -Sand Draw mineral withdrawal renewed in 2028-Cedar Rim mineral withdrawal established	-Emissions rise based on RCP 2.6, peaking between 2010 and 2020, then substantially declining. Summer air temp and winter snow water equivalent ~ same as current. -Longer growing season	-Germinants survive summer at current rates -Seed production a current rates -No invasives -No wildfires in area	
Worst scenario	-RMP renewed without protections against stressors (*i.e.*, oil and gas, recreation, and grazing) -Sand Draw mineral withdrawal expires in 2028 -Cedar Rim mineral withdrawal not established, and minerals are extracted nearby &/or at Cedar Rim	-Emissions rise continually throughout the century based on RCP 8.5. -Summer air temp +2 °C -Winter snow water equivalent -0.75 cm. -Overall much drier & much longer growing season	-Very few germinants survive summer heat -Very few viable seeds produced -Invasives outcompeting -Wildfire occurs	
Mixed scenario	-RMP renewed without protections against stressors (*i.e.*, oil and gas, recreation, and grazing) -Sand Draw mineral withdrawal expires in 2028 -Cedar Rim mineral withdrawal not established, and minerals are extracted nearby &/or at Cedar Rim	-Emissions rise based on RCP 2.6, peaking between 2010 and 2020, then substantially declining. Summer air temp and winter snow water equivalent ~ same as current. -Longer growing season	-Germinants survive summer at current rates -Seed production a current rates -Invasives outcompeting -No wildfires in area	

Table 7, continued.

2060

Scenario	Management	Effects of Climate Change	Other Stressors	Conservation Actions
Continuation scenario	-RMP continues to provide protections against stressors - Sand Draw mineral withdrawal renewed in 2048 -Cedar Rim mineral withdrawal not established	-Emissions continue to rise based on RCP 4.5, peaking ~ 2040, then declining. -Summer air temp +1.5°C, -Winter snow water equivalent -1 cm. -Overall drier & longer growing season	-Fewer seedlings survive summer heat -Fewer viable seeds produced -Invasives rarely establish -No wildfires in area	-Monitor for invasive and remove when found -Monitor surrounding area for fire danger -Install fencing -Supplemental watering
Improvement scenario	-RMP continues to provide protections against stressors -Mineral withdrawals for both Sand Draw and Cedar Rim renewed in 2040	-Emissions rise based on RCP 2.6, peaking between 2010 and 2020, then declining. -Summer air temp and winter snow water equivalent ~ same as current. -Longer growing season	-Germinants survive summer at current rates -Seeds produced at current rates -No invasives -No wildfires in area	
Worst scenario	-RMP renewed without protections against stressors (*i.e.*, oil and gas, recreation, and grazing) -Sand Draw mineral withdrawal expired -Cedar Rim mineral withdrawal not established -Minerals extracted nearby &/or at either population	-Emissions rise based on RCP 8.5 continually throughout the century. -Summer air temp +3.7 °C, -Winter snow water equivalent -2 cm. -Overall much drier & much longer growing season	-Very few germinants survive summer heat -Very few/no viable seeds produced -Invasives outcompeting -Wildfire occurs	
Mixed scenario	-RMP renewed without protections against stressors (*i.e.*, oil and gas, recreation, and grazing) -Sand Draw mineral withdrawal expired -Cedar Rim mineral withdrawal not established -Minerals extracted nearby &/or at either population	-Emissions rise based on RCP 2.6, peaking between 2010 and 2020, then declining. -Summer air temp and winter snow water equivalent ~ same as current. -Longer growing season	-Germinants survive summer at current rates -Seeds produced at current rates -Invasives outcompeting -No wildfires in area	

4.3.2 Improvement Scenario

2040: In this scenario, management also dictates much of the security of both populations. We expect that the Lander RMP will continue to be in place to protect habitat, and the mineral withdrawal for both populations will be secured and/or renewed. We do not expect to see impacts resulting from climate change at this point because spring precipitation and summer temperatures continue to fall within what is typical for the desert yellowhead's habitat. Because this is an improvement scenario, we expect to see at least some production of viable seeds and seedling survival at the Cedar Rim population. See Table 8 for a visual interpretation of the response of each population to habitat and demographic factors and an overall population resiliency score. This leads to an overall high condition for both populations (=28 for Sand Draw and =27 for Cedar Rim). Under this scenario, both populations are highly resilient and will likely remain extant, and representing the full range of ecological settings within the species' distribution, maintaining redundancy and representation at current levels.

2060: In this scenario, management also dictates much of the security of both populations. We expect that the Lander RMP will be renewed to continue to protect habitat, and the mineral withdrawals for both populations will be renewed when they expire. We do not expect to see impacts resulting from climate change at this point because spring precipitation and summer temperatures continue to fall within what is typical for the desert yellowhead's habitat. Because this is an improvement scenario, we expect to see at least some production of viable seeds and seedling survival at the Cedar Rim population, and improved viability at the Sand Draw population. See Table 8 for a visual interpretation of the response of each population to habitat and demographic factors and an overall population resiliency score. This leads to an overall high resiliency for both populations (=28 for Sand Draw and =27 for Cedar Rim). Under this scenario, both populations are highly resilient and will likely remain extant, and representing the full range of ecological settings within the species' distribution, maintaining redundancy and representation at current levels.

4.3.3 Worst Scenario

2040: In this scenario, management is almost entirely responsible for the security of both populations. We expect that the Lander RMP will be changed or in some way fail to protect habitat for desert yellowhead, and the mineral withdrawal for Cedar Rim will never be established (resulting in impacts to the soil at the population site as well as nearby, leading to the removal of Cedar Rim through direct or indirect effects). The mineral withdrawal for Sand Draw will have expired in 2028, resulting impacts by mineral extraction in the area, but is likely not yet removed through mining activity. Invasive species will also begin to encroach on the habitat of both populations. Climate change-related effects include spring precipitation and summer temperature that fall outside of what is typical for the desert yellowhead's habitat. These hot, dry summers or inadequate levels of soil moisture will lead to a decrease in the survival of seedlings. Because of competition with invasives for resources, diminished access to sunlight, and fewer pollinators available, the production of non-fertile achenes or sterile seeds will increase. See Table 8 for a visual interpretation of the response of each population to habitat and demographic factors and an overall population resiliency score. Overall, the Sand Draw population is categorized as being in moderate condition (=20), but Cedar Rim will be destroyed (=18) due to habitat loss or indirect effects from mineral development nearby. Under this scenario, both redundancy and representation are diminished from current low levels due to the loss of Cedar Rim and its contribution to the species' overall viability.

2060: In this scenario, management is almost entirely responsible for the security of both populations. We expect that the Lander RMP will be changed or in some way fail to protect habitat for desert yellowhead, and the mineral withdrawal for Cedar Rim will never be established (resulting in impacts to the soil at the population site as well as nearby, resulting in direct effects and indirect effects to the population). Additionally, the mineral withdrawal for Sand Draw will have expired in 2028, leading to mineral extraction in the area or potentially at the site, leading to direct or indirect impacts to desert yellowhead plants in that population. Invasive species will also encroach on the habitat of both populations. Climate change-related effects include spring precipitation and summer temperature that fall outside of what is typical for the desert yellowhead's habitat. These hot, dry summers or inadequate levels of soil moisture will lead to a decrease in the survival of seedlings. Because of competition with invasives for resources, diminished access to sunlight, and fewer pollinators available, the production of non-fertile achenes or sterile seeds will increase. See Table 8 for a visual interpretation of the response of each population to habitat and demographic factors and an overall population resiliency score. Overall, both populations may be lost due to mineral extraction in the area or within occupied habitat resulting in low resiliency scores (=15 for both Sand Draw and Cedar Rim). Under this scenario, both redundancy and representation are diminished from current low levels due to the loss of Cedar Rim and its contribution to the species' overall viability and the negative impacts to the Sand Draw population as a result of stressors affecting the habitat where it occurs.

4.3.4 Mixed Scenario

2040: This scenario suggests that on-the-ground management actions are driving the security of both populations. We assume that the Lander RMP will be changed or in some way fail to protect habitat for desert yellowhead and the mineral withdrawal for Cedar Rim will never be established (resulting in impacts to the soil in and around the area occupied by the population, leading to the removal of Cedar Rim through direct or indirect effects). The mineral withdrawal for Sand Draw will have expired in 2028, resulting in impacts by mineral extraction in the area, but the Sand Draw population is likely not yet removed through mining activity. Invasive species will also begin to encroach on the habitat of both populations. We do not expect to see impacts resulting from climate change at this point because spring precipitation and summer temperatures continue to fall within what is typical for the desert yellowhead's habitat. Because climate factors follow the climate projections from the improvement scenario, we expect to see at least some production of viable seeds and seedling survival at the Cedar Rim population. See Table 8 for a visual interpretation of the response of each population to habitat and demographic factors and an overall population resiliency score. Overall, the Sand Draw population is categorized as being in moderate condition (=25), but Cedar Rim will be destroyed (=23) due to habitat loss or indirect effects from mineral development nearby. It appears that even with modest gains achieved through longer growing season and improved survival of all life stages, the removal of habitat leads to the projected decline of the populations. Under this scenario, both redundancy and representation are diminished from current low levels due to the loss of Cedar Rim and its contribution to the species' viability.

2060: This scenario suggests that on-the ground management actions are driving the security of both populations. We assume that the Lander RMP will be changed or in some way fail to protect habitat for desert yellowhead, and the mineral withdrawal for Cedar Rim will never be established (resulting in impacts to the soil in and around the area occupied by the population, resulting in direct and indirect effects to the population). Additionally, the mineral withdrawal for Sand Draw will have expired in 2028, leading to mineral extraction in the area or potentially at the site, leading to direct or indirect impacts to desert yellowhead plants in that population. Invasive species will also encroach on the habitat of both populations. We do not expect to see impacts resulting from climate change at this point because spring precipitation and summer temperatures continue to fall within what is typical for the desert yellowhead's habitat. Because climate factors follow the climate projections from the improvement scenario, we expect to see at least some production of viable seeds and seedling survival at the Cedar Rim population, and improved viability at the Sand Draw population. See Table 8 for a visual interpretation of the response of each population to habitat and demographic factors and an overall population resiliency score. Overall, both the Sand Draw population (=24) and the Cedar Rim population (=23) are considered in low condition due to direct destruction of the occupied habitat, habitat loss, or indirect effects from mineral development nearby. It appears that even with modest gains achieved through longer growing season and improved survival of all life stages, the removal of habitat leads to the projected decline of the populations. Under this scenario, both redundancy and representation are diminished from current low levels due to the loss of Cedar Rim and its contribution to the species' viability.

Table 8. Summary of future resilience condition predictions for each population based on predictions of the habitat and demographic factors for desert yellowhead in 2040 and 2060. Note overall population resiliency is based on the sum of all habitat and demographic factors, with seedling survival counted twice. Low condition (orange) is a total between 10–16, moderate condition (yellow) is a total between 17–23, and high condition (green) is a total between 24–30. Exceptions where suitable soil condition drives resiliency are indicated with an asterisk (*).

		Habitat factors						Demographic factors			Overall population resiliency
2040	Population	suitable soil conditions	low competition	sunlight for photosynthesis	pollinators	adequate spring precipitation	mild summer temperatures	seedling survival	established plant survival	seed production	
Continuation scenario	Sand Draw	3	3	3	3	2	2	1	3	2	23
	Cedar Rim	2	3	3	3	2	2	1	3	1	21
Improvement scenario	Sand Draw	3	3	3	3	3	3	2	3	3	28
	Cedar Rim	3	3	3	3	3	3	2	3	2	27
Worst scenario	Sand Draw	2	2	2	3	2	2	1	3	2	20
	Cedar Rim	1	2	2	3	2	2	1	3	1	18*
Mixed scenario	Sand Draw	2	2	2	3	3	3	2	3	3	25*
	Cedar Rim	1	2	2	3	3	3	2	3	2	23*
2060											
Continuation scenario	Sand Draw	3	3	3	3	2	2	1	3	2	23
	Cedar Rim	1	3	3	3	2	2	1	3	1	20*
Improvement scenario	Sand Draw	3	3	3	3	3	3	2	3	3	28
	Cedar Rim	3	3	3	3	3	3	2	3	2	27
Worst scenario	Sand Draw	1	2	2	3	1	1	1	2	1	15
	Cedar Rim	1	2	2	3	1	1	1	2	1	15
Mixed scenario	Sand Draw	1	2	2	3	3	3	2	3	3	24*
	Cedar Rim	1	2	2	3	3	3	2	3	2	23*

Regarding future redundancy and representation for desert yellowhead, none of the scenarios predict the discovery of any additional populations, new forms of connectivity between the two known populations, or increases in genetic or ecological diversity. In fact, if one or both population is lost due to opal mining or another stressor, we would anticipate that the redundancy and resiliency of the species would be even lower than the low condition assigned to the species in its current condition. Therefore, we predict that the species' redundancy and representation will continue to be low in 2040 and 2060 for all of the scenarios.

Chapter 5. Synthesis and Viability

Regarding resiliency and redundancy, potential stochastic and catastrophic events that may affect desert yellowhead in the future include mineral development, the effects of climate change, competition with nonnative invasive species, and wildfires. The stressor of mineral development has been eliminated from the habitat surrounding Sand Draw population through 2028 with the current mineral withdrawal. However, the potential for renewal of the mineral withdrawal is uncertain and dependent upon decisions made by the BLM. Occupied, suitable, and potentially occupied habitat outside of Sand Draw is not covered by the mineral withdrawal, including the Cedar Rim population; therefore, it is possible that Cedar Rim or an unknown population may be directly impacted by mineral extraction and loss of suitable habitat. Furthermore, if mining occurs within suitable habitat for the species, it will decrease the potential for new areas to be colonized, and removal of the soil on which the species depends will likely decrease recruitment potential.

As discussed under *3.2.9 Climate change*, climate models predict that precipitation will increase in the winter and spring, decrease in summer, and remain about the same in fall (USGS 2016, p. 3) and that snow water equivalent will decline in the winter and spring, and soil water storage will decline in the summer and fall (USGS 2016, pp. 4–6). An increase in available CO_2 in the atmosphere will allow plants to grow more rapidly and potentially use less water. A combination of more CO_2, warmer climate, more precipitation in winter and spring may expand the growing season for this species, though declines in soil water storage in the summer may limit viable seed production, which can cause declines in recruitment. Furthermore, a decrease in snow water equivalent during winter, a time when desert yellowhead seedlings are likely to be vulnerable to desiccation, may lead to lowered survival and recruitment, as evidenced by lower numbers of non-flowering plants. A severe and extended drought may have the potential to eliminate the species by preventing flowering, viable seed production, germination success, or all three of these important functions of population growth. While climate change models are not predicting any extended droughts for the area in which desert yellowhead occurs, many global climate models are predicting that droughts, intense precipitation events, and other extreme climate events will occur more frequently worldwide (Dai 2013, p. 52), and this stochasticity may negatively affect the resiliency of the species.

Nonnative invasive species are presently not affecting desert yellowhead due to the general inhospitable nature of the unstable soils where the species exists. However, in the future, there is potential for nearby invasives such as cheatgrass to encroach and invade the habitat. This potential invasion by cheatgrass or some other nonnative invasive species may occur over a short period if the invaders outcompete desert yellowhead plants for resources such as soil, sunlight, and water.

Wildfire is not considered a stressor affecting desert yellowhead currently. However, invasion of fire-prone species and increasing droughts resulting from changing climate may result in a wildfire affecting the area around desert yellowhead habitat. We anticipate that the species' habitat will not be directly involved in a wildfire and will likely serve as a fire break, although it is possible that individual desert yellowhead plants near or touching other plants or plant material could be lost. The frequency and intensity of wildfires is likely to increase in the future given future predictions of drought and conversion of the surrounding sagebrush steppe habitat to invasive annual grasses. Conversely, a wildfire may serve to improve available habitat for desert yellowhead by removing competing plants and exposing and creating currently unoccupied areas, thus creating new habitats available for colonization by desert yellowhead. A very intense, catastrophic fire can have the potential to destroy an entire population or patch of desert yellowhead. Additionally, because the two populations are so near each other (8 km/5 mi), it is possible that the same catastrophic fire could remove both populations from the landscape, which would eliminate the known range of the species entirely. Because there are two populations, each composed of several patches of plants, there is some level of protection against a localized catastrophic event, though a large-scale event could lead to the elimination of the species altogether.

Due to the lack of information on population genetics, we evaluated representation based solely on the breadth of ecological diversity within the species. This includes: albedo, slope, soil characteristics, density of surrounding vegetation, and aspect. Since the species is a narrow endemic plant occurring in a small area, these are not wide variations, but even this low level of variation may provide some level of representation. Additionally, it is possible that shifts in trait expression may occur given environmental pressures or in response to stressors. However, the species may suffer even lower levels of representation if one population is lost due to opal mining activities or other stressors. Therefore, because diversity within the species is low currently and is anticipated to remain low into the future, we consider representation to be low.

Viability is the ability of a species to sustain populations over time, where high levels of resiliency, redundancy, and representation lead to high viability. In *Chapter 3*, we assessed the current condition of desert yellowhead by reviewing the current status of the 3Rs in terms of individual and population-level resilience, redundancy in response to catastrophic events, and representation as indicated by ecological diversity and the presence of two populations. Our results indicate that the current condition of desert yellowhead is characterized by having one highly resilient and one moderately resilient population, low redundancy, and low representation.

In *Chapter 4*, we evaluated the potential future condition of desert yellowhead by predicting the species' response to a range of scenarios involving changes in management, climate, competition with nonnative invasive species, and wildfires, which were deemed the most likely stressors to affect desert yellowhead into the future. We found that the future condition of the species can be somewhat improved from the current levels of the 3Rs in the improvement scenario with increases in habitat protections, but can also be diminished if stressors impact one or both of the populations through ineffective decisions in species management. The continuation scenario predicts some decreases in the 3Rs, specifically resulting from impacts to the resiliency of the Cedar Rim population related to opal mining. The worst scenario has low levels of the 3Rs due to lapses of protections that are currently in place to protect the Sand Draw population from opal exploration and mining and the failure of the BLM to provide adequate protection to the Cedar Rim population. The mixed scenario showed that even improvements in the projected trajectory of climate change cannot provide enough benefit to the populations to compensate for the loss of habitat resulting from management that allows mineral exploration and extraction within and around occupied habitats. In summary, we find that the viability of the species in the long-term is largely dependent upon the protections put in place by the BLM, where management of the lands occupied by and surrounding the two populations of desert yellowhead is the key driver to the species' continued viability.

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